EFFECT OF NAVIGATION WINDOWS ON SALINITY IN THE APALACHICOLA ESTUARY, FLORIDA

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Abstract. The response of the Apalachicola River and Bay to sudden, relatively large changes in stage and flow due to navigation windows on the ACF system is examined using data collected over the summer of 1993 and a one-dimensional (river) hydrodynamic model. Of interest is the change in salinity in the East Bay portion of Apalachicola Bay as a function of changes in river flows. The summer of 1993 encompassed five navigation windows. The river model indicated that flow patterns associated with a navigation window were maintained through the distributaries and data from salinity stations in East Bay indicated freshwater pulses caused by these navigation windows modified the salinity structure of this portion of the estuary over both short and long term time scales.

INTRODUCTION

The response to various forces such as tides, winds, and river inflows is indicative of the unique characteristics of an estuarine system. In the case of Apalachicola Bay, large temporal variation of the meteorological forcing variables over time scales of hours to years is normal. This variation is a significant part of the character of the bay and presumably adds to the resiliency of the estuarine system.

The Corps of Engineers (COE), in looking for opportunities to improve navigation on the Apalachicola, Chattahoochee, and Flint (ACF) river system, used this variability in the river flow to introduce navigation windows. A navigation window is defined as a redistribution of natural flows which produces a higher river stage (flow) at selected times for the purpose of moving barges on the river system (Walker et al. 1994). The presumption by the COE is that these navigation windows act similar to naturally occurring river flows. The effect that these short term variations in river flow have on biological and chemical processes in the bay has not been studied.

During the summer of 1993 the COE operated the river to create five navigation windows. These windows significantly altered river flow over short time spans during the low flow period of the year. A review of changes in the flows reflected by the stage/flow data from a USGS gage (Figure 1) in the Apalachicola River at Sumatra, FL suggests that this flow would be integral in defining a changing salinity regime. Of importance to the natural system are whether or not these types of changes, especially during the low flow spectrum of the hydroperiod, influence the bay and what is the spatial extent of this influence. The combination of a number of physical characteristics of this bay however, makes the connection between the river and the bay difficult to determine with any certainty.

Congruent with this period, a set of salinity, temperature and velocity data was collected at the John Gorrie Bridge at the mouth of East Bay (Figure 2). East Bay is considered a vital component for the survival of this estuarine system providing, among other benefits, a nursery area for many bay and ocean species. This paper analyzes this data to examine the relationship between changes in river flow and the subsequent response in temperature and salinity in East Bay.

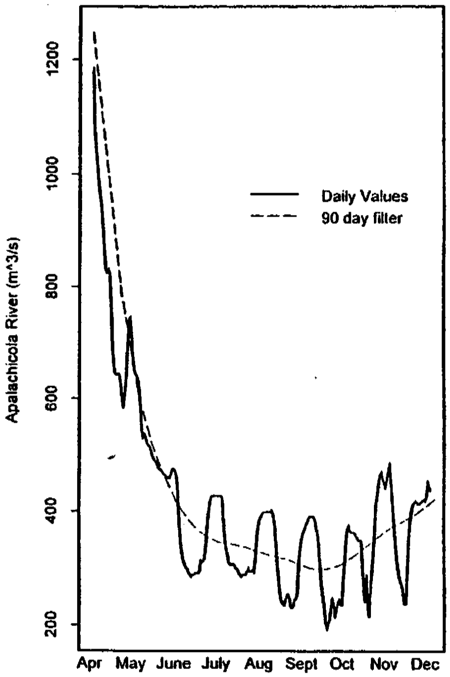

Figure 1. 1993 Apalachicola River flows (solid line) with the five navigation windows, and approximate average flows (dashed line) without the navigation windows.

