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The impact of anthropogenic activities on nutrient dynamics in the tropical Wenchanghe and Wenjiaohe Estuary and Lagoon system in East Hainan, China

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ABSTRACT

Biogeochemical observations were carried out in the Wenchanghe and Wenjiaohe Estuary, Bamen Bay and Gaolong Bay during 2006–2009 to understand the nutrient dynamics of these areas and their relationship with the sustainability of the ecosystems in the coastal areas of Eastern Hainan Island and its adjacent South China Sea. Nutrients in river/estuary waters, groundwater, aquaculture effluents and rainwater samples were analyzed using spectrophotometry. Nutrient levels in the tropical Wenchanghe and Wenjiaohe show a wide range of variation depending on the system, nutrient element and season. These two rivers are enriched with DIN and depleted in PO_4^{3-} with the DIN:PO_4^{3-} ratios varied from 60 to 411. In the rivers, TDP was mainly composed of DOP, representing ~65%. DON accounted for 40% of TDN in the Wenchanghe and 76% of that in the Wenjiaohe. Dissolved silicate levels in the Wenjiaohe and Wenchanghe were lower than average levels in tropical systems.

Nutrients in the Wenchanghe and Wenjiaohe Estuary behave either conservatively or non-conservatively depending on the element being considered and the season. Based on observations of nutrients in various aquatic environments, a simple steady-state mass-balance box model was employed to assess nutrient budgets in the estuary system. Nutrients in the studied system were mostly from riverine input, groundwater discharge and aquaculture effluents. The nutrients exported in the studied system are largely confined to the immediate estuaries. The typhoon-induced runoff of terrestrial rainwater can not only increase nutrient inputs to the coastal ecosystem but can also result in nutrient imbalance, affecting phytoplankton production and composition.

1. Introduction

Riverine transport is a principal pathway of particulates and dissolved elements from land to sea. Estuaries modify riverine nutrient fluxes to the sea significantly through biogeochemical processes (Liu and Zhang, 2004; Liu et al., 2009; Soetaert et al., 2006). Small and midsized rivers, which are more easily affected by natural and environmental changes than the major river systems, can still contribute to substantial changes in the ecosystems in coastal ocean (Jennerjahn et al., 2004). Dramatic increases in the delivery of riverborne nutrients and changes in nutrient ratios owing to anthropogenic activities are known to result in eutrophication, which modifies the aquatic food webs and causes severe hypoxic events in coastal environments (Turner and Rabalais, 1994; Turner, 2002; Liu et al., 2009; Diaz and Rosenberg, 2008).

Hainan Island, situated in the southern part of China in the South China Sea (SCS), is abundant in tropical ecosystems, such as mangroves and coral reefs, and has a surface area of 33,920 km^2 and population of 750×10^4 inhabitants. A tropical monsoonal insular climate prevails in Hainan Island, with northerly winds in the winter and southerly winds in the summer (Su, 2004). However, since the 1970s, many fringing reefs have been destroyed by tourism and for high-grade lime and cement purposes, which has resulted in an approximately 100-meter retreat of the coastal zone (Chen and Teng, 1996). Since the 1980s, the mangrove area has been reduced; 2×10^5 m^2 of the whole Hainan Island mangrove ecosystem has been changed to a manmade shrimp ecosystem (Jin et al., 2008). Due to climate change and anthropogenic activities, such as intense agricultural, fishing and tourism activities, the tropical ecosystems of Hainan Island are facing serious problems, such as changes in land use, destruction of mangroves, aquaculture effluents, overfishing, use of illegal fishing techniques (i.e., dynamite

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and cyanide), sedimentation, waste discharge and fertilizer and pesticide use, which are threatening more than 90% of the sensitive ecosystems of the island (Jin et al., 2008; Gong et al., 2008).

