A Mathematical Model of Apalachicola Bay Salinity and its Effects on Oyster Harvesting

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Abstract. Biological productivity in estuaries is strongly influenced by freshwater inflows that provide nutrients and determine salinity variations; in particular, oyster growth and mortality are directly related to salinity. The salinity in Apalachicola Bay, Florida, is heavily influenced by flows in the Apalachicola River, the lower part of the Apalachicola-Chattahoochee-Flint (ACF) river basin. The ACF is shared by Alabama, Florida, and Georgia, and is subject to on-going negotiations on competing water demands that may result in significant operational and flow regime changes. Apalachicola Bay is the most important ACF basin ecosystem. The bay is hydro-dynamically complex. The river flow enters perpendicular to the main estuary axis as a surface buoyant jet. Its subsequent mixing in the bay is influenced by periodic tidal currents that are primarily diurnal and semidiurnal. Winds, particularly those blowing along the long estuary axis, can significantly affect circulation and volume fluxes and therefore salinity and water quality. Although the bay is very shallow it can have strong vertical density stratification. The relative magnitudes of the various driving forces, wind, tide, and freshwater inflow, vary, resulting in significant temporal and spatial (i.e., horizontal and vertical) salinity variations. A three-dimensional hydrodynamic model of the bay was set up, calibrated and validated using Delft3D and existing data. The purpose of the model is to assess the impacts of upstream regulation and climatic changes on salinity. The modeling effort resulted in realistic simulations of the major estuary major hydrodynamic characteristics. The modeled water levels are in very good agreement in phase and magnitude with measured values at all available recording stations. Salinity results also follow reasonably well the general observational trends. Long term salinity variations were assessed through a 16-year simulation experiment, clearly showing the significant influence of river flow on salinity. Salinity in oyster bar regions exhibits considerable variability over intra-annual time scales, but its interannual and long term statistical distribution is consistent with previously identified ranges favorable to oysters. Salinity-based indicators for environmental change and oyster sustainability are proposed and used to identify the existence of possible trends. Such trends are indeed detected, with salinity conditions gradually shifting away from those favorable to oysters. The article discusses the likely sources contributing to these trends and makes adaptation recommendations.