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TAKING THE PULSE OF AN ESTUARY: A QUESTION-BASED APPROACH TO ENVIRONMENTAL MONITORING WITHIN THE SOUTH SLOUGH NATIONAL ESTUARINE RESEARCH RESERVE, OREGON

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INTRODUCTION

Pacific northwest estuaries exhibit substantial diversity in geomorphology, and they differ considerably in the spatial and temporal extent of influence by riverine inputs versus oceanic forcing. Oregon's large drowned river-mouth estuaries are typically considered to be dominated by river discharges (*i.e.*, Columbia, Umpqua, Coquille) or by tidal inputs (Tillamook, Yaquina, Coos Bay / South Slough). Ambient status and trends monitoring conducted by the South Slough National Estuarine Research Reserve System-Wide Monitoring Program (SWMP) was used to evaluate spatial and temporal changes in inputs into the South Slough estuary from the moist maritime climate and nearshore Pacific Ocean. The analysis was focused to address: *"to what extent are chlorophyll levels and nutrient dynamics within the South Slough estuary driven by oceanic forcing and seasonal upwelling events versus watershed inputs?"* This example of question-based monitoring contributes to our understanding of the South Slough as a case-history for a Pacific northwest estuary. In addition, the information also contributes to the emerging effort to develop a better understanding of nutrient loadings and water quality as fundamental components of an ecosystem-based approach to management of the Coos estuary and nearshore marine ecosystem.

SOUTH SLOUGH ESTUARY

The South Slough estuary (Figure 1) is an ebb-dominated, well-mixed, drowned river-mouth tidal basin that functions to integrate inputs from the nearshore Pacific Ocean and the adjacent coastal watershed. The estuarine tidal basin encompasses the full hydrographic gradient from marine-dominated waters at the mouth (Boathouse), to polyhaline waters in the mid region (Valino Island), and mesohaline/oligohaline waters in the riverine region (Winchester Creek).

TEMPORAL AND SPATIAL PATTERNS

The physical characteristics and water quality signature of the South Slough exhibit spatial, seasonal, and tidal changes along the estuarine gradient. For example, concentrations of dissolved inorganic nitrate (NO_3^-) are generally higher in the wet season (Nov-Mar) and lower in the dry season (May-Sep; Figure 2). The seasonal pattern of nitrate availability was consistent throughout all regions of the estuarine tidal basin during sampling of the water column conducted at low tide, and at the Winchester Creek (riverine) and Valino Island (polyhaline) stations at high tide (Figure 2). This pattern is indicative of substantial riverine input of nutrients that is driven by rainfall events and watershed discharges that enter the headwaters of the estuary through numerous small creeks and streams. In contrast, the nitrate concentrations at the mouth of the estuary (Boathouse / marine-dominated) were greater in the dry season and lower in the wet season, particularly during high tide (Figure 2). This reversal in the seasonal pattern of nutrient availability is indicative of the input of nitrate from marine sources in the northern region of the estuary when the tidal basin is flooded by nutrient-rich waters from the Pacific Ocean.

