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Short Communication

Flood discharges of a small river into open coastal waters: Plume traits and material fate

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Abstract

The dynamics of plumes from large rivers are relatively well known. Many estuaries are small, however, and discharge directly onto exposed, open shorelines and presumably produce smaller plumes that may have different properties. Therefore this study measured traits of a small estuary on the Australian East Coast as a model system, focusing on (a) plume size, (b) distinctness of plume edges, and (c) imprints on the seafloor. Although plumes were found to be limited in spatial extent (ca. 1 km offshore × 2.4 km longshore) and were constrained near the shore by onshore winds, they exported high nutrient loads from an urbanised watershed. The small plumes were shallow (<2 m) and strongly buoyant, with sharp vertical and horizontal clines similar to much larger plumes. The edges of the plumes were highly distinct, clearly separating disparate water masses that trapped significantly higher amounts of nutrients inside the plume. Some particulate material exported from the estuary in the plumes reached the benthos of the nearshore zone, as evidenced by increases in copper concentrations in sediments under the plume. By contrast, the amount of land-sourced carbon delivered by small plumes to the seafloor was minor in comparison to larger inputs from marine sources (e.g. onshore advection of phytoplankton blooms or algae dislodged from reefs) that swamped any contribution from plumes. Overall, small plumes can be important in land–ocean coupling, but their zone of influence may be limited.

Keywords: Australia; estuary; heavy metals; river; stable isotope analysis

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1. Introduction

Rivers and estuaries often discharge in the form of plumes, which act as conduits for the export of sediments, nutrients, and organic material from land to the oceans (Furnas et al., 1995; Rabalais et al., 2000). Plumes are often buoyant, spatially confined, and characterised by sharp clines in salinity and turbidity (Grimes and Kingsford, 1996). Plumes are areas of enhanced biological processes in the pelagos (Devlin et al., 2001), and modify the benthos via precipitation of particulate matter (Alliot et al., 2003).

Plumes have mostly been studied for large rivers (e.g. Mississippi, Amazon) that deliver high loads of nutrients and deposit organic material over large areas of the shelf (Smith and Demaster, 1996; Alongi, 1998; Lohrenz et al., 1999; Rabalais et al., 2000). Plume traits may, however, not scale down linearly from larger systems in situations when small rivers discharge directly onto exposed shorelines. Such small estuaries on open coastlines are common in most of Australia and South Africa (Eyre, 1998; Harrison, 2004). In addition to estuarine size (and presumably plume size), the discharge characteristics of such small estuaries may also differ from larger rivers. In Australia, freshwater flow in 70% of estuaries is in the form of episodic, short-lived, but large, freshwater spikes that occur mostly during the austral summer (Eyre, 1998).

Given the paucity of data on plumes from small estuaries that discharge directly onto open shorelines not bounded by bays or offshore islands, we targeted such small plumes and quantified three key properties: (1) the spatial extent of small plumes, (2) the concordance between visually sharp plume

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boundaries and chemical differences of water masses, and (3) possible plume imprints on the seafloor.

2. Methods

Small plumes were studied off the Mooloolah estuary, SE Queensland, Australia (Fig. 1). The estuary is small (catchment 194 km^2), shallow (1–5 m) and short (tidal reaches 13 km; Schlacher et al., 2005). It discharges directly onto an exposed coast through a narrow and shallow mouth (ca. 3 m deep × 80 m wide). Because significant river discharge along this coast occurs mostly during the austral summer in the form of distinct spikes (Eyre, 1998), sampling concentrated on the rainy season during the austral summer and autumn of 2002/2003 that included several rainfall pulses.

The spatial extent of surface plumes was determined from physical sampling of the water column (CTD casts of salinity, temperature, turbidity and isotopic and elemental signatures – δ^{13}C, δ^{15}N, %C, %N – of suspended organic particles), complemented by aerial surveys in light aircraft. We contrasted conditions after the largest rainfall spike during the rainy season of 2002/2003 (10 February 2003, river discharge 1500 ML day^{-1}, rainfall 95 mm) with "low-flow" conditions (20 December 2002, river discharge <100 ML day^{-1}, no rainfall in preceding fortnight). Water samples were taken at 22 sites chosen from visual assessments by observers in boats and in aircrafts overhead. To determine the properties of plume edges, vertical profiles of water chemistry and physics were recorded at 10 sites distributed inside the plume and just seawards of the plume's edge (Fig. 1c). Seafloor imprints of plumes were assessed from sediment collections at 24 sites (Fig. 1a), comprising sets taken before (13 and 20 December 2002) and after (31 December 2002, 14 January 2003) a significant discharge event.