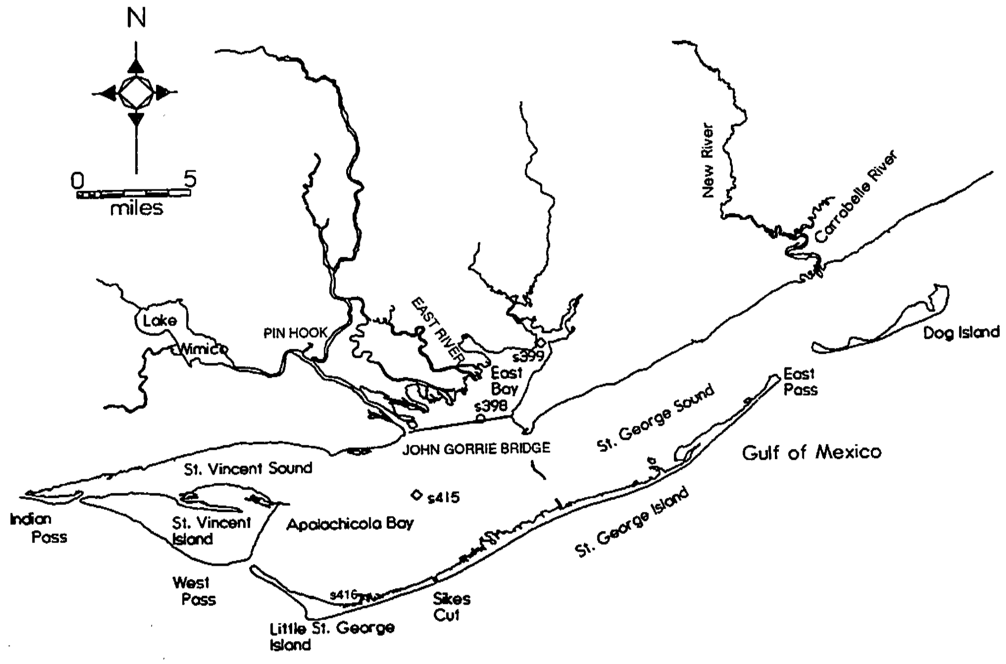

Figure 2. Apalachicola bay areas. Station S398 at the John Gorrie Bridge was the salinity station discussed here.

Concept of Navigation Windows

Water oriented industries are in competition for freshwater. In normal rainfall years, the existing distribution of water resources does not appear to have a significant effect on the downstream users. Competition obviously becomes more prevalent as water resources become scarce as in the case of summertime droughts. The Apalachicola River typically has its lowest flows in late summer and early fall. Flow can drop to low enough levels to restrict navigation as early as May and last through November. In addition to low flows (or stage), continued degradation of the river bed in the reach between Jim Woodruff dam and Blounstown, as well as restrictions to dredging in the mid-river area (Blountstown to south of Wewahitchka) because of the lack of appropriate spoil sites, have caused significant modification to the shape of the channel and require additional water to provide a stage sufficient for a requisite 7.5 foot channel.

The concept of navigation windows was developed in 1988 by the Corps of Engineers (COE) to provide relief to the navigation industry without causing damage to the water dependent estuarine system downstream. The navigation window is a technique where water is saved in upstream reservoirs over a period of time and then released to provide an adequate channel for a ten to fourteen day period to allow for moving commodities up the river, loading or unloading and returning. Navigation channel users are coordinated through Tri-Rivers Waterway Development Association so that the best use of the waterway can be made (Walker, et al., 1994).

Effect of Navigation Window on Streamflow

Figure 1 is a plot of (a) the flow rate through the Jim Woodruff dam at the Florida/Georgia border, the headwaters of the Apalachicola River, and (b) a 90-day moving average over this record to illustrate flows without the windows. Two points to make are: 1) The navigation windows in 1993 caused nearly a three-foot change in elevation at the Blountstown gage and modified the hydroperiod of floodplain communities. There was obviously a higher stage during the navigation window than what would have been provided under "normal" conditions. This was also associated with a lower stage while water was being stored. It is unclear as to what effect these changes have on the riverine system. Effects of changing stage in the Apalachicola River on the floodplain will be discussed in other papers. 2) There was more than a 100% change in the flow over a two-day period. The ecological system depends on variability; however, variability induced by man should remain within the range of the natural variability of the system.

ANALYSIS

Distributary System

The main stem of the Apalachicola River discharges into Apalachicola Bay and for the most part is carried south and west, leaving the bay through West Pass. A large portion (>27%) of the flow recorded at the Sumatra, FL gage, 33 km north of the mouth, is diverted from the main stem of the Apalachicola River into the system of distributaries that eventually flows into East Bay (Jones et al., 1994) (Figure 2). This diversion of flow from the main river is considered to be important to the ecology of East Bay as it provides the majority of its freshwater For navigation windows to have an effect on the salinity structure of East Bay, changes in flow must maintain the basic signature of the flow pattern from the upstream gage as it passes through the distributaries.