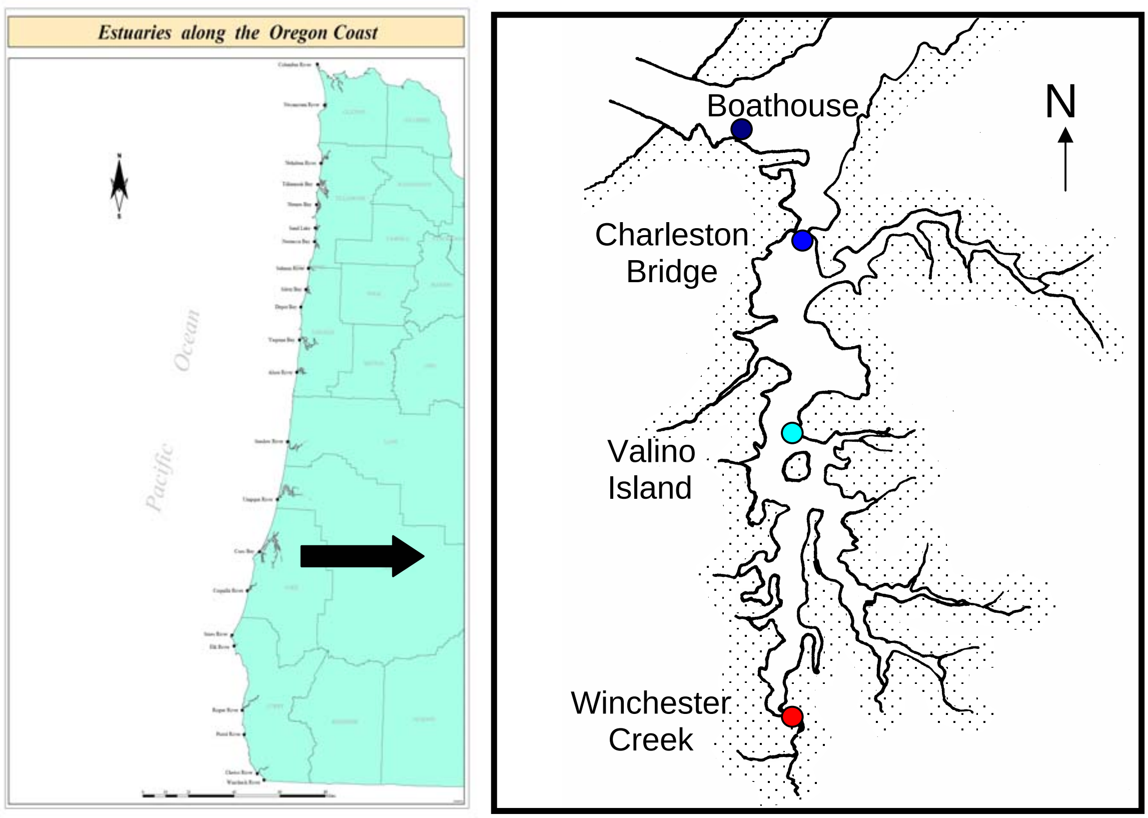

Figure 1. Estuaries along the Oregon coast, and map of the South Slough estuary with location of monitoring stations along the estuarine gradient.

Our seasonal monitoring data collected during the wet season at high tide also revealed a spatial decrease in nitrate concentrations from their highest values in the riverine (Winchester Creek) region to substantially lower values in the marine (Boathouse) region (Figure 2d-f). However, the opposite pattern was observed during the dry season when nitrate concentrations at high tide were greatest at the Boathouse, intermediate at Valino Island, and lowest at Winchester Creek (Figure 2d-f). A seasonal reversal was also observed in the relationship between nitrate levels and salinity of the estuarine water column. During the wet season, nitrate concentrations throughout the estuary decreased directly with salinity (negative slope; Figure 3a). The highest nitrate values occurred at

Winchester Creek (oligohaline; salinity 0-5) and the lowest values occurred at the Boathouse (euhaline; salinity >30). During the dry season, nitrate concentrations generally