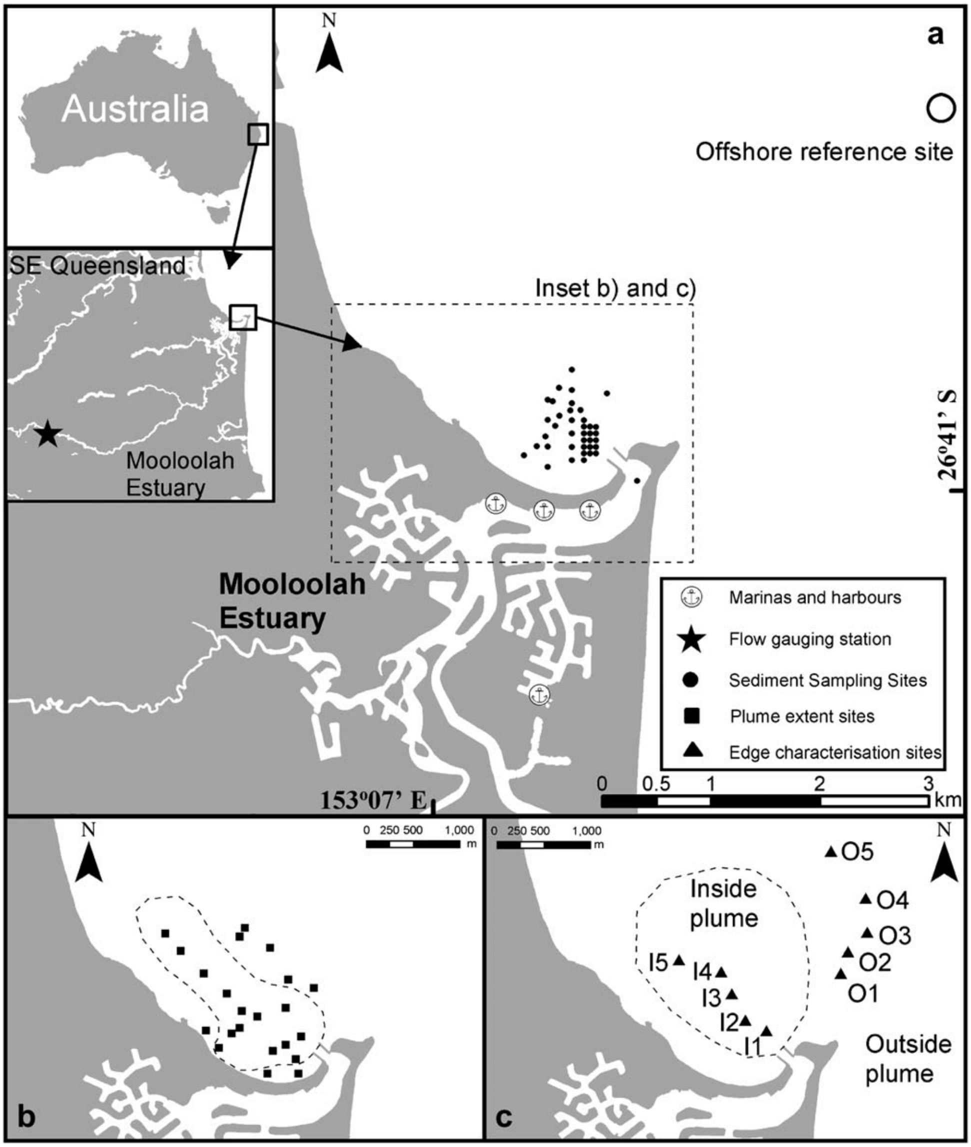

Fig. 1. The Mooloolah estuary showing sampling location for (a) sediment mapping, (b) plume extent, and (c) edge characteristics. The approximate spatial extent of plumes, estimated from CTD casts and visual observations, is represented by the dotted line in (b) and (c).