Hydrodynamic Model

The estuarine system at East Bay is directly influenced by freshwater that is diverted from the main stem of the Apalachicola River through the tributaries just south of Sumatra. The distributaries are an intricate set of interconnecting well defined channels that span a 33 km system of tidal marshes and swamps. Because of the large area and tidal influence, adequate measurements of flow are difficult. A one-dimensional model (DNYHYD, EPA) was developed and used to transfer the Apalachicola River flow as recorded at the Sumatra gage through the distributaries to Apalachicola Bay and East Bay. The model calculates flow using the time dependent equations of motion and is forced by dynamic head conditions from variable tides across the mouths of the distributaries. The model was calibrated using limited velocity (converted to flow) measurements made in the distributaries and main stem.

The signal from the navigation window is clearly evident in the results of the one-dimensional model in the distributaries and as far down the mainstem of the river as Pin Hook. Below Pin Hook the flow in the main stem does not appear to maintain the pattern of the navigation window. Tidal head appears to dominate this six mile reach of the river forcing a significant flow into the Jackson River and to Lake Wimico where the signal is dampened by the large lake and marsh. More work needs to be conducted to see if this, in fact, is occurring.

East River is the largest contributor of freshwater of all the distributaries to the bay. The signal associated with each navigation window is clearly seen in the East River discharge (Figure 3), and indicates that the majority of the flow that diverted from the mainstem and is discharged into East Bay does so in the form of freshwater pulses. From this result we can conclude that at least some portion of East Bay is affected by these changes in flows.

The East River channel is well defined, regular, and relatively deep. Independent measurements of velocity taken in 1994 (not associated with navigation windows) in the East River ranged between 0 and 50 cm/s depending on tides. If we use the simple relationship of flow equal to velocity times cross-sectional area (Q = A V) with 25 cm/s as a representative velocity and we consider a constant width of 100 m, we can calculate the stage in the East River for flows of 100 m^3/s and 70 m^3/s respectfully. If there were no bay to fill the channel back up, there would be a meter drop in stage between these two flows (tidal change is generally 0.6 m). As fresh water flows in East River decrease, the volume in the channel is made up by water from East Bay which is salty. This is an extremely crude estimate; however, it illustrates the potential of a significant intrusion of salt water into the channel due to the navigation window alone.

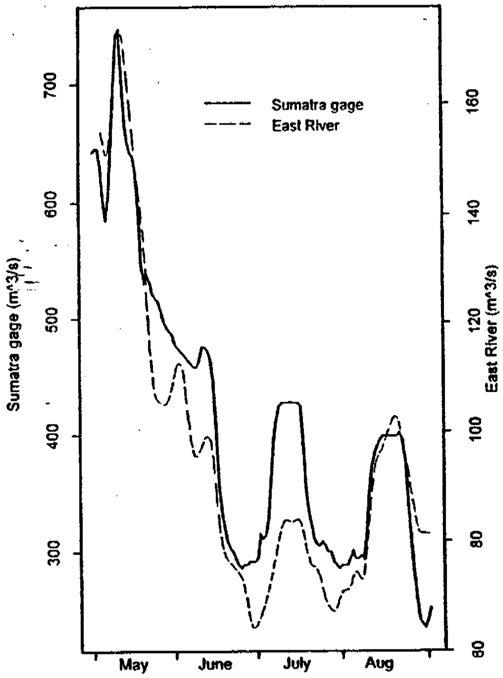

Figure 3. Apalachicola flow at Sumatra (solid line) and at East Bay (dashed line) from the distributary system.

Salinity in East Bay

To determine how much of the bay responds to freshwater pulses created by navigation windows, three salinity stations were examined over the period of the five recorded navigation windows. The data collected from the John Gorrie Bridge site is discussed here. The stations (Figure 2) were part of the data collection program for the Apalachicola River and Bay component of the Apalachicola-Chattahoochee-Flint-/Tallapoosa-Coosa-Tallapoosa Comprehensive study. These stations were so located that they should measure changes due to the large freshwater flux as seen in a navigation window. Salinity was measured at half-hour intervals. The meters were positioned in shallow water (<3m) with the sensors just off the bottom.