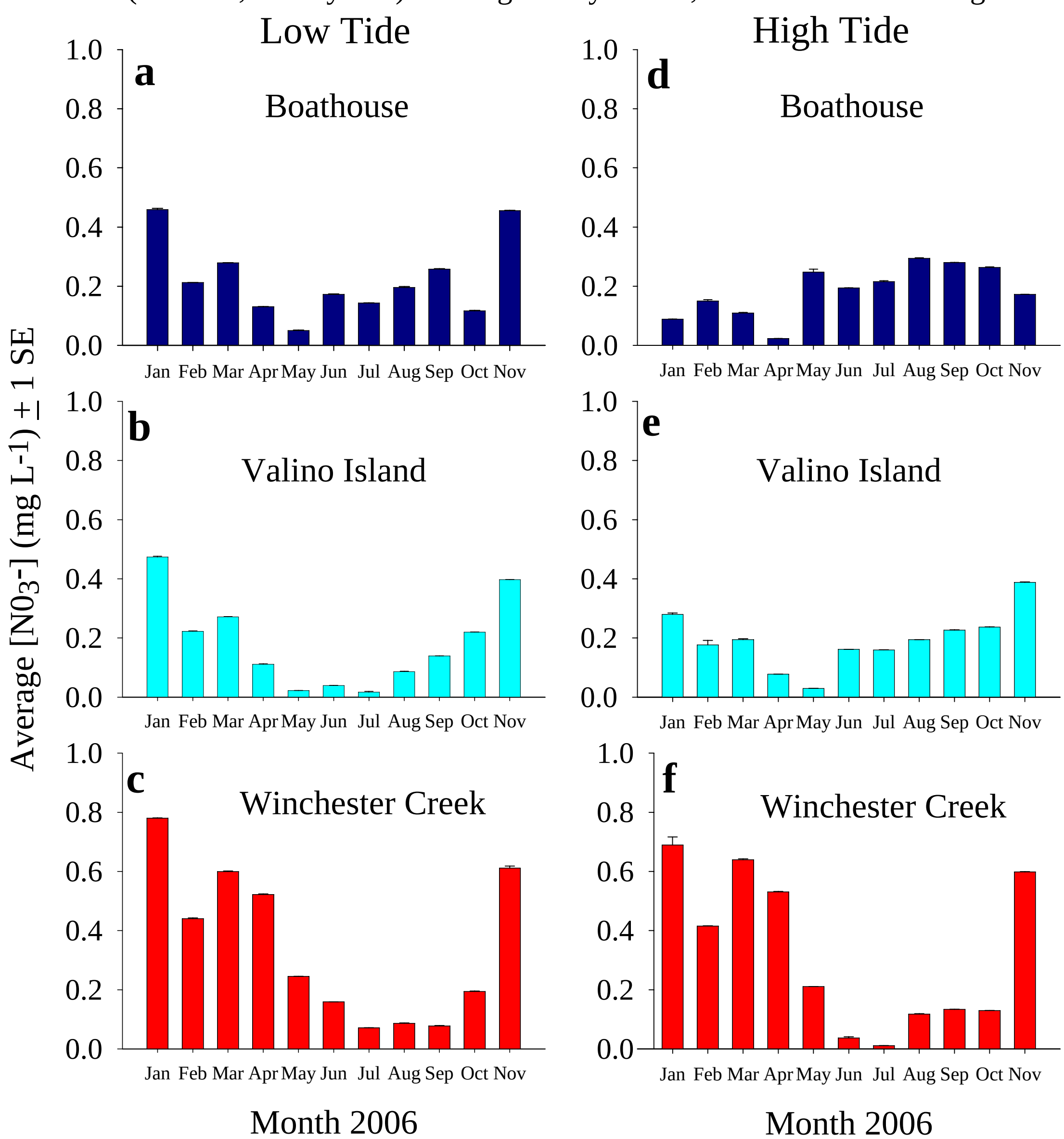

Figure 2. Nitrate concentrations (n=3 per month) during low (a-c) and high (d-f) tides (Jan-Nov 2006) at three stations along the estuarine gradient of the South Slough, OR (Boathouse, marine; Valino Island, polyhaline; and Winchester Creek, riverine).

increased with salinity (positive slope); however, the seasonal reversal pattern was weaker (Figure 3b). It is important to note that the relationship between nitrate concentrations and salinity differed substantially between the different hydrographic regions of the estuary during the dry season (Figure 3b). These differences in the seasonal pattern of nitrate availability provide further evidence that riverine sources are important throughout the estuary during the wet season and that nutrient inputs from marine sources are important during the dry season.

