Brooke, B. 2003. The role of sedimentological information in estuary management. Proceedings of Coast to Coast 2002 - "Source to Sea" Conference, Tweed Heads, pp. 31-34.

The role of sedimentological information in estuary management

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Abstract: The analysis of sediment cores from estuaries can provide a range of useful insights into their environmental history and health. In many Australian estuaries the rate and nature of sedimentation has significantly changed since European settlement. Wave-dominated estuaries in particular, which act as efficient sediment traps, are more rapidly infilling. In these estuaries the deeper central basins are filling with fine sediments, while fluvial deltas are rapidly prograding into the estuary. Turbidity has also increased because of resuspension of the fine lithic and organic sediments by waves and tidal currents. Analysing cores of sediment from the various estuarine depositional environments can provide measures of the rate of sedimentation and temporal changes in the character of sediments. These data can be used to identify the physical impacts on the estuary of catchment land use practices. Sediment cores can also provide evidence of recent changes in the concentrations of nutrients and other pollutants that have entered the estuary, as well as recent changes that have occurred in estuarine vegetation communities. Clearly, this information can help inform the management of the estuarine environment.

1. INTRODUCTION

Wave-dominated estuaries have developed on the moderate to high wave energy coasts of southeastern and southwestern Australia [Heap et al., 2001]. Barrier estuaries are a type of wave-dominated estuary that are particularly efficient at trapping terrestrial sediment eroded from their catchments. They have developed on low-gradient coasts following the deposition of shore-parallel bodies of sand approximately 7,000 years ago, and since then have been infilling with sediment (Fig. 1). Indeed, during the late Holocene several former barrier estuaries have been essentially filled in to form coastal floodplains and deltas [Roy et al., 2001]. In estuaries that are currently infilling, marine sand also is brought in by flood tide currents, while terrestrial sand and silt accumulates around the mouths of creeks and rivers in the head of the estuary (Fig. 1). Between these environments there is usually a relatively deep central basin that forms the main sink for catchment-derived fine sediment, and autochthonous organic debris. Following European settlement, catchment clearance and disturbance has increased sediment loads in streams discharging into these estuaries, significantly increasing the rate at which they are infilling (Table 1). This enhanced sedimentation is bringing about rapid changes in the form and function of many estuaries. In this paper the nature and rate of modern estuary infilling is examined and the impacts of enhanced sedimentation on the form and function of the estuaries are described. Identifying past and current sedimentary patterns in estuaries is promoted as essential information for effective management of these depositional environments.

2. IMPACTS OF INCREASED SEDIMENTATION

Infilling rates derived from sediment cores show that the modern rates can be at least double the rates during the late Holocene (Table 1). For example, provisional sedimentation data for Pumicestone Passage in SE Queensland, from a mud basin (Tripcony Bight) and tidal creek (Bullock Creek) both show higher rates during the last century (≥0.5 and ≥1.5 mm/yr^{-1} respectively) compared to rates during the previous centuries (0.2 and 0.3 mm/yr^{-1}). These and other data in Table 1 show that modern sedimentation rates in sites marginal to fluvial deltas can be much faster than in central muddy basins, with the coarser sediment accumulating proximal to the stream outlets, resulting in progradation of the shoreline.

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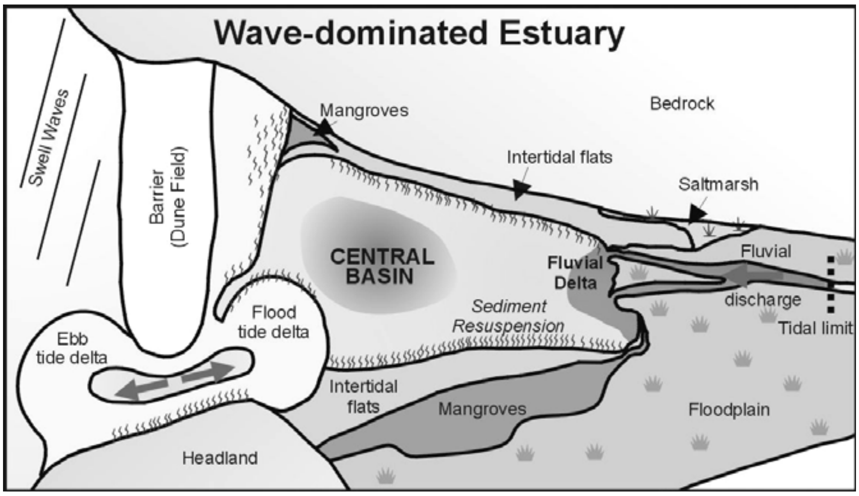