The salinity field near the bottom is less sensitive to river flow than that on the surface. especially during low flow periods where the volume of freshwater to flush East Bay is smaller. Tidal forces continually replace a reduced amount of freshwater transported out of East Bay on the surface with saltier Apalachicola Bay water along the bottom. This is evident from the summer long trend of decreasing river flow and subsequent higher salinity at all three local salinity stations (dashed line, Figure 4).

Figure 4 (a) depicts the daily flows at Sumatra and (b) the salinity record that has been smoothed using a two week moving average filter to remove high frequency (tidal) oscillations. During the first ten day period, when flows were reduced to store water in reservoirs for the navigation window, salinity levels increased from approximately 18 to 25 ppt. Upon the subsequent release of freshwater, salinity then dropped to nearly 15 ppt. This pattern repeated itself

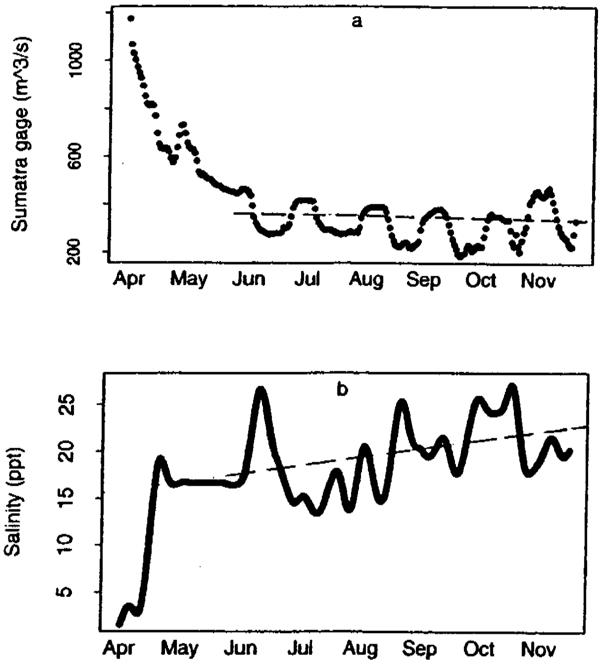

Figure 4. (a) Apalachicola River flow at Sumatra Gage, and (b) Filtered salinity data from John Gorrie Bridge. Dashed line is a least square best fit on the data between June and November, 1993.

throughout the summer with East Bay becoming saltier and the short-term salinity change becoming less.

As another measure of the effect of freshwater changes, we can examine the resistance time of East Bay. A rough estimate of the volume north of the John Gorrie Bridge is 45x106 m^3. If flows are on the order of $100m^3/s$, it would take approximately five days to replace the volume. Though an over-simplification of the dynamics, this exercise indicates that the time scale of salinity change seen in the data is realistic.

CONCLUSION

This paper takes an initial look at effects of navigation windows on the distributary system and East Bay. Results from DYNHYD, a 1-d model of the distributaries, indicated that East River, the largest of the distributaries, does carry the freshwater pulses created by the navigation window to the bay. Crude estimates infer that water level changes of up to one meter in East River could be attributed to the navigation window alone. This illustrates that reduction of flows at this level could allow for greater excursions of salt water up the distributary potentially affecting the freshwater marsh system. If this is true, we need to understand what changes to the hydroperiod of the marsh system along the distributaries are made and whether they have a detrimental effect. It remains unclear whether the natural diversion of water from the main stem of the Apalachicola River into the Jackson River significantly modifies this signal.

It appears that freshwater pulses derived from control of the river during navigation window were seen in the salinity record at the mouth of East Bay. Increases and decreases in salinity appeared to be inversely correlated with the freshwater signal of the navigation windows. The time scale associated with these large salinity changes was consistent with the resistance time of East Bay and expected flows in the distributaries. We do see that all of East Bay is affected by the long term (summer) reductions in freshwater in the form of increased salinity.

We have not addressed the issue of serial correlation between the river and salinity data. This will be done through other work and is required prior to making definitive statements on correlations. Additional work is also being conducted to quantify the percent of variability in the salinity field caused by changes in freshwater delivery.

Though the results shown here appear reasonable, they are not yet conclusive of cause and effect. A three-dimensional model is being used to quantify the effect of navigation windows on East Bay but also to examine any other bay-wide influences that may be present. As the implementation of navigation windows becomes more of a standard operations policy on the ACF, we need to examine the effect that these quickly changing flows and stage have on the biological and chemical processes important to a productive bay.

ACKNOWLEDGMENTS

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