PROTOTYPING AN ENGINEERED ALGAE FIELD TO ATTENUATE LONG SWELLS

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INTRODUCTION

Sea level rise, increased storminess and land changes due to plate tectonics threaten South America's western coasts with flooding, beach erosion and infrastructure damage. The significant amount of coastal systems exposed to such hazards in the region has motivated the design, construction and monitoring of a new prototype of engineered algae field (EAF), aimed to attenuate waves and reduce erosion, a widespread impact in Chilean coasts (Martínez et al. 2021). The EAF will be deployed by mid-2024 in a management and exploitation area of benthic resources (AMERB) located in Maitencillo (32.64°S,71.44°W), Chile. With this applied research project, we aim to fill a gap in a research topic where literature is focused on relatively stable coasts, shallow waters and mild wave climates which substantially differ from the highly energetic wave conditions and relatively deep shores found in subduction zones. The study aims to assess the technical feasibility of the EAF using local kelp species on the project site, and if proved successful, to scale up the solution. The design process considers a combination of numerical and physical models to assess the performance of the EAF. Once deployed, a monitoring scheme will include measuring its hydraulic efficiency, structural stability and algae growth rate for one year. The project is funded by ANID's agency under grant FONDEF ID23I10078.

THE PROTOTYPE

The 0.5-hectare EAF prototype consists of a supporting structure (Figure 1) fixed to the seafloor by means of a grid of artificial reefs and structural polypropylene lines, and secondary lines where seedlings of Giant Kelp, *Macrocystis pyrifera*, are grown (Figure 2). The artificial reefs are made of concrete and have cylindrical holes aimed to promote ecological niches (Toledo et al 2000). Structural lines have a diameter of 32 mm and will be tensioned during the deployment, forming squares of 13x13 m^2, where 13 secondary lines will be used (Figure 1). The overall length of structural lines and seedling lines is of 988 m and 5408 m, respectively, but its final configuration may be altered during deployment. Nearly 108000 seedlings will be fixed every 5 cm to the secondary lines in an inland hatchery. The expected rate of seedling survival is 40%, so the final density is expected to be of 16 units/m^2, which is higher than natural densities. This configuration is aimed to reduce wave heights between 10 to 30% in relatively hard conditions characterized by mean significant wave heights on Hs = 2-3 m and peak periods of Tm = 12-14 s. In contrast to submerged breakwaters, the nearly unlimited growth of kelp used in the EAF is expected to adapt to changes in the tide and coseismic seafloor changes, which may be in the order of meters.

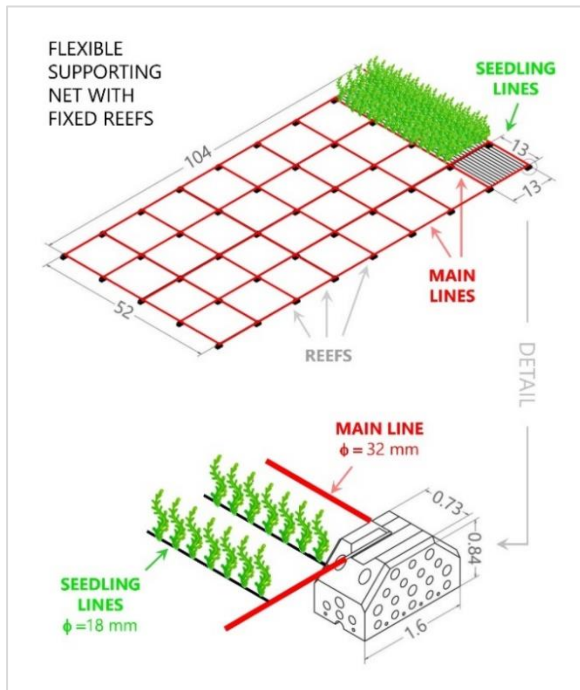

Figure 1 – Prototype of EAF (up) and detail of a joint between the supporting net and an artificial reef (down).

Figure 2 – Detail of an artificial reef and seeding.

DESIGN PROCESS

The design considers the use of a set of numerical models to study different processes, namely 1) flow-algae interaction in ANSYS-FLUENT to compute drag coefficients of individuals and arrangements (Figure 3, up), 2) a nearshore wave model in XBEACH to define the optimal location within the site, to compute the hydraulic efficiency of the EAF and the coastal erosion on the neighboring beach and 3) a flow-structure model in AQUASIM aimed to evaluate the stability and deformation of the EAF (Figure 3, down). In parallel, a 1:40 physical model to evaluate the hydraulic efficiency and stability of the EAF, as well as its reduction in coastal erosion, will be conducted at the 15 m wave flume for several wave and tide conditions. Design conditions are 7-10 m depth, a tidal range of up to 2 m, a significant wave height of up to Hs = 5 m and wave periods of up to 16 s. The EAF will be located 500 me off the coastline.

