AQUABREAK: A NATURE-INSPIRED SOLUTION FOR COASTAL RESILIENCE

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Abstract

In this work we present a Nature Based Solution that aims at combining offshore aquaculture activities and coastal protection. This kind of solution is gaining popularity as nature-aligned alternatives appear as inviting options to conventional hard coastal protection structures. Several studies have been addressing the capacity of living organisms to promote wave energy damping, highlighting a great potential of such living structures for coastal protection purposes.

Here, we focus on design considerations that can be determining for the coastal protection effectiveness of a seaweed aquaculture system. We assess the importance of the parameters associated to such design considerations that are of great relevance to achieve an adapted solution design for each case specific needs and to answer stakeholders needs in coastal protection measures.

Context: The place of Nature Based Solutions within coastal protection

For its large coastal extension, of around 830 km, Portugal represents a privileged location for the implementation and development of multiple types of offshore floating facilities. Similarly to many coastal countries, Portugal is experiencing coastline retreat in several areas of its territory (Marinho et al., 2019). In reality, Portugal presents a western coast entirely exposed to a wide range of incoming sea state conditions, with significant wave heights reaching up to 5 m and mean wave period of more than 10 s, in winter months (Mendes and Oliveira, 2021). Allying the strong Portuguese sea-oriented culture and the current needs for coastal protection, the consideration of the Portuguese nearshore waters for the implementation of a pilot project on the applied use of seaweed aquaculture to coastal protection appears as timely and appropriate.

To mitigate coastal hazards, hard structures such as seawalls and breakwaters, are typically implemented as coastal defence. However, these conventional hard structures are challenged by the growing continuous and costly maintenance, intensified by increasing pressures associated to sea level rise (SLR) and higher storm frequencies and intensities. Even in the presence of hard coastal defences such as seawalls, situations of vulnerability to overtopping and flooding can occur in coastal communities, like it is the case in Furadouro, located in the municipality of Ovar (Tavares et al. 2021).

Hence, natural, and nature-based infrastructure appear as viable alternatives or complements to the coastal protection mainly assured by conventional hard structures, bringing to the system added economical value and ecological benefits (Borsje et al., 2011).

The AQUABREAK project

The aim of the AQUABREAK project, is to develop an eco-friendly and cost-optimized multi-purpose Nature Based Solution (NBS), combining offshore aquaculture activities and coastal protection. This is to be achieved through the implementation of a seaweed farming system that will simultaneously promote wave energy damping and consequent reduction on wave runup and overtopping, to enhance coastal protection.

The preliminary AQUABREAK system solution (Figure 1) will be tested in a wave flume, considering a set of relevant wave conditions where the system's performance will be evaluated, both regarding the feasibility of seaweed aquaculture exploitation, wave energy dissipation potential, overtopping reduction, and overall structural resistance capacity, centred on the interactions of the flow with the biological material.

Figure 1: Schematic representation of the AQUABREAK project.

Additional benefits from the use of seaweed farming as a solution are related to the Ecosystem Services that can be created or valued through the implementation of such systems. Notably, kelps in general, can absorb carbon, thus contributing to the mitigation of climate change impacts and reduce nutrients to improve water quality, therefore helping to prevent eutrophication and creating appropriate conditions for several other species.

Wave attenuation from suspended seaweed aquaculture structures and potential to induce reduction on wave runup and overtopping.

In nature, kelp beds grow from the bottom to the surface, fixing on hard substrate seabed. On the contrary, cultivated kelp is suspended near the surface, usually attached to a moored longline system. Theoretically, near surface cultivated kelp may damp more wave energy than bottom-fixed kelp since the wave motion decreases towards the bottom. Several studies have assessed the wave damping potential of longline seaweed aquaculture systems (e.g. Liu et al., 2015; Zhu et al., 2020). For instance, Mork (1996) has observed a 70% to 85% wave energy reduction across a 258 m long kelp bed (dominated by *Laminaria hyperborea*) with the highest wave attenuation observed during low tide, therefore verifying that densely grown kelp may have advantageous wave attenuation characteristics.

As it has already been demonstrated that aquatic suspended canopies are effective in damping wave energy, to our knowledge, there are still no studies evaluating the effect of such structures on runup and overtopping events. Nevertheless, this is valuable information to be provided to stakeholders and to assess viability, towards an effective implementation of nature-based solutions of such kind. However, this assessment constitutes future work to be performed within the project and here we will focus on key design considerations that will affect the above-mentioned coastal processes.

General considerations when projecting a NBS based on seaweed aquaculture

The AQUABREAK solution to be developed is a NBS aiming at accomplishing two main simultaneous functions: to promote coastal protection and support atmospheric carbon uptake. For these objectives to be reached and, at the same time create an environment-friendly structure, some design considerations need to be considered in order to fulfil all key requirements.

