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Reshaping beach morphology by modifying offshore breakwaters

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ABSTRACT

Use of static shore protection structures is often considered an irreversible change toward a decrease in shoreline dynamism, but structures can be modified to make them more compatible with human needs and create a more mobile beach. This concept is documented by comparing changes in shape and volume of the beach and nearshore resulting from modification of emerged, segmented offshore breakwaters to a continuous submerged structure. Emerged, segmented breakwaters were constructed between 1983 and 1987 in Follonica Bay on the Tuscan coast of Italy. The breakwaters created an asymmetric shoreline with beach salients landward of the structures and bays landward of the gaps. Between 2011 and 2013, the breakwaters were removed and the boulders were used to create a continuous submerged breakwater farther offshore, with a wider crest at −0.5 m below mean sea level. The purpose was to achieve better views of the sea and a more equitable beach width alongshore. In the process, natural processes were allowed greater freedom to reshape the beach. The shoreline straightened after alteration, but retreated an average of 12.9 m between 2013 and 2016. This study provides one of the few prototype before-after evaluations of modifying breakwaters to make shorelines function more naturally. The results indicate how human-induced geomorphic changes can occur at the local scale (tens to hundreds of meters alongshore) in response to the perceived needs of local managers, even where the new condition runs counter to the traditional goal of creating a more stable beach for shore protection.

1. Introduction

Static shore protection structures, such as groins, seawalls, and breakwaters are commonly used to stabilize the shoreline (Pilkey and Wright, 1988; Granja and Soares de Carvalho, 1995; Kochnower et al., 2015; Manno et al., 2016). These structures are often associated with negative effects, including (1) introducing an artificial asymmetry in the longshore distribution of beach width; (2) interfering with shoreline dynamism and sediment transfers that would allow beaches and dunes to function naturally; (3) shifting the erosion problem to nearby unprotected beach segments; (4) introducing hard structures to soft bottom habitat; (5) reducing habitat by truncating the beach profile; (6) potentially creating rip currents that are dangerous for swimmers; and (7) reducing water quality and aesthetic appeal (Pilkey and Wright, 1988; Frihy et al., 2004; Dugan et al., 2008, 2011; Anfuso et al., 2017).

Modifications to hard engineering structures may be needed after their construction because of detrimental effects of previous interventions, changes in the condition of the structures and their setting through time, changes in water levels and frequency of storms, and the desires of stakeholders (Anfuso et al., 2012; Burcharth et al., 2014; Nordstrom, 2014; Kuriyama and Banno, 2016; Pranzini, 2017). Recent studies call for the need to make protection structures more compatible with natural values and human recreational needs (Escudero et al., 2014; Nordstrom, 2014; Kochnower et al., 2015; Manno et al., 2016; Alves et al., 2017). Coastline change and economically driven human interventions are now recognized as mutually linked, often in iterative cycles of erosion and mitigation (Lazarus et al., 2011, 2016; Gopalakrishnan et al., 2011).

Modifications to shore protection structures include lowering breakwater crests or increasing the number or width of gaps between them to restore more natural circulation and attempt to overcome downdrift sediment deficits (Aminti et al., 2004; Cammelli et al., 2006; Gomes and da Silva, 2014); altering groins to decrease size or permeability to facilitate sediment transfers alongshore (Basco and Pope, 2004; Rankin et al., 2004; Bocamazo et al., 2011); removing portions of seawalls to create new natural habitat or allow for some erosion of the upland to supply sediment to the beach (Zelo et al., 2000; Toft et al., 2013); or modifying the surface characteristics of structures to enhance