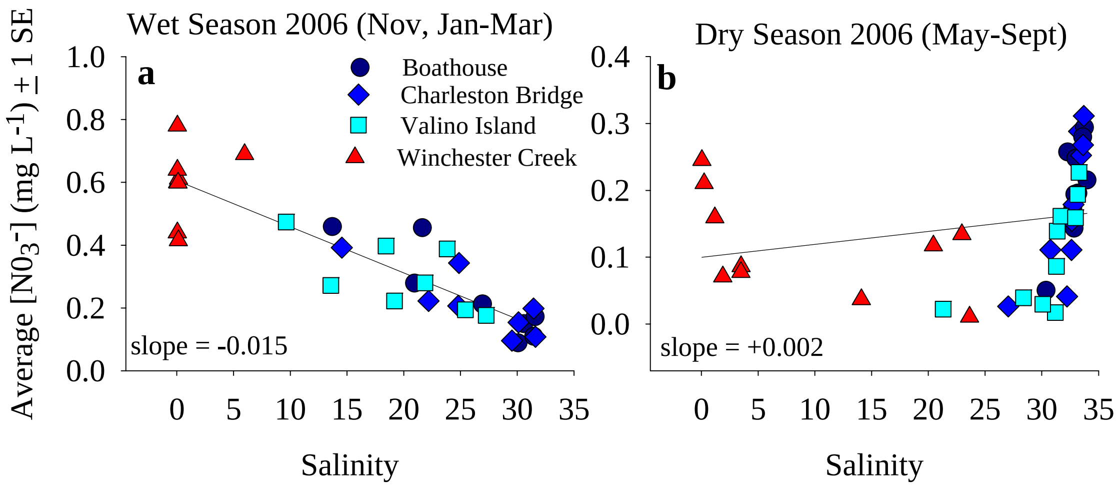

Figure 3. Relationships between nitrate concentrations (n=3 per point) and salinity during the a) wet (Nov-Mar) and b) dry (May-Sept) seasons of 2006 at four stations within the South Slough, OR; (see Figure 1 for locations of study sites). Note different scales on y axes; lines represent linear regressions.

Characteristics of the estuarine water column also change on a daily basis between the flood and ebb cycle of the semi-diurnal high and low tides. During the wet season, concentrations of both nitrate and chlorophyll-a are directly out-of-phase with the rise and fall of the semi-diurnal tides (Figure 4a). The high concentrations of nitrate and chlorophyll-a at low tide are indictative of riverine inputs of nutrients from the South Slough watershed coupled with primary production of phytoplankton within the estuary. In contrast, during the dry season concentrations of nitrate and chlorophyll-a are directly in-phase with the rise and fall of the tides (Figure 4b), indicative of nutrient inputs from marine sources and production by phytoplankton that are brought into the estuary by flooding tides.

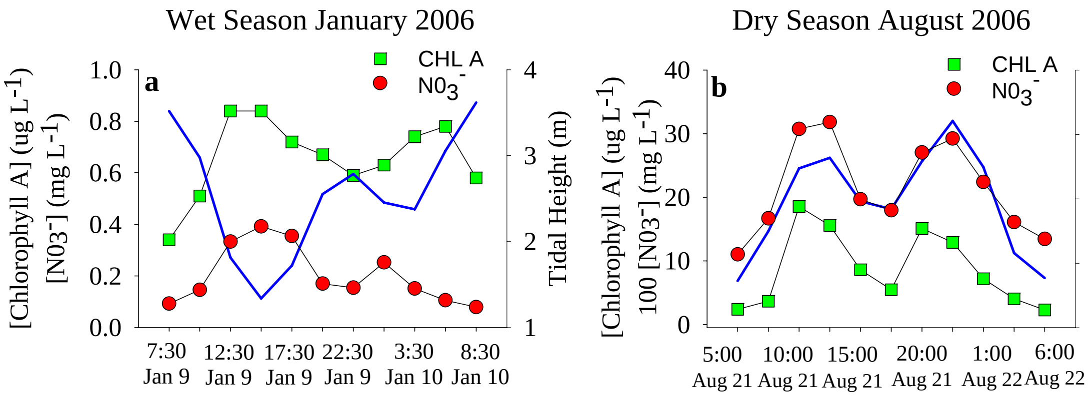

Figure 4. Tidal changes in nitrate and chlorophyll-a concentrations during the a) wet and b) dry seasons at the Charleston Bridge SWMP station. Note the different scales on the y-axes. The nitrate concentration for the dry season has been scaled up (100x) to compare chlorophyll-a and nitrate on the same graph.