On a first stage of the design thinking, the following specific points are considered:

- **Modularity** – The aquaculture structure needs to be modular to be easily adaptable and scalable to different dimensional needs. This modularity is to be achieved both on the cross-shore and longshore directions.

- **Biological material as main wave-dissipator feature** – An essential aspect to fulfil the NBS standards is that the core feature providing the expected services (coastal protection and carbon sequestration) is of biological origin. This implies to take advantage of the natural features of biological organisms and optimize them as much as possible within the solution design.

- **Key functions: increase coastal resilience and contribute to CO2 uptake** – The AQUABREAK solution design needs to be able to cope with the environmental conditions it is going to be exposed to and at the same time respond to the functions it is aimed for. This is mainly determined by the cultured species.

- **Feasibility of implementation** – The AQUABREAK solution design needs to consider practical issues regarding the availability and characteristics of local species. In the implementation phase it also needs to account for feasibility of harvesting of the biological material at a posterior exploitation stage of the project.

Considering these points is essential to achieve the design of an adapted solution to each case specific needs and to answer stakeholders needs in coastal protection measures.

Figure 2 depicts a schematic representation of key parameters to be considered in the design of the AQUABREAK solution, in a scenario of complement to conventional hard coastal defence against inundation. These parameters are site specific as local considerations need to be made, based on the local wave climate, beach profile, characteristics of available local seaweed species. The overall characteristics of the cultured canopy field will affect its capacity to attenuate the incident waves whereas an appropriate positioning of the aquaculture structures needs to be determined, regarding distance from the coast, in order to guarantee an effectiveness of this attenuation, that will also translate into a reduction in wave runup and inundation. These concepts are summarised in Table 1.

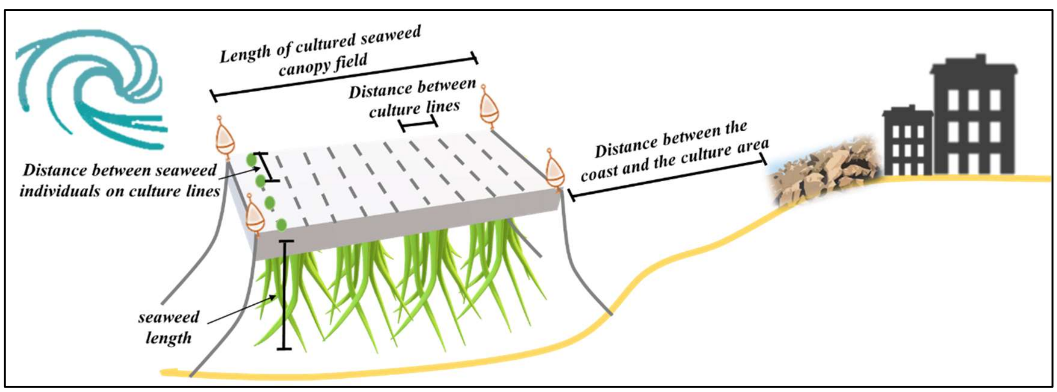

Figure 2: Schematic representation of site dependent key parameters to consider in the design of the AQUABREAK solution: Length of cultured seaweed canopy field; Distance between culture lines; Distance between seaweed individuals on culture lines; Seaweed length and Distance between the coast and the culture area.

Table 1: Summary of site dependent parameters to consider in the design of the AQUABREAK solution.

<table>
<tr><th>Parameter</th><th>Factors affecting the parameter</th><th>Effects of parameter</th></tr>
<tr><td>Length of seaweed cultured canopy field</td><td>Depends on incident wave conditions (modulable parameter)</td><td rowspan="4">Attenuation field density (with consequent effect on effectiveness of wave runup and overtopping)</td></tr>
<tr><td>Distance between culture lines</td><td>Depends on physical characteristics (growth dimensions) of seaweed species and light needs</td></tr>
<tr><td>Distance between seaweed individuals on culture line</td><td>Depends on physical characteristics (growth dimensions) of seaweed species and light needs</td></tr>
<tr><td>Seaweed length</td><td>Depends on seaweed species characteristics</td></tr>
<tr><td>Distance between the coast and the culture area</td><td>Depends on relationship between incident wave characteristics and length of cultured canopy field</td><td>Effectiveness of wave runup and overtopping</td></tr>
</table>

Conclusions

In this paper we presented the AQUABREAK project, that aims at combining coastal protection with seaweed aquaculture, to promote addition economic and ecological benefits. The main design considerations of such Nature Based Solution were presented, highlighting a flexibility of adaptation of such type of structure (through modularity) and the great influence of site-specific parameters that can be determinant to the effectiveness of the structure capacity to damp incident wave energy and reduce wave runup and coastal inundation.

Future works under the project concern the implementation of physical and numerical modelling for better evaluation of the AQUABREAK system solution to answer the coastal protection needs.

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