Figure 1: Plan view of a typical barrier estuary, showing the various structural elements and depositional environments [after Heap et al., 2001].

Table 1: Sedimentation rates for several wave-dominated estuaries. CB: central basin; FD: fluvial delta

Estuary	Site	Infill rate mm/a^{-1} Holocene	Recent	Dating Method	Reference
Bega River NSW	CB		3.1, 3.4	^{210}Pb	Hancock, 2000
Lake Illawarra NSW	CB	1.2 - 2	3 - 5	^{14}C, ^{137}Cs, AAR	Jones & Chenhall, 2001 Sloss,2001
	FD		3.2 - >10	^{14}C, AAR, marker sediment	Chenhall et al., 1994, 1995; Sloss, 2001
Lake Tabourie NSW	CB		0.9 - 2.2	^{210}Pb, pollen	Jones & Chenhall, 2001
L. Wollumboola NSW	CB	0.47	0.71	^{14}C, ^{210}Pb	Baumber, 2001
	FD		3.63	^{210}Pb	
Lake Tuggerah NSW	CB	~1.4	4	trace elements	King & Hodgson, 1995
Walllis Lake NSW	CB		~1.4 - 2.6	pollen	Logan et al., 2002
Sydney Harbour NSW	CB	0.8	10 - 15	hydrographic surveys	McLaughlin, 2000
Moreton Bay Qld	CB		≤6.2, ≤12	^{210}Pb /^{137}Cs	Hancock, 2001
Pumicestone Passage Qld	CB	0.2	≥0.5	^{14}C, ^{210}Pb, pollen	This paper
	FD	0.3	≥1.5	^{14}C, ^{210}Pb, pollen	
Lake Alexandria SA	CB	0.5	1.7	^{210}Pb	Barnett, 1994
Stokes Inlet WA	CB		17 - 20	^{137}Cs	Hodgkin & Clark, 1989

Several studies have shown that sediment loads delivered to estuaries have dramatically increased where their catchments have been cleared for intensive agriculture [e.g. Hodgkin and Hesp, 1998; Neil, 1998] and extensive urban expansion [e.g. Chenhall et al., 1995; Hancock and Hunter, 1999; McLoughlin, 2000]. In these estuaries, there has been both rapid siltation, infilling the shallow margins of the estuary, and shoreline progradation as fluvial deltas migrate into the estuary [Fig. 2; McLoughlin, 2000; Sloss, 2001]. It has also been found that in some estuaries the rate of infilling may have further accelerated during the last few decades compared to earlier in the last century [e.g. Hancock, 2001; Jones and Chenhall, 2001], highlighting sedimentation as an ongoing management issue.

In estuaries with highly degraded catchments, catastrophic siltation has been recorded following intense rainfall events [e.g. Hodgkin and Hesp, 1988; Neil, 1998; McLoughlin, 2000]. In these events, large slugs of sediment from rural and urbanised catchments move down streams into the estuaries, rapidly infilling channels with coarser material, while finer sediment is deposited across much of the estuary, which may have negative ecological impacts [e.g. Heil et al., 1998]. The deposition of relatively large volumes of catchment-derived sediment may also produce longer-term sedimentological impacts in the estuary. The finer grained sediments that were originally deposited in shallow areas are continually remobilised by wind-generated waves, producing chronic turbidity

[Thornton et al., 1995; Dennison and Abal, 1999]. These sediments are largely transported to sea by tidal currents, however, a proportion is redistributed within the estuary, eventually settling in sheltered reaches and mud basins where water depths are below the estuary wave base [Thornton et al., 1995; Hancock and Hunter, 1999; Dennison and Abal, 1999]. Fine sediments derived from the catchment and produced within the estuary by the decomposition of biota may also flocculate and settle in the margins of the estuary, forming mud flats where there may have formerly been relatively clean sand [Thornton et al., 1995; Neil, 1988].

