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## Use of ecosystems in coastal erosion management

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## ABSTRACT

With a global increase in coastal development, together with increasing storminess and continuing sea level rise, coastal erosion has become a serious problem along a significant percentage of coastlines of many countries. Coastal erosion and shoreline management plans are often implemented on an action-reaction and post-disaster basis, resulting in installation of hard engineering structures, such as, groins, seawalls, revetments, gabions and breakwaters. These hard stabilization structures usually alter the natural environment of the coast, producing negative impacts. They do little to work with nature, and sustainability is a currently a critical issue. Under present and future environmental conditions, the world requires smarter coastal protection strategies that are adaptable, sustainable, multi-functional and economically viable to help solve immediate and predicted coastal erosion problems. An ecosystem-based approach based on the creation and restoration of coastal ecosystems, such as wetlands (e.g. mangroves), biogenic reef structures (e.g. corals, oysters, and mussels), seagrass beds and dune vegetation can offer optimal natural alternatives to help solve coastal erosion. Coastal ecosystems have some capacity for self-repair and recovery, and can provide significant advantages over traditional hard engineering approaches against coastal erosion. Also, they play a vital role in reducing the susceptibility of coastal communities to hazards through their multiple roles in processes, including sediment capture, system roughness and thus attenuation of wave energy. This paper seeks to undertake a general review of adaptation and protection measures against coastal erosion issues, based on incorporation of ecology and ecosystem services into coastal erosion management strategies.

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## 1. Introduction

Currently, a high percentage of world coastlines experience issues related to coastal erosion (Zhu, 2010; Pilkey and Cooper, 2014). Under current conditions of a warming climate and rising sea levels, it is expected that coastal erosion processes will shortly reach unmanageable proportions for humanity (Jones and Phillips, 2011; Shi and Kaspersen, 2015). The coastal erosion problem becomes much more significant, as coastlines are the ideal place for human concentrations, and the development of different productive activities (Barragan and Andreis, 2015).

The complexity of coastal erosion causes has been addressed worldwide in many studies (Van Rijn, 2011; Pranzini and Williams, 2013), and interrelationships between anthropogenic influences and natural processes have been emphasized (Rangel-Buitrago et al., 2015a,b). In general terms, coastal erosion processes are produced by factors that can be contrasted and include, amongst others: relative sea level rise (RSLR), extreme wave events and alteration in the sediment supply, both natural and human induced.

Most of the world's megacities are situated in the coastal zone where a very particular combination of geographic, economic, and historical conditions are still attracting people and stimulating different migration processes (Brown et al., 2009; Seto et al., 2011; Barragan and Andreis, 2015). Only in the last half century have world coastline populations recorded values close to 3% of the annual average standards for urban growth rate. Under current climate change scenarios, it has been estimated that along low coastlines, almost 30% of residences, if sited within 200 m from the sea, may be severely affected by erosion-related property losses over at least the next 50 years (UN-Habitat, 2009; Leatherman, 2017).

The above, demands urgent sustainable development strategies with implementation of adequate coastal erosion management plans (EU, 2004; Boruff et al., 2005; Pranzini and Williams, 2013). Management plans must become an issue of widespread worldwide concern. Unfortunately, a high percentage of the decision-making within coastal erosion management is strongly conditioned by economic considerations, based on a cost-benefit analysis approach (Cooper and McKenna, 2008) or an action-reaction basis (Rangel-Buitrago et al., 2015a,b, 2017).

Coastal erosion management strategy choice must be a function of a series of variables that include: erosion severity, property rights, funding/legislation, and aesthetics (Williams et al., 2017). Likewise, management strategies must include the techniques, knowledge, equipment, and institutional instruments required to minimize or eliminate coastal erosion related impacts.

Currently, four options can be identified as the main coastal erosion management strategies (see Williams et al., 2017):

- **Protection:** preservation of population centres, economic activities and natural resources (vulnerable areas) using hard structures and/or soft protection measures.
- **Accommodation:** occupying sensitive areas, but acceptance of a greater degree of flooding by changing land use, construction methods and improving preparedness.
- **Planned retreat:** removing structures in developed areas, resettling inhabitants with the requirement that new development is set back from the coast, as appropriate.
- **Sacrifices:** allowing property loss when the suggested protection is non-viable, or the accommodation and retreat option does not exist.

Usually, the protection approach using hard structures is widely perceived as the best coastal erosion management strategy, and in many countries this method is the only alternative (Pranzini, 2017;

Rangel-Buitrago et al., 2017). However, hard structures are not necessarily the most adequate solution, and their negative influence has been seen as a critical problem along many coastlines around the world (Griggs, 2005; Charlier et al., 2005; Pranzini and Williams, 2013; Pilkey and Cooper, 2014; Rangel-Buitrago et al., 2017). Hard protection approaches can generate adverse effects such as:

- Accelerated bottom erosion in front of the structure and downdrift scouring.
- Disturbance of sediment supply and beach reduction.
- Alteration of alongshore sediment transport.
- Restricted public access.
- Potential risks for bathers.
- Negative visual effects on the seaside landscape (scenery).

Hard structures are severely challenged in many locations, and are becoming unsustainable due to their costly and continual maintenance requirements, as well as any widening and height increase to keep in step with the increasing coastal erosion risk. Additionally, such structures significantly alter the natural adaptive capacity of any coastline (Temmerman et al., 2013).

Negative experiences prevail over positive ones in the implementation of hard structures as protection measures against coastal erosion due to interfering processes operating at a wide spatial scale (>100 km, Pilkey and Young, 2009; Neal et al., 2017; Rangel-Buitrago et al., 2017; Williams et al., 2017). To avoid such negative experiences, correct application of adequate management policy is required to preserve ecosystems as well as socio-economic activities.

Recently, an ecosystem-based coastal erosion management strategy has been brought into practice as an approach that is more cost-effective, and sustainable, than conventional hard protection approaches (ecosystem-based approach). Management based on habitat diversification can be applied worldwide, particularly in areas that have space between existing urbanization and the coastline to allow for ecosystem development (for example into accommodation and planned retreat strategies). Because ecosystems have the natural ability to reduce extreme wave effects (Shepard et al., 2011), their growth can keep pace with sea-level rise by means of sediment accretion if available (Kirwan et al., 2010), and provide other benefits that go beyond the realm of the coastal protection (e.g. supporting fisheries and tourism, reducing CO<sub>2</sub>, amongst others).

This paper reviews adaptation and protection measures against coastal erosion issues based on incorporation of ecosystems. Information presented will be useful to local and national coastal managers and planners who need fresh and innovative approaches, and are a basis for ascertaining facts on which to make sound management decisions that can be implemented into coastal erosion management.

## 2. Ecosystem management: a necessary step in coastal erosion management

The UNEP (2009) defined Ecosystem Management as “an integrated process to conserve and improve ecosystem health that sustains ecosystem services for human well-being”, combining two particular actions:

- Develop and/or maintain ecosystems quality.
- Attempt to ensure in the best way the delivery of different ecosystem services to human well-being.

Under current climate-change conditions, ecosystem manag-

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