Marine Geology 251 (2008) 183–194

Contents lists available at ScienceDirect

Marine Geology

journal homepage: www.elsevier.com/locate/margeo

Sediment transport and dispersion in a cool-temperate estuary and embayment, Saco River estuary, Maine, USA

L.L. Brothers [a,*], D.F. Belknap [a], J.T. Kelley [a], C.D. Janzen [b]

[a] Department of Earth Sciences, University of Maine, Orono, ME 04469, USA
[b] Sea-Bird Electronics, Inc., Bellevue, WA 98005, USA

ARTICLE INFO

Article history:
Received 11 June 2007
Received in revised form 12 February 2008
Accepted 20 February 2008

Keywords:
sand transport
estuary
nearshore
sedimentary pathways
New England

ABSTRACT

The Saco River flows through a rock bound, mid-latitude estuary recognized as the primary source of sand to the Saco Bay barrier beach system. To better constrain the conditions under which the Saco River contributes sand to Saco Bay, three moorings equipped with current meters and a CTD were deployed inside and outside the Saco River jetty system, from April to June, 2005. These measurements characterized high-discharge events and their competence for transporting sand outside the jetty system. Discharge values from 125–175 $m^3 s^{-1}$ were identified as the threshold envelope at which the Saco River transports sand in its bedload to Saco Bay. Put in an 89-year historical context with USGS stream gauge data, the Saco River is expected to contribute sand annually to the embayment, but the amount of transport varies significantly from year to year. The moored hydrographic data were augmented by geophysical, Langrangian drifter data, and local wind observations to better ascertain nearshore dispersal patterns once sand exits the jettied river mouth. These data suggest that transported sand responds to seasonably variable shelf conditions, reacts to artifacts of the jetty system, or exits Saco Bay. The results and methods of this study suggest that relatively small, rock-bound estuaries are potentially significant sources of sand to adjacent beach systems and the inner shelf, although the pathway for sand from river to shoreface to beach or inner shelf is complex and mediated by local meteorological and oceanographic conditions.

1. Introduction

1.1. Background

Rivers have been recognized as conduits for offshore sediment transport in tectonically active margins with high relief, such as the western continental shelf of the United States, and in large watersheds forming deltaic deposits (Morgan, 1970; Inman and Nordstrom, 1971; Wright and Coleman, 1973; Milliman and Meade, 1983; Sternberg, 1986; Kuehl et al., 1986; Nittrouer, 1999; Sommerfield and Nittrouer, 1999; Ogston et al., 1999). Estuaries associated with rivers on passive margins have been conventionally characterized as sedimentary traps, or sinks, owing to the confluence of suspended material at the freshwater/marine interface and the landward transported bedload within the salt wedge of stratified estuaries (Pritchard, 1967; Potsma, 1967; Meade, 1969; Boyd et al., 1992; Dalrymple et al., 1992). Recent evaluations of mid-latitude, cool-temperate, bedrock channeled estuaries indicate that in these settings, under high-fluvial discharge, river flow can overcome the estuaries' tidal prism and transport coarse-grained sediment, primarily in the bedload, seaward within the estuary (Milliman and Meade, 1983; Horne and Patton, 1989; Fenster and FitzGerald, 1996; Fenster et al., 2001; FitzGerald et al., 2002; Lobo et al., 2002; FitzGerald et al., 2005). Despite the recognized potential for sediment transport and deposition in these rock-bound estuaries, the relative frequency and magnitude of such occurrences are not fully characterized. Furthermore, subsequent sediment dispersal and deposition on the inner shelves of these structurally controlled coastal environments is also not well constrained. The role of estuaries as sediment conduits has relevance to questions regarding mass sediment flux from the continents to the shelves and the long-term evolution of these coastal systems. Better understanding of how and when rock-bound estuaries function as sediment conduits also benefits a variety of practical concerns including pollutant mitigation and coastal erosion management.

This paper documents an investigation of river estuary sediment transport and modern nearshore deposition along a glaciated, passive continental margin located in Saco Bay, ME, USA (Fig. 1). This location allowed us to evaluate a class of estuary not adequately described by previous estuarine models and a size of river not well studied in other sediment-transport works (Boyd et al., 1992; Dalrymple et al., 1992; FitzGerald et al., 2000). The objectives of this study were to: 1) assess the river's capability for delivering sand to its inner shelf by determining a discharge threshold for seaward bedload sediment transport; 2) apply this threshold to historical discharge records, thus constraining the frequency and duration of such sediment delivery;

* Corresponding author. Tel.: +1 207 581 1998; fax: +1 207 581 2202.
E-mail address: laura.brothers@umit.maine.edu (L.L. Brothers).

