Altered Hydroperiod and Saltwater Intrusion in the Bald Cypress Swamps of the Loxahatchee River

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ABSTRACT

The Loxahatchee River is located in southeastern Florida, USA, and contains one of the last remnants of bald cypress (*Taxodium distichum*) river-swamp in the region. Hydrological modifications in the river channel and watershed have resulted in reduced freshwater flow and saltwater intrusion into this historically freshwater ecosystem, which has caused the retreat of bald cypress upriver. The loss of bald cypress as salinity in the floodplain increases has been accompanied by a transition to mangrove-dominated communities, which are more salt-tolerant. Previous watershed modeling efforts have focused on predicting river salinity under various management scenarios, with the goal of keeping river salinity below identified threshold levels for bald cypress health, but have not addressed hydrological conditions in the floodplain, which are a key control on floodplain vegetation. The aim of this study is to characterize soil moisture and soil porewater salinity dynamics in the floodplain at several depths and distances from the river during both wet and dry seasons. Twenty-four combined dielectric probes measuring soil moisture, salinity, and temperature were installed at four locations and three depths along two transects perpendicular to the river. Analysis of data collected over a three-year period has shown that soil moisture can be functionally tied to distance, topographical elevation, and river stage. These relationships are useful in evaluating the effects of proposed river management scenarios on floodplain hydrology. Additionally, increases in soil porewater salinity in floodplain during the dry season were shown to be related to the magnitude and duration of river salinity, with an apparent time lag between river and porewater salinity peaks (22-64 days), which increases with elevation and distance from river.

INTRODUCTION

The upper watershed of the Northwest Fork of the Loxahatchee River is home to one of the last remnants of bald cypress (*Taxodium distichum*) swamp in southeast Florida. However, a changing salinity regime in the river and its floodplain has been linked to vegetative changes in the floodplain (SFMWD 2005). Of primary concern is the loss of bald cypress and transition to mangrove-dominated communities as salinity in the floodplain increases. A Minimum Flow and Level (MFL) for the Northwest Fork was adopted in April 2003. However, due to reduced freshwater flow in the Northwest Fork, it was recognized that low dry-season flows would immediately trigger exceedances of the MFL, requiring the development of a Recovery Plan. The proposed Recovery Plan initiated an intensive watershed and hydrodynamic modeling effort focused on predicting river salinity under various management scenarios, with the goal of keeping river salinity below identified threshold levels for bald cypress health (2 parts per thousand, equivalent to an electrical conductivity [EC] of 0.3125 siemens per meter [S/m] at 25º C). As these models have not addressed hydrological conditions in the river floodplain (soil moisture and soil porewater salinity), the aim of this study is to characterize soil moisture and salinity dynamics at several depths and distances from the river in the floodplain during both wet and dry seasons. An additional objective is to derive relationships between river hydrology (stage and salinity) and floodplain soil conditions to better predict the effects of management scenarios proposed by the South Florida Water Management District (SFWMD).

METHODS

Twenty-four combined dielectric probes (Stevens Hydra Water, Beaverton, OR) were installed at four locations and three depths along two previously-established vegetation survey transects perpendicular to the Northwest Fork of the Loxahatchee River. Transect 1 is in an upriver location not impacted by daily tides and is dominated by upland forest and hydric hammock at higher elevations and mature bald cypress swamp in the floodplain. Transect 7 is in a transitional area that receives daily tidal flooding and contains both upper tidal and riverine forest types. At each transect, twelve probes were installed at four distances from the river and three depths below ground surface (bgs) to capture the spatial and temporal variation of hydrological parameters over wet and dry seasons. Each cluster of three probes was wired to a field data logger (CR-10, Campbell Scientific, Logan, UT), which recorded soil moisture, soil bulk EC, and temperature every 30 minutes. Data collection began in September 2004 and has been ongoing since.

