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Modes of water renewal and flushing in a small intermittently closed Estuary

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ABSTRACT:

Many estuaries are under threat of reduced flows and consequent choking of the mouth by marine sands as more of their natural freshwater supply is abstracted for human use (Barton et al., 2008; Haines et al., 2006). Anticipated sea level rise, alterations in rainfall patterns, and increased severity/frequency of storms associated with climate change, point to an enhanced threat to these coastal wetlands (Duong et al., 2015; IPCC, 2007; 2013; Ranasinghe, 2016; Scavia et al., 2002). In the light of growing and diverse anthropogenic disturbances of estuaries, including threats such as the enhanced input of nutrients and organics, and habitat alteration and destruction, public authorities are recognising their responsibility to intervene (EEA,1999; MacKenzie et al., 2010; Peirson et al., 2002; Quevauviller, 2011; Waikato Regional Council, 2013). This is reflected in the growing debate about environmental flows and sustainable estuary management within the field of coastal management (Barton et al., 2008; Kennish, 2002; King and Brown, 2006; Richter, 2010; Schallenberg et al., 2010). Of specific concern are small, bar-blocked estuaries that may close intermittently, also referred to as TOCEs (temporarily open/closed estuaries) or ICOLLs (intermittently closed open lakes and lagoons) (Potter et al., 2010; Whitfield et al., 2012). The connection of these systems to the sea is particularly vulnerable to altered river flow and nearshore conditions (Boyd et al., 1992; Ranasinghe et al., 1999; MacKenzie et al., 2010; Schallenberg et al., 2010; Duong et al., 2015; Slinger, 2016). Further, although these estuaries are naturally closing, it is the connection to the sea and concomitant flushing of the water column that coastal and water managers rely upon to sustain the water quality that supports ecological functioning and socioeconomic value. Accordingly, public authorities are increasingly undertaking activities such as controlled freshwater releases and

mechanical breaching of the mouth to enhance flushing in these estuaries (Keneley et al., 2013; Rustomji, 2007; Van Niekerk et al., 2005; Human et al., 2016). Legislation such as the National Water Act (No. 36 of 1998) of South Africa specifies that the flows required to meet basic human needs and maintain aquatic ecosystem function be determined. Similar legislation in Europe, namely the Water Framework Directive (WFD: 2000/60/EC) requires member states to assess the ecological quality status (EcoQS) of their water bodies. Such legislation and developing management practice (e.g. Awal and Rahman (2016) in Australia) have highlighted the need for sustainable management of coastal water bodies, particularly the replenishment of water of poor quality, located in deep scour holes despite the relatively small volumes. Indeed, concerns regarding the ecological effects of trapped, low oxygen water (cf. Gale et al., 2006; Human et al., 2016) have stimulated academic interest in understanding the mechanisms by which water is flushed from an estuary (e.g. Coates and Guo, 2003; Coates and Mondon, 2009 amongst others). In this paper, we aim to deepen understanding of the flushing mechanisms in small, intermittently closed estuaries and so inform decisions on environmental releases and mouth management. First we briefly review the state of understanding of flushing mechanisms in small, bar-blocked estuaries, and then move on to describe the case study site and study methods. Next, we draw upon field data to describe and compare the efficacy of three types of flushing events in a small, bar-blocked estuary in South Africa: (i) partial flushing of the estuary by a minor freshwater release, and the effect of subsequent tidal intrusion after mechanical breaching of the mouth; (ii) complete flushing of the estuary by a much larger freshwater release and accompanying mouth breaching; and (iii) flushing due to intrusion of seawater thatwashed over the sand spit during a coastal storm with high waves (limited shore-face erosion and no breaching of the sand bar). The flushing events are assessed in terms of changes in water quality (salinity, temperature, dissolved oxygen and dissolved inorganic nutrients), due to dilution, displacement and purging of resident estuarine water. Here ‘purging’ is defined as complete removal of resident water from the estuary, ‘displacement’ as the action of moving resident water of a particular water quality from its original position to another position in the estuary and replacing it with water of a different water quality, and ‘dilution’ as the alteration in resident water quality due to the mixing of one water type with another of weaker concentration (e.g. the dilution of seawater through mixing with fresh river water).