A COMPARATIVE STUDY OF HYDROLOGIC EXCHANGE IN SUB-TROPICAL ESTUARIES, SOUTHWEST, FLORIDA, USA

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INTRODUCTION

Estuaries are tidally dominated embayments where ocean water and inland drainage mix (Duxbury and Duxbury, 1984). Inland drainage in sub-tropical estuaries is derived from a variety of sources, including groundwater from salt water and freshwater marshes and mangrove forests, surface water drainage from streams and tidal inlets, and overland flow (EPA, 2001). Hydrologic exchange between ocean water and inland drainage effect both the physical and geochemical properties of estuarine waters (Savarese et al., 2000).

Estuaries support diverse ecosystems of flora and fauna, which rely on salinity variation and nutrient fluxes from both inland and ocean sources (EPA, 2001). The hydrologic exchange in estuaries enables them to be among the most biologically productive ecosystems in the world. Annually, estuaries produce more organic carbon than comparable areas of forest, grassland, or even agricultural land (EPA, 2001). Additionally, estuarine circulation and tidal mixing serve to flush inland derived anthropogenic pollution out to sea (Duxbury and Duxbury, 1984).

Over the past fifty years, Florida's coastal population has grown, threatening estuarine ecosystems (Savarese et al., 2000). To accommodate growth, water control structures, such as weirs and canals, have been constructed to regulate flooding during the wet season and maintain an adequate supply of water during the dry season (Savarese et al., 2000). Land alteration in southwest Florida impacts water sources, quantity and quality of water, water flow pathways, and discharge areas of inland drainage into estuaries (Savarese et al., 2000).

To preserve, manage, and protect estuarine ecosystems in urbanized coastal regions, it is important to identify inland derived sources of water into estuaries and understand hydrologic exchange between ocean and inland drainage in estuaries. The purpose of this study was to use geochemical and carbon isotope variation in estuaries as a proxy to identify the dominant source of inland drainage and investigate hydrologic exchange in three estuaries in Southwest Florida.

STUDY AREA

This study was conducted in sub-tropical riverine estuary systems within the Rookery Bay National Estuarine Research Reserve (RBNERR) located in southwest Florida, USA (Figure 1). Southwest Florida has a humid, temperate to subtropical climate, averaging between 1.19 to 1.57 m of annual precipitation (Perlmutter, 1982). However, the area's seasons are based on rainfall, with wet summer and fall months; while winter and spring months are relatively dry (Savarese et al., 2000).

Three estuarine systems in the RBNERR were investigated in this study. Blackwater River, a relatively pristine estuary, was used as a control for comparing two altered estuaries, Henderson Creek and Faka Union (Savarese et al., 2000). All three estuary's watersheds are similar in size and geomorphologic structure (Savarese et al., 2000). Blackwater River, Henderson Creek, and Faka Union are located entirely within a coastal wetland system.

The upper region of Blackwater River is comprised of freshwater and saltwater marshes that grade to mangrove forest towards the ocean. Henderson Creek is located to the northwest of Blackwater River, while Faka Union is located to the east of Blackwater River (Figure 1). The headwaters of Henderson Creek drain an area that is predominantly residential and agricultural. Faka Union's headwaters are extensively canalled, and drain a large freshwater-marsh complex.

The headwaters of Faka Union and Henderson Creek estuaries have water control structures used to regulate the rate and timing of freshwater input to the estuaries. The weir on Henderson Creek is a top-opening-gated weir, and Faka Union has a fixed-crest weir at its headwaters (Savarese et al., 2000). During the study, water was flowing over the Faka Union weir, but was impounded behind the Henderson Creek weir. Blackwater River lacks a control structure.

METHODOLOGY

Water from Blackwater River, Henderson Creek, and Faka Union estuaries was sampled for geochemical parameters and stable carbon isotope analysis during the onset of the wet season (June 18- July 5), 2001. Sampling was completed twice in each estuary, from the headwaters to the ocean (Figure 1). During the rising tide sampling period, the high tide interface was crossed approximately half-way down the estuary, allowing sampling of headwaters at low tide, middle reaches as tide invaded, and lower reaches at high tide. During the high tide sampling period, the tidal front was followed as tide invaded the estuary, so that all samples were collected at high tide. Sampling dates were chosen with similar relative tide ranges, thus minimizing the effects of tide magnitude for relative comparison between estuaries. Salinity, total dissolved inorganic carbon (DIC), and carbon isotopes ($\delta^{13}C$) were utilized as geochemical tracers.