Soil moisture time series developed for each probe are reported as measured soil moisture. However, Mortl (2006) found three major soil categories in the Loxahatchee River floodplain to have widely varying hydraulic characteristics, and thus, when comparing moisture values across soil categories it is helpful to scale the measured values using effective soil moisture (Θ), which ranges from a value of zero at residual moisture (θ_r) to 1 at saturation (θ_s). Effective soil moisture was then fit to a common three-parameter sigmoid model at Transect 1 (eqn. 1):

$$\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \frac{A}{1 + e^{-\frac{h-b}{c}}} \qquad (1)$$

where h is river stage, and A, b, and c are fitting parameters. Model selection was made by minimizing combined r^2 values for all measurement locations. Porewater EC values were calculated from bulk EC and soil moisture based on calibrations by Mortl (2006) and compared to river salinity values at each transect and with known bald cypress thresholds. Piezometers, slotted at probe installation depths, were also installed in several locations in 2007 to verify probe EC measurements and fill data gaps due to equipment failure.

RESULTS

Experimental results for several locations on Transects 1 and 7 are given in Figure 1. Effective soil moisture was plotted against river stage, and fit to a common sigmoid model (not shown). The Nash-Sutcliffe coefficient of efficiency (*ceff*) was used as a measure of goodness of fit. For soils which exhibited a wide range of θ values, the sigmoid model does a good job of predicting soil moisture based on river stage (0.72 < *ceff* < 0.89). For deeper sandy soils which are below the water table for long periods and surface soils of the lower floodplain, which only rarely dry out, the sigmoid model performed fairly (0.32 < ceff < 0.66). At Transect 7, daily tidal flooding resulted in near-constant soil saturation for all probes (Fig. 1), however responses to brief periods of drawdown in the shallowest (i.e., highest elevation) probes were evaluated using a Fourier smoothing technique. When mean tide elevation is above probe elevation, smoothing collected Data from 15-and 30-minute readings to a 6-hour time series revealed a close correlation between measured soil moisture and tidal stage data (not shown).