This study presents the results of biogeochemical observations in the Wenchanghe and Wenjiaohe Estuary and Lagoon system during 2006–2009. Nutrients in river/estuary waters, groundwater,

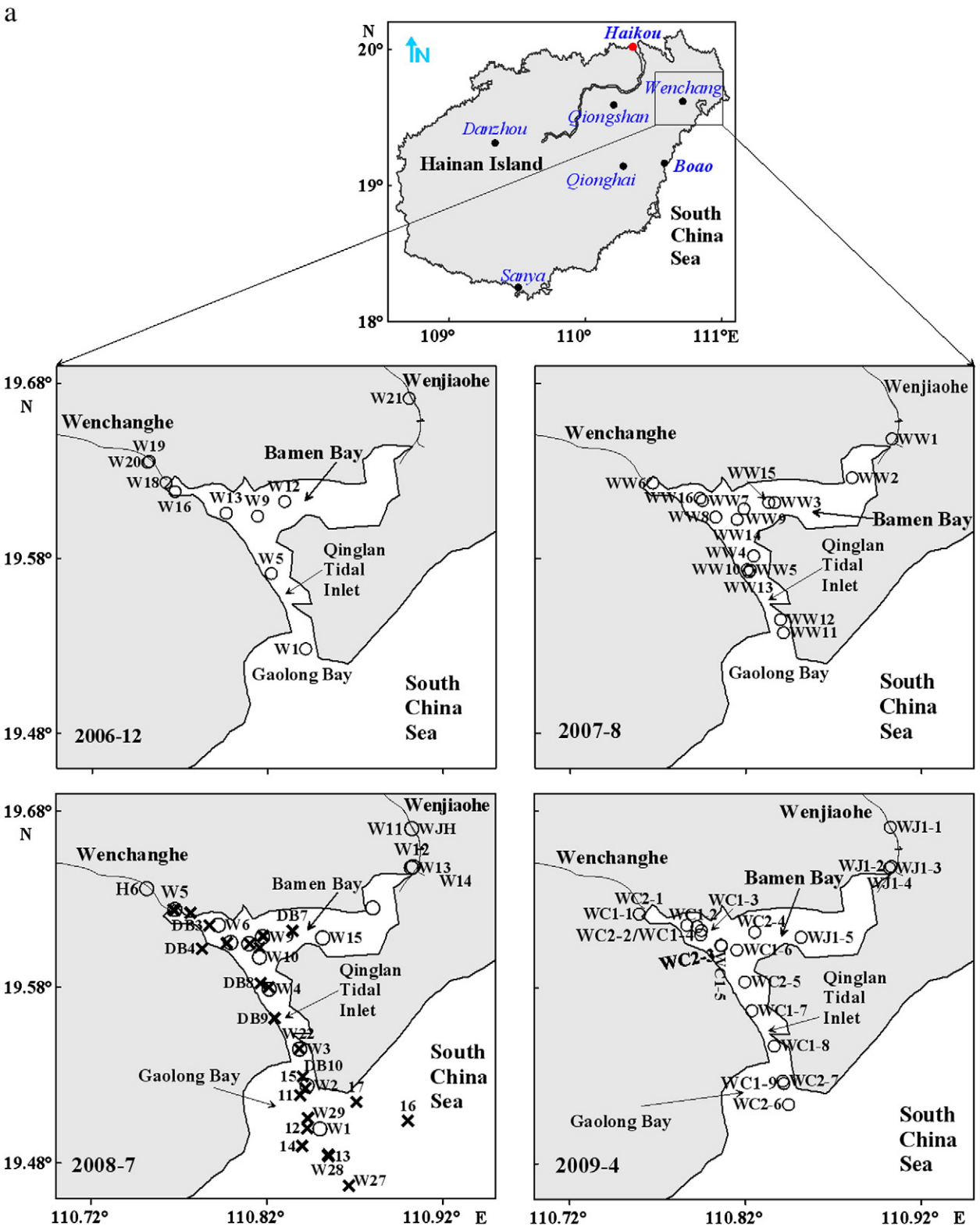

Fig. 1. (a) Locations of the stations for the cruises in the Wenchanghe and Wenjiaohe Estuary and Lagoon system from 2006 to 2009, which shows the sampling periods of December 2006, August 2007, July–August 2008 and March–April 2009 in the estuary. (b) The sampling stations in the submarine groundwater (left, ●: 2007; ◊: 2008; ○: 2009) and aquaculture effluents (right, ○: 2008; ▲: 2009). In addition, two anchor stations (★) were observed over 25 h in Bamen Bay and the Qinglan tidal inlet in 2008, and one anchor station was observed each day over the investigation periods in Gaolong Bay in 2007, 2008 and 2009. (c) The tracks of the drift observations in the Qinglan tidal inlet and Gaolong Bay in 2008. The tracks for each drift observation were identified with progressive vectors (arrows) to show the track directions.