0025-3227/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.margeo.2008.02.004

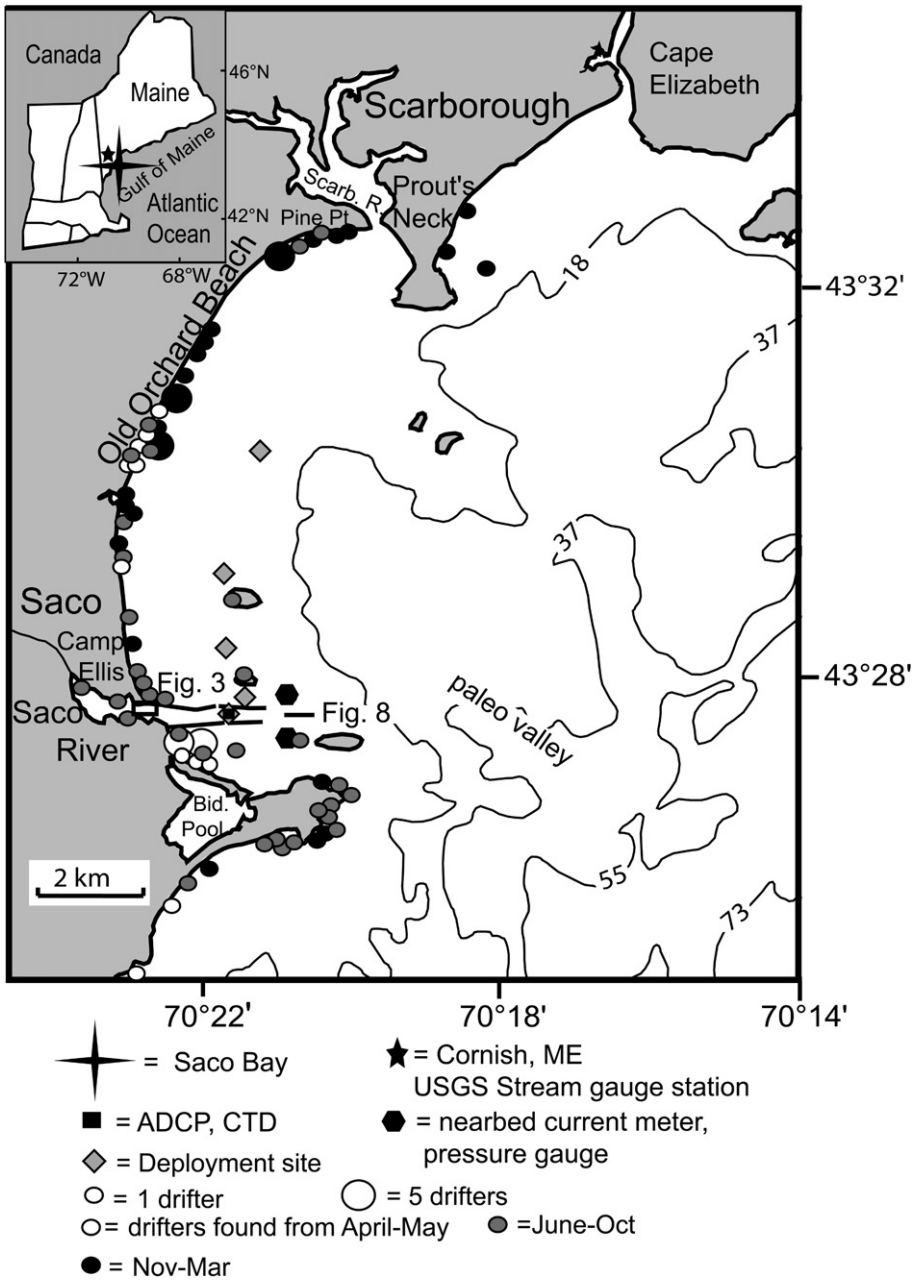

Fig. 1. Location and bathymetry of the study site, Saco Bay, within the Gulf of Maine, and place names used in the text. Locations of moored instrumentation, Woodhead seabed drifter deployments and recoveries, and other numbered figures in this paper are indicated by symbols and boxes. Bathymetry data comes from Barnhardt et al. (1996).

and 3) determine, through drifter surveys, hydrographic and geophysical analysis, depositional sites of sand in the inner shelf. A better characterization of modern sedimentary processes and pathways in mid-latitude, nearshore estuarine settings will improve process-based coastal zone management strategies in such developed coastal regions. Moreover, it will provide a baseline for evaluating other dispersal systems in similar glaciated, rock-bound estuarine environments.

1.2. Previous work

Several estuarine facies models examine estuaries based on the relative importance of tide and wave energy (Boyd et al., 1992; Dalrymple et al., 1992). FitzGerald et al. (2000) demonstrated that the Kennebec River, ME exhibits patterns of sedimentation and sand bodies that differ markedly from accepted estuarine models. He found that in regions where a strong structural grain exists, the geologic structure strongly influences the geometry of the drainage systems as well as the position and morphology of individual river channels including their estuarine mouths (FitzGerald et al., 2000). Horne and Patton (1989) and Lobo et al. (2002) also found conduit behavior in estuaries associated with discharge events, structural control and extensive drainage basins (>20,000 km^2) in New England and the Iberian Peninsula. Although the Saco River (Fig. 2) has a significantly smaller drainage basin (4400 km^2), it too is located in a structurally controlled region and contains few of the morphological features diagnostic of the tide dominated estuarine models (Boyd et al., 1992; Dalrymple et al., 1992).

Due to United States Army Corps of Engineers' (USACOE) navigation works and consequent sediment budget concerns in Saco Bay, much