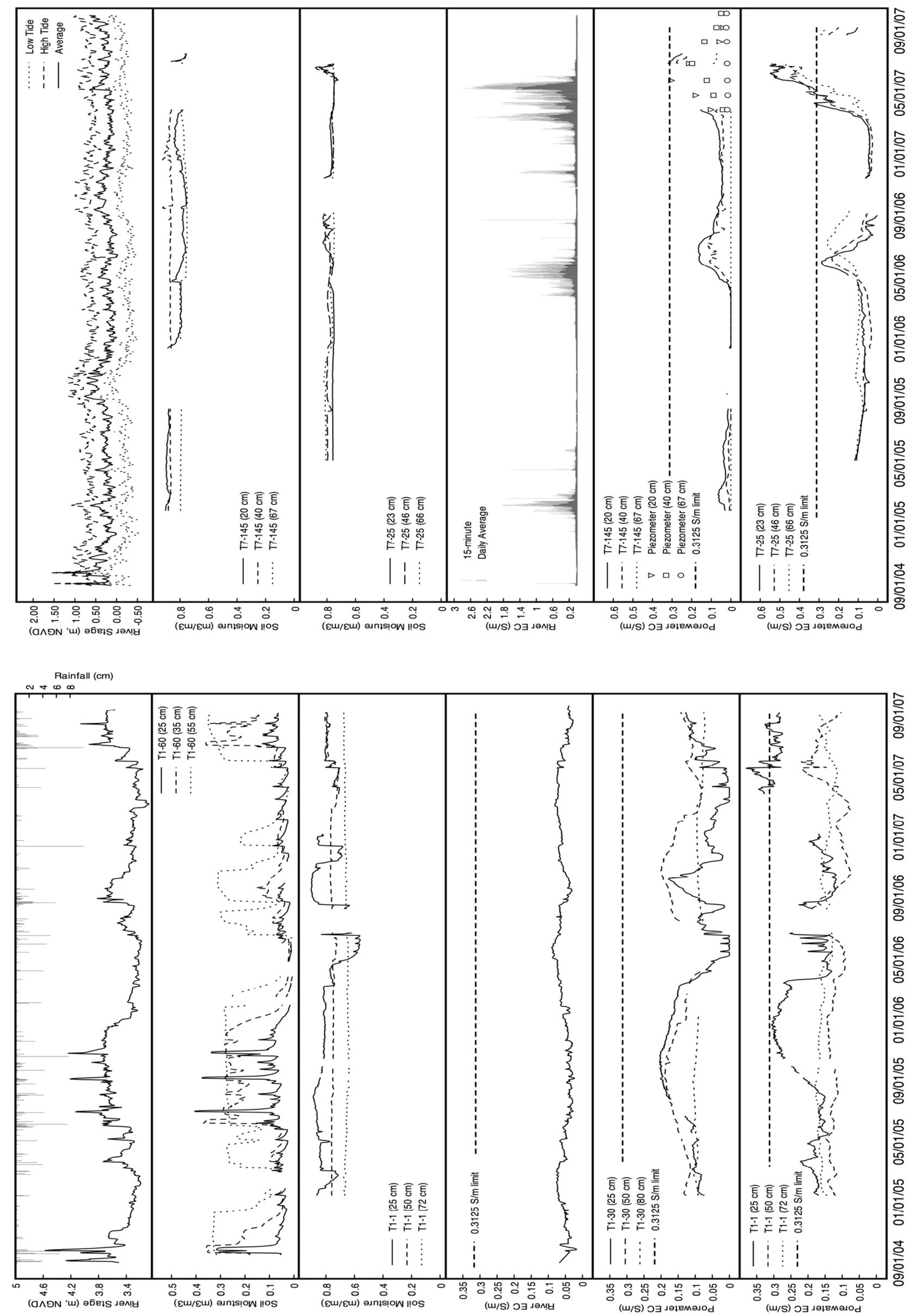

Figure 1. River stage, precipitation, soil moisture, river EC, and soil porewater EC measured at several stations on Transects 1 and 7 during the three-year study period. Station names indicate transect number (T1/T7), distance from river (m), and probe depth bgs (cm). EC at station T1-1 was negligible and is not shown. Piezometer data at station T7-145 are single monthly grab samples.

Soil porewater EC in the floodplain at Transect 1 (upriver) is slightly higher closer to the river and is relatively stable for most of the study period, with only the surface probes showing significant variation during the extended dry periods. Soil porewater is consistently higher than river EC (by a factor of 2-3), likely due to concentration of salts due to evapotranspiration. Dry season peaks in soil porewater EC were observed in all probes on Transect 7 (tidal transect), which mirrored peaks in river EC (Fig. 1). For the probes furthest from the river (T7-145), these peaks increased in magnitude in each of the study years, but reached the critical limit (2 ppt) only in 2007, and only in the most superficial soils (20 cm bgs). For the station 25 m from the river (T7-25), where floodplain vegetation begins to transition from bald cypress to mangroves, measured porewater EC was higher, exceeding the critical value for 83 days in surface soils (23 cm bgs), 85 days in middle soils (46 cm bgs), and 64 days in deeper soils (66 cm bgs).

DISCUSSION AND CONCLUSIONS

Analysis of data from Transect 1 (upriver) shows that soil moisture is dominated by distance from river and elevation, with precipitation, evapotranspiration, microtopography, and soil heterogeneity identified as additional factors. Since the health and reproductive success of bald cypress is dependent on freshwater conditions and varying flood levels and soil moisture throughout the year, the functional relationships developed here (sigmoidal curves) serve as a useful tool for the SFWMD to evaluate adopted MFL standards and proposed restoration scenarios. Soil porewater EC values in the lower floodplain of Transect 1 were often higher than EC values in the river, likely due to high rates of evapotranspiration by vegetation in the floodplain. At Transect 7 (tidal), it is apparent from the collected data that the soil porewater EC in the root zone of the floodplain vegetation reaches critical values (2 ppt) at times, but does not reach levels observed in the river. Higher peaks in soil porewater EC were observed in drier years, and maximum soil porewater EC values were also closer to peak river EC values during these years. Increases in soil porewater EC in floodplain during the dry season are related to the magnitude and duration of river salinity, however, there is a time lag between river and porewater EC peaks (22-64 days), which increases with depth and distance from river.

REFERENCES

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