In association with increased rates of sedimentation, the amount of sediment-bound nutrients (e.g.Total P, TN, TC) and trace elements (e.g. Fe, Zn, Pb) entering estuaries from their catchments has also increased [e.g. Chenhall et al., 1995; McComb and Lukatelich, 1995]. Greater nutrient loads can lead to periods of eutrophication and abundant planktonic and benthic algal growth. As a consequence, infilling is enhanced, even where the volume of terrestrial sediment influx is low, due to the increased amount of organic material accumulating in the estuary. In combination with high turbidity, these pressures can lead to the loss of healthy benthic habitats [Fig. 2; Dennison and Abal, 1999].

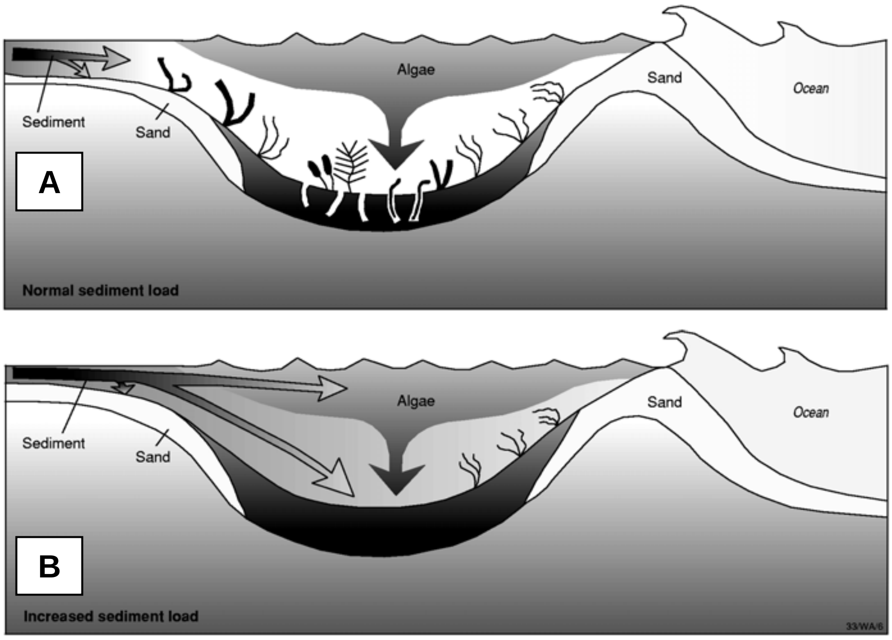

Figure 2: Schematic cross-sections of an idealised barrier estuary, showing depositional environments with (A) natural rates of sedimentation and (B) increased sedimentation.

3. ACTIONS - SEDIMENTOLOGICAL STUDIES AS A MANAGEMENT TOOL

In order to make better-informed management decisions there is clearly a need to accurately assess the rate and nature of sedimentation in the various depositional environments within estuaries. The analysis of sediment cores can provide these data, which can form a geoscientific basis for recommending remedial action in catchments to reduce sediment inputs. Targeted cores can also indicate the relative contributions of sediment from different subcatchments. Importantly, sedimentation data can be used to gauge the integrity of benthic habitats (Fig. 2). Geochemical analyses of sediment cores can also identify pools of nutrients or other pollutants within the estuary fill, which is important information for managers where dredging work is proposed. The identification of microfossils in sediment cores can provide a detailed record of recent changes in estuarine vegetation communities or harmful algal blooms [McMinn et al., 1997; Harle et al., in this volume]. These types of sedimentological data are especially important where conservation or restoration actions are being planned and there is a lack of historical information to indicate how the estuarine environment has changed over the last two centuries or past few decades. Likewise, these data can aid in the development of models of sediment transportation. The information gained from the analysis of sediment cores, therefore, needs to be viewed as basic environmental data needed for the effective management of estuarine systems.

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