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The sediment budget of an urban coastal lagoon (Jamaica Bay, NY) determined using ^{234}Th and ^{210}Pb

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ABSTRACT

The sediment budget of Jamaica Bay (New York, USA) has been determined using the natural particle-reactive radionuclides ^{234}Th and ^{210}Pb. Inventories of excess thorium-234 ($^{234}Th_{xs}$, half-life = 24.1 d) were measured in bottom sediments of the Bay during four cruises from September 2004 to July 2006. The mean bay-wide inventory for the four sampling periods ranged from 3.5 to 5.0 dpm cm^{-2}, four to six times that expected from ^{234}Th production in the overlying water column. The presence of dissolved ^{234}Th and a high specific activity of $^{234}Th_{xs}$ on particles at the bay inlet (~30 dpm g^{-1}) indicated that both dissolved and particulate ^{234}Th could be imported into the bay from the ocean. Based on these observations, a mass balance of ^{234}Th yields an annual input of ~39 ± 14 × 10^{10} g sediment into the bay. Mass accumulation rates determined from profiles of excess ^{210}Pb (half-life = 22.3 y) in sediment cores require annual sediment import of 7.4 ± 4.5 × 10^{10} g. Both radionuclides indicate that there is considerable marine-derived sediment import to Jamaica Bay, consistent with earlier work using ^{210}Pb. Such sediment input may be important in sustaining longer-term accretion rates of salt marshes in the bay.

1. Introduction

Coastal lagoons are usually sinks for organic and inorganic sediments and can be highly impacted by anthropogenic processes (Kjerfve, 1994). One such system, Jamaica Bay, is located along the southern coast of western Long Island (O'Shea and Brosnan, 2000, Fig. 1A, B). The bay area is 53 km^2 (subtidal area 39 km^2; Benotti et al., 2007), with numerous salt marsh islands, a mean water depth of ~5 m, and no significant riverine input. Ocean water enters the Bay through Rockaway Inlet, which serves as a pathway for particle and water exchange between the Bay and the New York Bight. Waves in the Bay are produced by local winds.

Jamaica Bay has been subjected to impacts associated with heavy urbanization in the surrounding New York city area, such as extensive dredging, marsh ditching and filling, bulk-heading, marsh restoration and landfill construction (Black, 1981; Botton et al., 2006). In particular, areas were dredged in the northern bay (Grassy Bay) to create landfill for expansion of J.F. Kennedy International Airport (Fig. 1A). As well, the dominant supply of freshwater to the bay is wastewater from four sewage treatment facilities (Fig. 1A).

Historical changes to Jamaica Bay may have altered both the patterns of circulation and the sediment budget. A potentially important aspect of the sediment budget of Jamaica Bay is supply of inorganic (mineral) material to the salt marsh islands. Between 1951 and 2003 the vegetated marsh area of Jamaica Bay decreased from 9.5 to 3.5 km^2 (Update on the Missing Marshes of Jamaica Bay, NY, 2007). This loss has been attributed to widening of tidal channels, slumping and erosion along the marsh margins, expansion of internal tidal pools and increased marsh fragmentation (Hartig et al., 2002). Sediment deposition, or rather the lack thereof, may be important either as a driver of the process of marsh degradation or as a factor that may simply exacerbate the problem once it begins.

Naturally occurring particle-reactive radionuclides (e.g. ^{234}Th and ^{210}Pb) are useful tracers to determine sediment budgets in coastal marine systems (Feng et al., 1999; Giffin and Corbett, 2003) because their well-characterized sources permit construction of mass balances and their strong association with particles permits