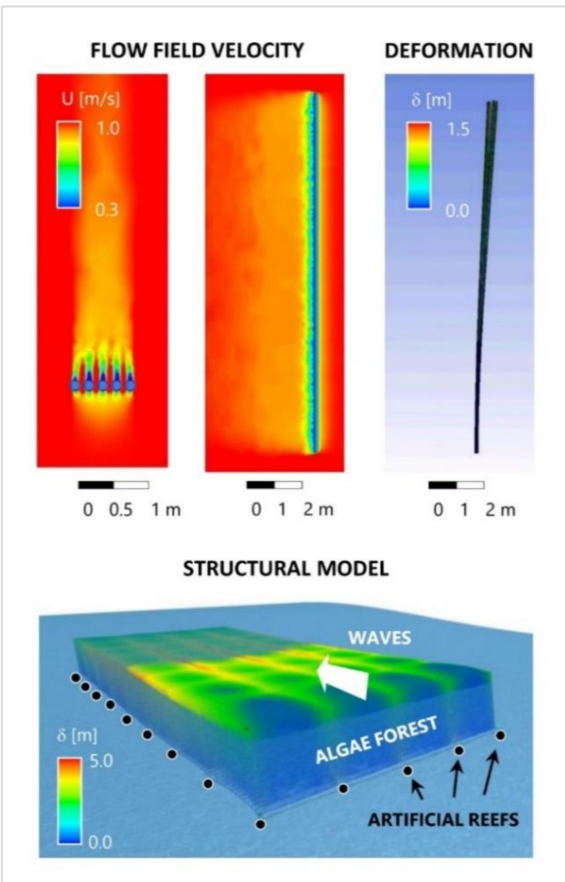

Figure 3 – Velocity field and deformation of a simplified arrangement of individual five algae computed with ANSYS AQWA (up) and deformation of the EAF modelled with AQUASIM (down).

FIELD MONITORING

The deployment and monitoring are in a planning phase. However, an operational wave model built from WAVEWATCH III and SWAN is already available to evaluate local conditions during both phases. This local wave and tide 7-day forecast has already been integrated into an early warning operational system in Chilean bays (Molina et al. 2022), which was calibrated and validated with offshore satellite data and wave buoys (Beyá et al. 2017). The hydraulic efficiency will be monitored with two ADCPs located immediately before and after the EAF, cameras and proprietary codes built with artificial intelligence, while the growth of algae will be regularly monitored by aquaculture engineers and divers from our group.

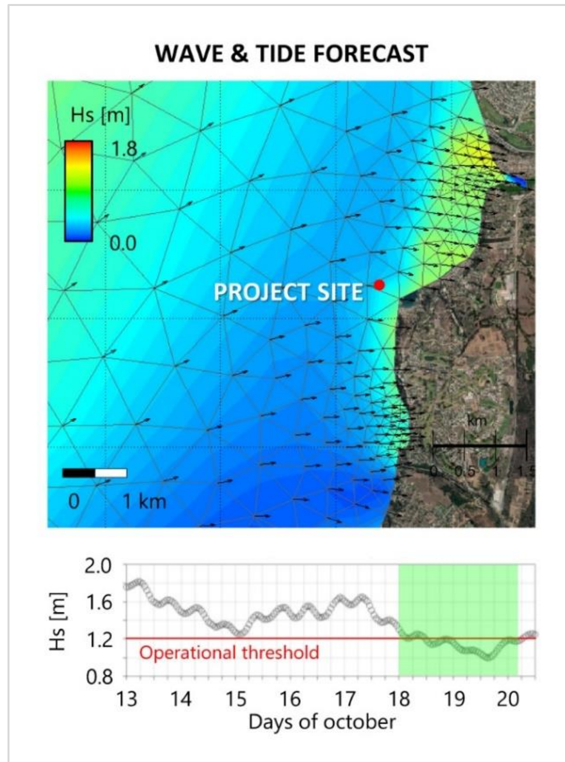

Figure 4 – Nearshore wave propagation pattern of relatively normal wave conditions (up) and 7-day time series of significant wave height. Wave period, wave direction and tide level are also forecasted in the system.

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