

LONG-TERM ECO-MORPHOLOGY MODELLING FOR ASSESSING RISK REDUCTION BY LARGE-SCALE RESTORATION OF SEAGRASS IN ARCACHON BAY (FRANCE)

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INTRODUCTION

Seagrass beds are present throughout all European coastlines and serve potentially many critical ecological functions and ecosystem services (ESS) amongst which: coastal flooding control, erosion control and coastline stabilization, habitats for a high diversity of marine species and support of coastal fisheries, carbon capture and storage. The EU Biodiversity Strategy for 2030 specifically mentions them as carbon-rich ecosystems to be protected and emphasizes the need to anticipate the climatic effects on them. These key habitats are however declining rapidly worldwide including in Europe (IPBES report, 2019). Urgent large-scale actions must be undertaken for their preservation and restoration in order to enhance coastal resilience.

In the Arcachon Bay, a semi-confined triangular-shaped lagoon located in the southeast of the Bay of Biscay (France), seagrass restoration actions are explored within the H2020 Green Deal project Rest-Coast, due to chronic seagrass decline observed since the beginning of the 21st century (Auby et al. 2011).

One objective of the Rest-Coast project is the definition of enablers for upscaling coastal restoration (Sanchez-Arcilla et al., 2022). At Arcachon Bay, the effect of seagrass restoration on sediment dynamics and on the resulting coastal morphology evolution is investigated, in order to address socio-economic impacts (e.g. dredging needs, navigability for fishing or tourism), and coastal erosion risk reduction. The current study aims at presenting long-term morphological changes induced by different restoration scenarios and under climate conditions, obtained following a coupled eco-morphodynamic modeling approach.

MATERIALS AND METHODS

The Arcachon Bay is a complex system made of primary and secondary channels, surrounding tidal flats. Its surface is about 174 km² at high tide, and about 65% emerges at low tide. The tidal cycle is semi-diurnal with a weak diurnal inequality (amplitude of 0.8 - 4.6m) (e.g. Ganthy et al. 2013). Several types of sediments are present within the Bay: mainly medium sand for main channel and mouths (320-500 μ m) and gravels, mainly sand and muddy-sand for secondary channels (175-365 μ m), and sandy-mud and muddy-sand for tidal flats (Cayocca, 1996; Bouchet et al. 1997).

The Delft-Flexible Mesh (D-FM) suite is applied, coupling hydrodynamics with morphodynamics, and implemented on a 2D curvilinear grid encompassing Arcachon Bay and

the coastal area located on the ocean side (western part; Figure 1). The resolution of the grid varies between 100m within the Bay and 300m at offshore boundaries. The hydrodynamic module calculates water levels and vertically averaged currents from tidal forcing, and sets sediments in motion. The morphodynamics module is applied for representing the sediment dynamics, via bedload and suspended load transport of cohesive and non-cohesive sediments, and accounting for bed level update using the morphological acceleration factor concept (Lesser et al., 2004). To take into account the complex sand-mud mixtures present within the Bay, the formulation of van Ledden (2003) is used, coupled with the van Rijn (1993) transport formula for sand.

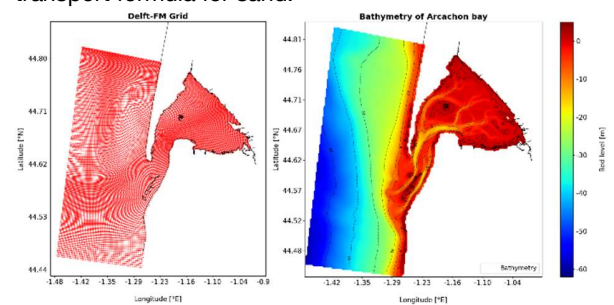


Figure 1 – 2D curvilinear grid and bathymetry used for the coupled DFM model.

The effect of seagrass meadows is implemented in the coupled model. Following the formulations of Baptist (2005), the effect of the vegetation on flow resistance and bed roughness are separated. In some usual formulations, the flow resistance is calculated by means of the increase of the bed roughness (James et al. 2012). However, it leads to higher bed shear stress and larger sediment transport rates in case of morphological modelling. This is typically the opposite to what to be expected. Here, a $-(\lambda u^2)/2$ term is then included in the momentum equation (λ represents the flow resistance of the vegetation, u the flow velocity).

