DROUGHT, WINTER RAINS AND HURRICANES: HYDROLOGIC OBSERVATIONS FROM 2014-2017 OF THE EASTERN PANHANDLE COASTAL MARSH AND NORTHEAST FLORIDA BAY, EVERGLADES NATIONAL PARK, FL, USA.

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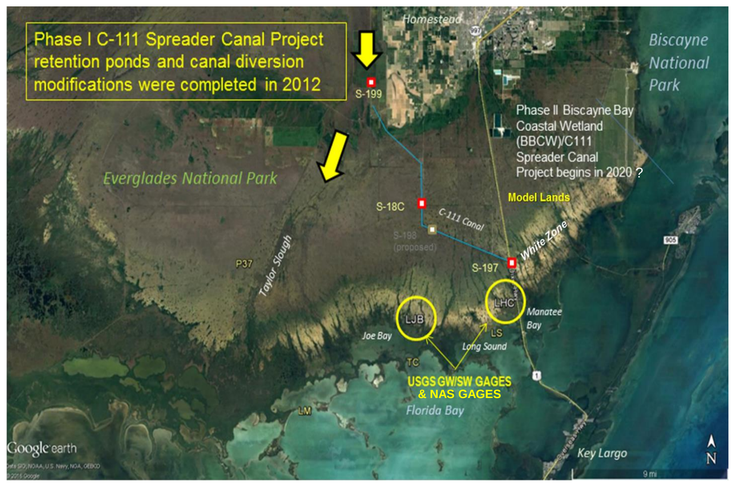

Figure 1. Southeast Everglades National Park, Biscayne Bay Coastal Wetland and C-111 Canal.

Background

The Eastern Panhandle (EP) coastal marsh of Everglades National Park (ENP) is hydrologically disconnected from its historical upstream freshwater watershed by the C-111 canal. This marl sediment marsh transitions (north to south) from freshwater sedges into scrub mangrove, whose waters drain into NE Florida Bay via small ephemeral creeks (fig 1).

Seasonally, the marsh hydrology consists of flashy pulsed rain-driven events in the summer and fall, and prolonged dry conditions in the spring. During the average dry season (Nov-Apr), there is limited rainfall or upstream overland flow, leading to marsh dry down and increased creek and soil salinity. Rainfall in the Eastern Panhandle basin is the primary source of upland freshwater sheet flow into NE Florida Bay when upstream freshwater from canal water releases are limited.

The Western C-111 Spreader Canal Project Phase I (C111SCWP) completed in 2012 was initially deemed successful from observed lower estuary salinities and increased SAV abundance (Audubon, 2014). However, water pumping (S-199) into Taylor Slough was only in part the reason for lower salinities. Excessive rainfall in WY 2012 (Oct-Sep) of ~ 69 inches (average ~ 46 in.) contributed to more upstream canal releases and greater overland freshwater flow from basin rainfall.

In subsequent years (2013-2015), upstream water deliveries to Taylor Slough and the lower C-111 wetland diminished because of less than average annual rainfall. In fact, C111SCWP overall effectiveness has been difficult to determine, given three extreme weather events that occurred from 2014-2017: 1. Reduced rainfall contributed to the worst drought in over 25 years (1988-1989) during the spring 2014 through summer 2015, creating hypersaline conditions killing many scrub mangrove, and reducing SAV (*Ruppia, sp.*) abundance, especially in the Long Sound/Highway Creek marsh region; 2. The second wettest winter (Nov 2015-Feb 2016) on record (1896-2016) caused by a strong ENSO (El Niño); 3. Hurricane Irma (Sept 10, 2017) dropped an unprecedented rainfall total (~22 inches) within Florida Bay and southeastern coastal Everglades.

Methods

The USGS and science partners at National Park Service and Audubon Florida have monitored surface water hydrology in the EP and NE Florida Bay since the 1990's (Anderson, et al, 2014). In October 2015, two inactive U.S. Geological Survey paired shallow groundwater (GW) and surface water (SW) monitoring wells (LJB and LHC) in the lower EP marsh of ENP were re-gaged to establish a GW/SW salinity baseline in the EP to support NPS of restoration efforts and in anticipation of future water delivery modifications, including the development of the Eastern C-111 Spreader Canal and Biscayne Bay Coastal Wetlands (C111SCEP/BBCW) projects We used C-111 flow, rainfall and salinity data to highlight three dramatic hydrologic events during 2014-2017 that impacted the EP marsh habitat and NE Florida Bay

C111 Spreader Canal

C-111 Spreader Canal Western Project, Phase 1 (C111SCWP) was completed in February 2012 as a sub-part of the Comprehensive Everglades Restoration Project (USACE, 2014). Upstream retention ponds and canal modifications were constructed, directing more water flow (S-199) into Taylor Slough. Initially, the project was lauded (fig 1, fig 2). Audubon Florida reported Taylor Slough fresh water deliveries from C111SCWP reduced coastal mangrove salinity by 12.5 PSU from pre-C111SW levels in 2013 (Kline et al, 2017). However, in the EP marsh, fresh water availability has declined and salinities increased, due to topographic discontinuity (ridge) between Taylor Slough and EP and by diverting C-111 canal water below structure S18C (fig 2).