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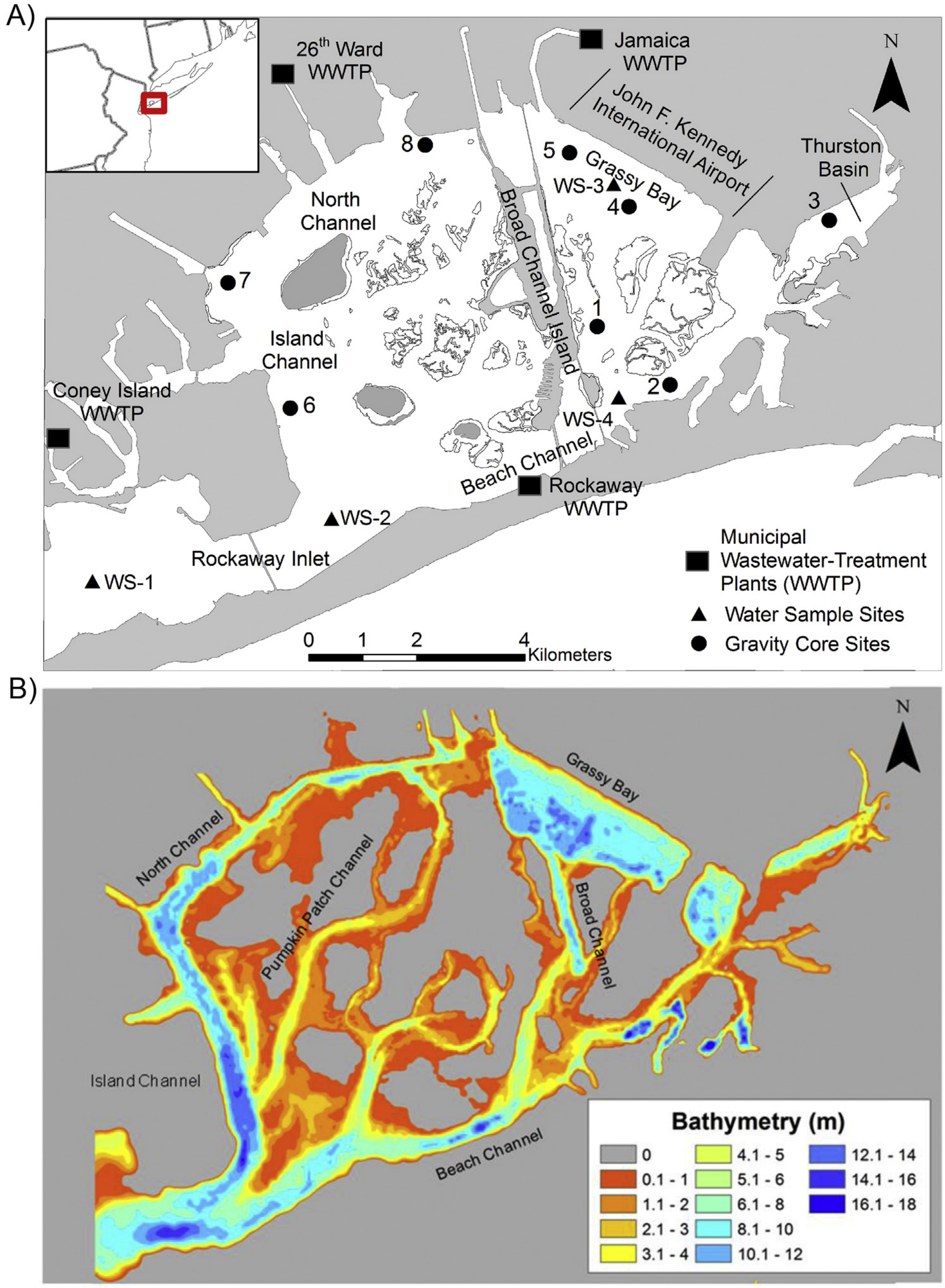

Fig. 1. A: Map of Jamaica Bay. Locations of wastewater treatment plants (WWTP) are shown as solid squares gravity cores (1–6) as filled circles, and water sampling stations as filled triangles. Inset map shows location of bay in northeastern USA. (adapted from Benotti et al., 2007). B: Bathymetric map of Jamaica Bay. Water depths are in meters. (Data provided by R. E. Wilson, Stony Brook University).

them to be used to evaluate fluxes of sediment transport and redistribution. The short-lived radionuclide ^{234}Th (half-life = 24.1 days) is useful in studying processes that operate over seasonal time scales (Aller and Cochran, 1976; Aller et al., 1980), whereas longer-lived ^{210}Pb (half-life = 22.3 years) is more applicable for investigating processes on longer time-scales up to about 100 years (Appleby and Oldfield, 1992; Corbett et al., 2006, 2007). Dominant sources of these radionuclides to coastal waters include in situ production from dissolved ^{238}U in the case of ^{234}Th and atmospheric input in the case of ^{210}Pb; both ^{234}Th and ^{210}Pb are rapidly scavenged onto particles and subsequently track the fate of the particles (Baskaran and Santchi, 1993; Baskaran and Swarzenski, 2007). Here we use the distributions of both radionuclides in the sediments of Jamaica Bay to characterize the sediment budget of the Bay on both seasonal and multi-decadal timescales.

2. Methods

2.1. Field methods

Subtidal sediment samples were collected in Jamaica Bay during cruises in September 2004, May and November 2005, and July 2006. Cruises were scheduled to compare changes in seasonal wind patterns, precipitation and frequency of storm events in the summer, spring and fall. The sample sites were distributed throughout the bay, with an emphasis on regions of interest that were