Time-series datasets collected by the South Slough NERR SWMP also include continuous real-time measurements (every 5 min.) of local meteorological parameters and near real-time measurements (every 30 min.) of multiple estuarine water parameters (Figure 5a). These time-series measurements provide a snap-shot illustration (1-16 Nov 2006), of short-term changes in the water column at the Charleston SWMP station located in the marine-dominated / polyhaline region of the estuary. Tidal forcing by the semi-diurnal tidal signal is strongly evident in the time-series measurements of salinity, dissolved oxygen (DO), and turbidity. For example, salinity values were generally high and varied between 28-30 during 1-6 Nov, and then decreased to 18-28 during 7-16 Nov following a significant rainfall event. The time-series signature for dissolved oxygen and turbidity also changed substantially after 7 Nov when DO values more closely matched the tidal signal and turbidity values decreased and became less variable (Figure 5a).

AN UNEXPECTED MONITORING APPLICATION

The underwater pressure sensor within one of our SWMP dataloggers also recorded the arrival time and magnitude of a small-scale tsunami generated by an undersea earthquake that originated about 8 hrs earlier in the Kuril Islands, Russia (Figure 5b). The mini-tsunami was detected at the Charleston Boat Basin by a NOAA/NWLON tide gauge and by the NERR SWMP station shortly after 11:30 am on 15 Nov 2006. The tsunami was greatly diminished and resulted in local disruptions in surface water levels by about 9-10 cm. Disruptions in estuarine water levels continued throughout the South Slough for about 12 hrs. The historic and near real-time datasets are accessible for the South Slough estuary via the internet from the NERRS Centralized Data Management Office (http://cdmo.baruch.sc.edu).

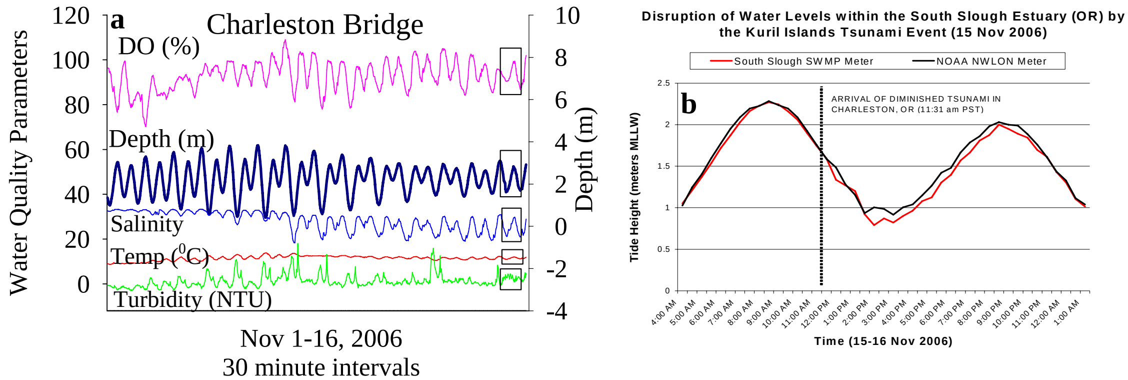

Figure 5. a) Time-series measurements (30 min. interval) of water quality parameters (dissolved oxygen, depth, salinity, temperature, turbidity) at the Charleston Bridge SWMP station, South Slough, OR. Boxes identify time period during small-scale tsunami event. b) Detection of a small-scale tsunami within the South Slough estuary, OR.

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