Figure 2. Left photo. Pump S-199, directs C-111 flows into Taylor Slough via secondary canal. S-199 has been operational since February 2012. Right photo. Spillway S18C with controls C-111 flows south to the EP and S-197 leading into Manatee Bay

Observations

We highlight three dramatic hydrologic events from 2014-2017 (drought, winter rains, and hurricane rain) that impacted the EP marsh habitat and NE Florida Bay by using C-111 upstream canal discharges, local rainfall (annual, seasonal and monthly), and marsh salinities and groundwater salinities.

Drought

Low rainfall and limited upstream freshwater discharge 2014-2015 led to drought conditions in the C-111 drainage and coastal marsh. The EP basin had its worst localized drought in over 25 years (1988-1990), creating prolonged hypersaline low-water marsh conditions that contributed to mortality of creek-lined red mangroves and reduction of freshwater marsh plants (fig 3).
Kline et, al. (2017) reported C111SCWP insufficient for improved water deliveries into Taylor Slough and Florida Bay during low rainfall periods.

Figure 3. Top: Mangrove mortality from drought (fall 2015).
Bottom: *Ruppia sp.* (Spring 2019)

Wet Winter

El Niño (ENSO) winter rainfall from Dec 2015 thru Feb. 2016 promptly ended the worst local drought in ~ 20 years. National Weather Service reported that 2016 was second wettest winter on record (1896-2016).
However, the preceding drought lead to high marsh plant mortality and subsequent plant recruitment and recovery has been slow. *Ruppia sp*. (fig 3) was the first SAV to re-colonize after drought, followed by *Utricularia sp* and Emergent herbaceous vegetation (EHV). Dry season SAV growth observed during 2015-2016 was atypical to typical summer SAV growth, and suggests strong evidence that salinity, not higher summer temperatures nor longer day length is the key driver of SAV abundance in the transition (Kline et al, 2017).

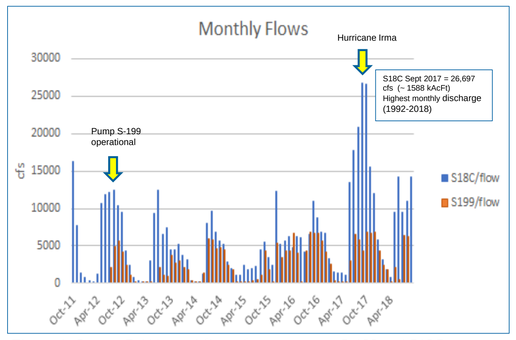

Figure 4. Lower C-111 canal flows from upstream S-199 and S18C.

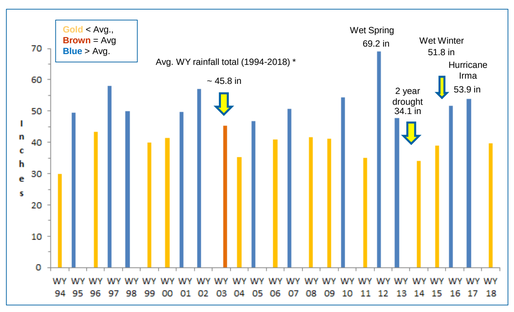

Figure 5. Average annual WY rain from 4 NPS gauges: LM, P37, TC, LS.

Hurricane Irma

Hurricane Irma (Sept 9-11, 2017) contributed to the greatest monthly rainfall (~ 30 inches) recorded for 30 years in Florida Bay/Taylor Slough/Eastern Panhandle of Everglades National Park. Rainfall totals for Sept 10 averaged 22 inches (fig 6) in Florida Bay and adjacent Taylor Slough and EP marsh. Local rainfall and canal discharges (figs 4, 5) overwhelmed the marsh and tidal creeks with freshwater, damping coastal marsh and NE Florida Bay water salinity for months. However, excessive fall rains alone have limited effectiveness in maintaining lower marsh salinity because the marsh has little capacity for watershed storage to be carried into the dry season. Contrasted with 2015-2016 winter rains which led to lower salinity throughout the dry season of 2016 (fig 7).

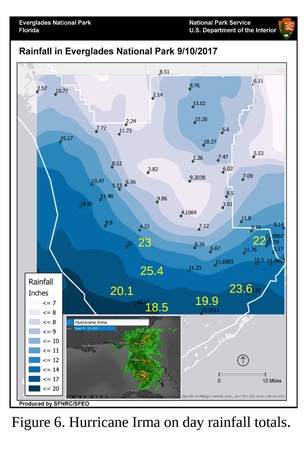

Figure 6. Hurricane Irma on day rainfall totals.

