

PREDICTIVE TOOL OF SEAGRASS HEALTH TO OPTIMIZE THE DESIGN OF LOW CRESTED STRUCTURES

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INTRODUCTION

In the last decade, the growing interest in the development of Nature-based Solutions (NbS) for climate change adaptation and disaster risk reduction has led to the development of new Low-Crested Structures (LCS) and types of armor units to favour the settlement and colonization of marine species on the structures, and thus, mimic the behavior of natural reefs. However, little attention has been paid to the ecological consequences of the construction of breakwaters by altering circulation and sediment transport to adjacent habitats, such as seagrasses.

It is recognized the importance of hydrodynamics (wave action, tides and currents) as one of the driving forces controlling seagrass bed development, since very strong currents or intense wave action may affect entire plants or prevent new shoots from being established (De Boer, 2007). Erosion and sediment dynamics can also alter seagrass growth though species such as *Posidonia oceanica* or *Cymodocea* are able to survive under moderate sand burial or erosion by elongating or reducing their vertical shoots (Bonamano et al., 2021).

In recent decades, seagrass area cover is declining worldwide, mainly due to reduced water quality, higher temperature, coastal development, storms and global climate change (Dunic et al., 2021). Many monitoring programs have been adopted to assess seagrass health as indicators of environmental status using biotic indices. Predictive habitat models have also been developed to investigate the potential effects of physical parameters (e.g. wave energy, light, temperature) on individual plants and predict seagrass occurrence, with optima or thresholds for seagrass growth and survival (Vacchi et al., 2014).

From a biological and ecological point of view, the indicators used in coastal monitoring programs are numerous, composed of many different variables and very diverse metrics, which reduces the possibility of providing a homogeneous overview of the state of seagrasses and leads to divergent responses. Environmental management goals must be clearly established and integrated into the planning, construction and monitoring phases to effectively manage the response of coastal defences. However, the fragmented and scientific-based criteria are difficult to handle in present engineering design and thus the ecological impacts are not usually considered.

SEGRALCS PROJECT

Within the SEGRALCS research project, a new quantitative prediction tool is developed to allow civil

engineers and decision-makers to optimize the design of breakwaters and reduce the uncertainty related to their environmental performance, thus promoting optimal conditions for seagrass restoration and conservation during breakwater lifetime. The project explores the fragmented state-of-the-art in ecological discipline regarding indicators used in seagrass health monitoring programs and predictive habitat models on seagrass meadows to find objective criteria of seagrass status applicable to coastal engineering, in terms on physical parameters controlled by breakwaters that can be integrated into a seagrass health prediction tool for direct engineering use.

Figure 1 shows the sketch of the SEGRALCS predictive model, where results from hydro-morphological numerical models often used in coastal engineering for breakwater design (e.g. wave heights, wave orbital velocities, wave currents, erosion/deposition patterns) are used as input to the predictive tool to obtain the seagrass state as output. Therefore, we can determine the effective ecological design of LCS that produce favourable conditions for seagrass growth and establishment.

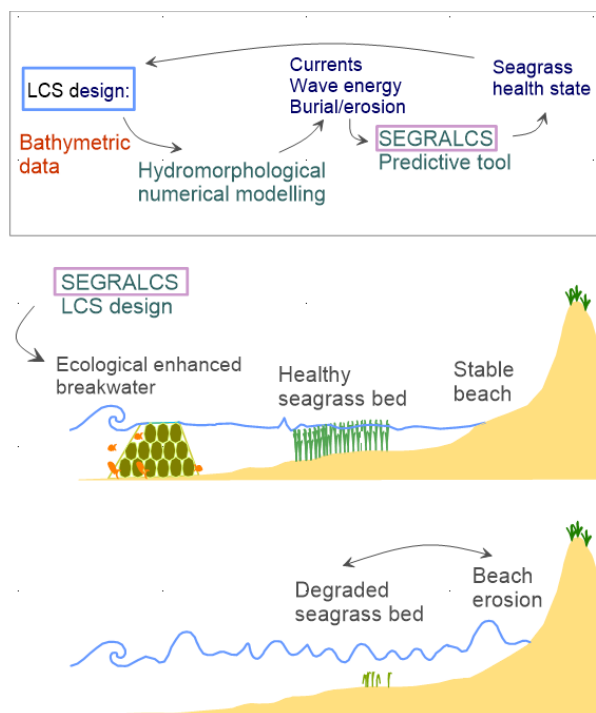


Figure 1 - SEGRALCS predictive tool for use in the ecological design of LCS.

In particular, the project focus on seagrasses on the Mediterranean Sea to protect and ensure the persistence of two characteristic seagrass species on these coasts, *Cymodocea nodosa* and *Posidonia oceanica*, though the methodology approach used for the construction of the predictive tool is extendable for the application to other coasts worldwide with different seagrass species distribution.

Four seagrass species are native of European waters, of which *Posidonia oceanica* is the dominant, most productive and endemic seagrass species in the Mediterranean; and a long-living, very slow-growing and the least plastic in comparison to the high rates of growth and production of species such as *Cymodocea nodosa* able to sustain even under considerable disturbance (Ivajnsič et al., 2022).

Several literature datasets on the effects on structural parameters of these seagrass species by beach fill, extreme events or harbour construction are available, including locations such as Spain (Aragonés et al., 2015) and France (Leriche et al., 2006) with measured variables like seagrass extent and density, and monitoring periods ranging from 1969 to 2010. On the other hand, Table 1 includes some of the predictive habitat models in the literature integrated into the SEGRALCS predictive tool.

Table 1. Predictive habitat models in the literature.				
Seagrass species	Hydrodynamic inputs	Morphological inputs	Output variables	Reference
<i>P. oceanica</i>	Wave orbital, Velocity, mean current	Sediment transport, bottom features	Meadow upper limit	Ruju et al., 2018
<i>P. oceanica</i>	Breaking wave energy, amplitude	Beach slope	Meadow upper limit	Vacchi et al., 2017
<i>P. oceanica</i>	-	Burial and erosion levels	Plant shoot growth	Bonamano et al., 2021
<i>C. nodosa</i>	-	Burial and erosion levels	Growth response	Marbà et al., 1994
<i>P. oceanica</i> & <i>C. nodosa</i>	-	Turbidity and siltation	Growth form	Vermaat et al., 1998

Statistical techniques and artificial intelligence techniques are explored to identify changes in seagrass state associated with hydromorphodynamic and sediment transport conditions. Seagrass structural and morphological variables that should conform the standards for defining seagrass health (e.g. shoot density, meadow cover, shoot burial, vertical shoot elongation, etc) are identified in terms on their responses to pressures by breakwater installation due to the variation of hydrodynamic, morphological or sediment dynamics conditions. Specific hydrodynamic and morphological parameters are established as input for the predictive tool. Seagrass monitoring data are used on

the one hand for the calibration process and on the other hand for validation, covering different environments and seagrass species.

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