RESULTS

Different trends and magnitudes of salinity, DIC, and $\delta^{13}C$ are apparent for each estuarine system (Figure 2). Salinity increased similarly toward the ocean during rising tide for all three estuaries, but salinity values at the headwaters of each estuary differed (Figure 2a). Salinities at the headwaters of Faka Union were lower compared to Blackwater River, while Henderson Creek headwaters had higher salinities relative to Blackwater River (Figure 2a). Salinities of all three estuaries converged towards value of ~39 ppt in the ocean portion of the estuaries (Figure 2a). High tide salinity trends for Henderson Creek differ from those of Blackwater River and Faka Union. During periods of maximum ocean water input into the estuary from tides, Henderson Creek salinity did not vary significantly from headwaters to the ocean, while the salinity for Blackwater River and Faka Union gradually increased from ~0 ppt to ~39 ppt (Figure 2b).

DIC and $\delta^{13}C$ trends for Blackwater River differed from salinity trends. Blackwater River DIC increased toward the middle portions of the estuary, and then decreased toward the ocean for both high and rising tide samplings (Figure 2c and 2d). DIC for Henderson Creek and Faka Union decreased from the headwaters toward the ocean (Figures 2c and 2d). Henderson Creek had lower DIC compared to Blackwater River. DIC in Faka Union was higher than that of Blackwater River, except in the mid-estuary during maximum tidal influence (Figure 2c and 2d). $\delta^{13}C$ for Blackwater increased in the headwater, decreased in the mid-estuary, and increased toward the ocean (Figure 2e and 2f). $\delta^{13}C$ for Henderson Creek and Faka Union increased steadily toward the ocean and their concentrations were higher compared to Blackwater River for both rising and high tide (Figure 2e and 2f).

DISCUSSION

Many of the observed differences between Henderson Creek, Faka Union, and the control estuary, Blackwater River, are related to differences in dominant sources of inland drainage and primary mechanism of hydrologic exchange. The spatial trends of salinity, DIC, and □^{13}C combined with differences in geochemical concentrations at the headwaters between minimum (rising tide) and maximum (high tide) tidal influence can be used to determine sources of inland drainage and mechanism of hydrologic exchange.

Blackwater River had low salinity for both the rising tide and the high tide (Table 1). Low salinity during periods of both minimum and maximum tidal influence suggests a significant source of freshwater drainage present at the headwaters of Blackwater River. Additionally, spatial trends in DIC and □^{13}C for Blackwater River trends indicate a source of high DIC/low □^{13}C mid-estuary (Figure 2c-2f). However, the salinity did not show trends similar to DIC and □^{13}C trends, indicating that inland drainage was moderately saline with high DIC and low □^{13}C. These characteristics are indicative of shallow groundwater drainage from the freshwater marsh, saltwater marsh, and mangrove forest. In addition, minimal change in DIC and □^{13}C, and the gradually increasing spatial salinity trends for both rising and high tide further suggest that a combination of inland drainage and tides drive hydrologic exchange in the estuary (Figure 2a and 2b and Table 1).

Henderson Creek experienced a high degree of headwater variation in salinity, DIC, and □^{13}C (Table 1). However, DIC and □^{13}C spatial trends indicated a source of inland drainage with moderate salinity, moderate to low DIC, and low □^{13}C (Figure 2a-2f). The geochemistry of the Henderson Creek headwaters were similar to the geochemistry of the mid-estuary water along Blackwater

River, suggesting that shallow groundwater from the mangrove forest was the dominant source of inland

drainage. Additionally, the significantly different concentrations of salinity, DIC, and □^{13}C between high and rising tides for Henderson Creek at the headwaters suggest that hydrologic exchange in this estuary is dominated by tidal flux.

Salinity and DIC at the headwaters of Faka Union varied little between periods of minimum and maximum tidal influence, similar to the headwaters of Blackwater River. However, DIC at the headwaters was relatively high indicating that water entering the estuary was predominantly stream water (Table 1). The gradual downstream trends in all geochemical and isotopic parameters for both high and rising tide suggest that hydrologic exchange in the Faka Union estuary is dominated by stream discharge and tidal flux.

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