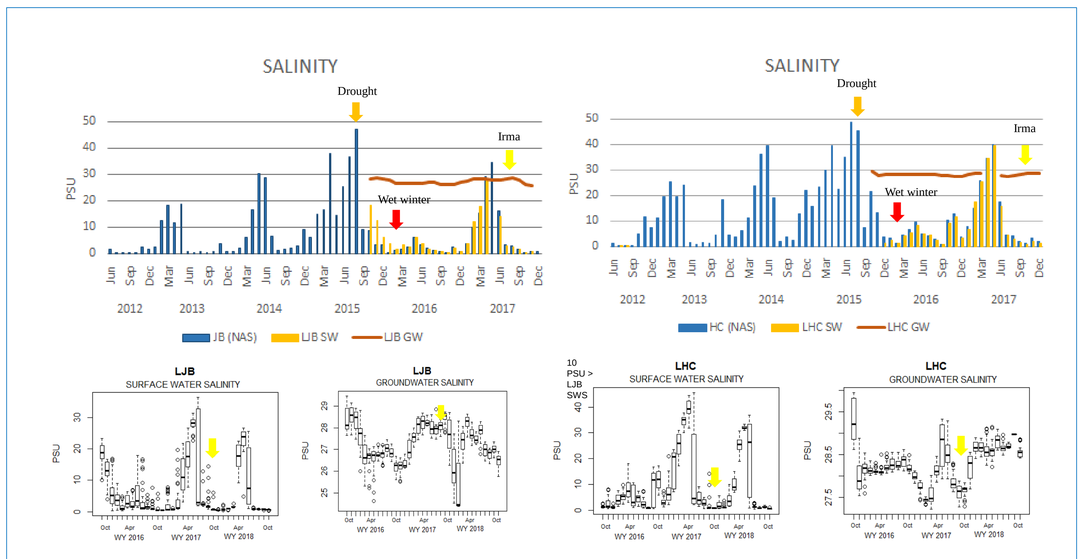

Figure 7. Top left. 2012-2017 merged averaged Audubon (JB) and USGS (LJB) Joe Bay monthly salinity (PSU, bar). Bottom left: USGS LJB surface and groundwater monthly salinity started Oct 2015 (PSU, box plot). Top right. 2012-2017 merged Audubon (HC) and USGS (LHC) Highway Creek monthly salinity (PSU, bar). Bottom right: USGS LHC surface and groundwater monthly salinity started Oct 2015 (PSU, box plot). Audubon gauge is in a tidal creek, USGS gauge is in the marsh. Surface salinities from both gauges track well, whereas the USGS groundwater salinity at less variable and responsive to surface changes. Highway Creek surface salinities peak is ~ 10 PSU greater because the site is closer to Florida Bay tidal influence. Top charts. 2014-2015 drought salinity peaks are denoted by orange arrow, 2015-2016 Wet winter salinity decease is indicated by the red arrow, and 2017 fall Hurricane Irma salinity decline is shown by yellow arrow.

Discussion

Extreme hydrologic events from 2014-2017 seriously test the ecological resiliency of the marsh. Drought and excessive fall rain do not lower dry season marsh salinity. However, winter or early spring rainfall or increased upstream overland or canal discharges can promote lower marsh salinities during the dry season. In fact, we observed that rainfall timing is more important than total rainfall (2012 vs. 2015-2106) to maintain lower marsh salinities needed to sustain vegetation (especially SAV), and to provide ecosystem stability essential for fish, birds and other fauna who reside in the habitat.

Everglades Eastern Panhandle and eastern Taylor Slough watersheds are disconnected by the C-111 canal from upstream overland marsh flows and simply too small to operate "naturally", especially from extreme "pulse events" such as storms, droughts, floods and saltwater intrusion (Strazisar, et al 2015).

Audubon reported the 2012 C-111 SCWP was ineffective at achieving restoration goals during low rainfall years. (Kline, et al 2017). Whereas, the anticipated Spreader Canal Project (C111SCEP) Phase II, with plans to backfill the lower C-111 canal and construct an upstream spreader canal would double the current EP watershed and greatly improve and stabilize the EP marsh.

C111SCEP Phase II (and the Biscayne Bay Coastal Wetlands) projects are currently stalled and their future development is uncertain. The USCOE Project Implementation Report objectives to restore the quantity, timing and distribution to the Taylor Slough and Eastern Panhandle marsh remains the same. However, given the C-111 SCWP Phase II spreader canal development uncertainty, stop gap efforts such as, increasing water levels at S18C, as was part of the original C-111 SCWP operational plan, could ameliorate this problem in the short term (Kline, et al 2017).

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Acknowledgements

This poster was presented at the 2019 Greater Everglades Ecosystem Restoration (GEER) Conference in Coral Springs, FL on April 24, 2019. Support for this study was provided cooperatively from Everglades National Park (NPS), and the USGS Wetland and Aquatic Research Center, Gainesville, FL. Ancillary data was graciously provided by Dr. Jerry Lorenz, Audubon Florida, and Damon Rondeau, Everglades National Park. Rainfall contour map was provided by Caryl Preston, Everglades National Park.

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