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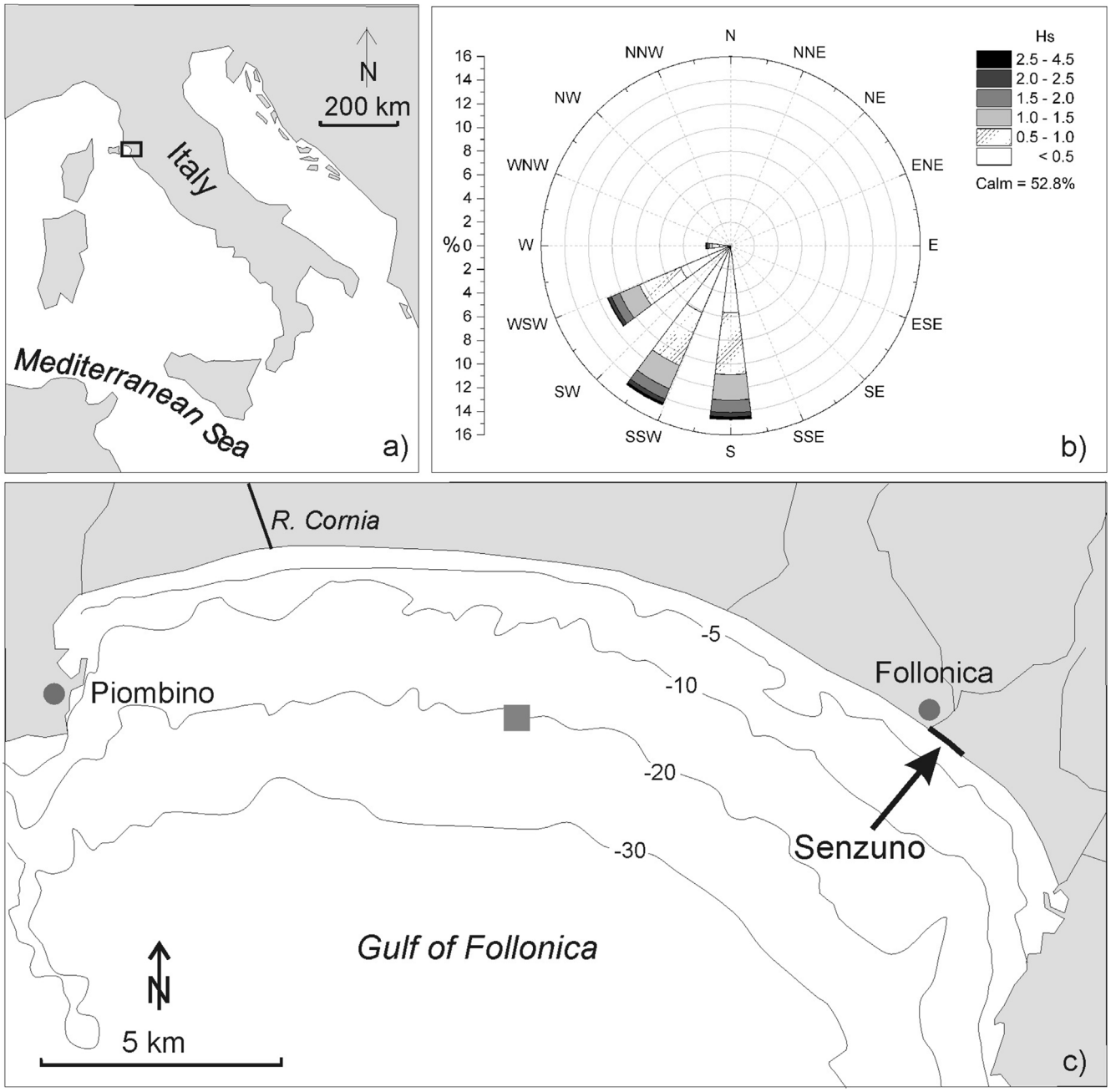

Fig. 1. Study area (map of Italy, bay, Follonica). Wave data (Panel b) were modelled at the position of the square in the bay (Panel c) by DEAM (2006).

value as habitat (Browne and Chapman, 2014; Evans et al., 2016). Our investigation evaluates how an emerged segmented breakwater system on the Tyrrhenian coast of Italy was reconfigured to enhance the beach landward of it for recreation. The purpose is to document how protection structures can be modified to adapt to the economic landscape and provide a more equitable distribution of opportunities alongshore.

Emergent segmented breakwaters create a visual intrusion into the seascape (Lamberti and Mancinelli, 1996; Tomasicchio, 1996; Lamberti et al., 2005), and the longshore differences in sheltering and exposure to waves result in a shoreline configuration of accreting salients and eroding bays (Thomalla and Vincent, 2003; Fairley et al., 2009). The unequal distribution of beach widths alongshore can be problematic on Italian beaches, where the shoreline is divided among many small lots managed as commercial enterprises by private interests. Beaches in the bays do not have the same carrying capacity for tourists as the beaches at the salients. The shallow water depths directly landward of breakwaters can restrict or eliminate bathing opportunities, and the deeper waters between breakwaters can channel and accelerate offshore flows and create a safety hazard for swimmers (Cappietti et al., 2013).

Submerged breakwaters provide a clear view of the sea from the beach. Enhanced views are correlated with increased economic value of coastal property (Bin et al., 2008). Greater wave energy can pass submerged structures and increase sediment reworking on the beach. The greater wave energies increase longshore current velocities that can help plane off the salients that form landward of emerged structures, with more equal distribution of beach space and greater water depths for swimming. The problems of unequal distribution of sediment alongshore and accelerated currents between structures would persist if submerged structures remained segmented, but these problems can be reduced by making submerged breakwaters continuous.

Moving breakwaters farther offshore can create more recreation

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