MORPHODYNAMICS AT THE MOUTH OF A BAR-BUILT ESTUARY: CARMEL RIVER, CA, USA

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INTRODUCTION

Bar-built estuaries (BBEs), also known as Intermittently Closed Estuaries (ICEs), are common to coastal climates with a strong seasonal precipitation pattern and waves including the US West Coast, Australia, South Africa, and Western Europe (McSweeney et al, 2017). In California, USA, these BBEs typically go through seasonal morphological transitions from a closed state to open state as precipitation increases during the winter months. However, timing of these events is challenging owing to variable behavior for given environmental forcing conditions, and as a result often lead to intermittent flooding of the surrounding areas that is difficult to predict (Behrens et al., 2013; Orescanin and Scooler, 2018).

This study uses a compilation of observations using in-situ moorings, topographic beach surveys, and remote sensing from unmanned aerial systems (UAS) to assess rates of morphological change at the Carmel River, CA, USA. The Carmel River is a 58km long river located in central California that enters Carmel Bay at a pocket beach bound by rocky headlands (Figure 1). This area typically experiences precipitation that drives breaching in the winter months (Jan-Mar) while a lack of precipitation causes closure from late spring through late fall. The river enters Carmel Lagoon, with an approximate surface area of 0.25 km^2. The offshore waves at this site are typically 1-3 m from the northwest, with occasional winter storms exceeding 5 m. Morphological change surrounding a single breach and closure event are compared with longer-term breach events that include migration of the breach channel.

METHODOLOGY

In-situ data measuring tides, waves, temperature, and salinity were collected in Carmel Lagoon since 2016. Topographic surveys of the beach were collected daily around several breach events in 2020-2022, and monthly for the remainder of the years. Lagoon bathymetry was collected prior to breaching in each fall, as well as after closure (the lagoon is typically exposed during breach events allowing for topographic surveys to include the lagoon area). UAS were used to both map the area using structure-from-motion as well as measure wave runup and plume-wave interactions.

RESULTS

Findings suggest breaching is driven by riverine processes while closure is driven by wave (and tidal) processes, yielding rapid (hours), large (meters) erosion and deposition. Furthermore, for breaches that remain open with sufficient riverine discharge, migration only occurs during periods of waves that have a westerly or southwesterly orientation in contrast to the typical northwesterly climate. Seasonal variations between wet years with migration and dry years without migration yield a relative sediment balance with offshore sediment transport (wet year) balancing onward sediment transport (dry year).

Figure 1 - Images of the Carmel River Mouth during closed (top) and open (bottom) states. In both images, the Carmel Lagoon is on the right and the Pacific Ocean (Carmel Bay) is on the left.

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