In order to assess future climate projections, conditions are defined following the IPCC projections. Typically, sea level rise is considered for scenarios SSP2-4.5 and SSP5-8.5, and horizons 2050, 2070 and 2100 are targeted. The coupled model has high computation cost, particularly for performing pluri-decadal simulations. Thus, the approach based on the morphological acceleration factor concept (e.g. van Rijn 2007) is used. Schematic representation of the tidal forcing, representative of long-term morphological bed evolutions, following Schrijvershof et al. (2023) method. Different restoration scenarios are also considered. The first

one (S0) considers that the actual vegetation coverage will be conserved for the next decades. A second one (S1) considers that no restoration actions are followed and the decline of seagrass will lead to their total extinction within the Bay. In addition, two additional scenarios (S2 and S3) are considered, assuming seagrass recovery in certain areas over time.

Finally, in order to assess impact on ESS, various socio-economic data are gathered and analyzed. Key Performance Indicators (KPIs) are defined and associated to hazard indicators.

RESULTS AND DISCUSSIONS

Morphological changes are compared with the scenario S1 and the delivery of ESS is analyzed as a function of restoration scale. The restoration shows a non-neutral impact on sediment dynamics with an erosion of the main and secondary channels (Figure 2), improving water renewal and quality, and a deposition of finer sediment within the vegetated area, preventing them from going on the beaches located further inside in the Bay. This dynamic tends to decrease the needs of dredging the harbors entrances around the Bay and then reduce the economic cost associated. Furthermore, it leads to increased navigability (e.g. the duration of access to fishing or tourism activities).

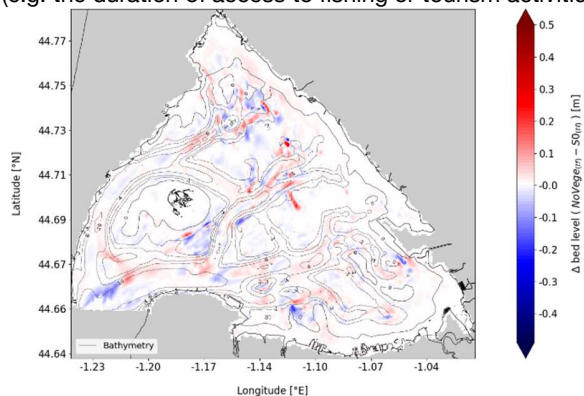


Figure 2 – Map of the difference in bed level evolution over three years between two scenarios: without vegetation – with actual vegetation.

Using global and refined analysis of socio-economic processes at stake, indirect and intangible impacts associated to restoration are characterized – in addition to primarily identified direct and tangible impacts – such as feedback loops (negative or positive) between seagrass development and anthropic activities within the Bay. For example, restored seagrass leads to a decrease in dredging activities. It also tends to decrease the release of pollutants present in the sediment and then helps improve water quality. An increase of the water quality will in return improve the health of seagrass located within the Bay.

CONCLUSIONS

The current study supports the upscaling of current seagrass restoration actions taken within the Bay, as part of

hands-on restoration within the REST-COAST project. The obtained results are moreover of direct use for planning considerations following an adaptive planning approach, that identifies critical pathways for long-term seagrass restoration at the Arcachon Bay.

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REFERENCES

- Sanchez-Arcilla, Caceres, Le Roux, Hinkel, et al. (2022): Barriers and enablers for upscaling coastal restoration, *Nature-Based Solutions*, ELSEVIER, vol. 2, pp. 2-15.
- Auby, Bost, Budzinski, Dalloyau, et al. (2011): Régression des herbiers de zostères dans le Bassin d’Arcachon : état des lieux et recherche des causes, Ifremer report, FR, 195 pages.
- Baptist (2005): Modelling floodplain biogeomorphology, PhD, Delft University of Technology, 213 pages.
- Bouchet, Deltreil, Manaud, Maurer and Trut (1997): Etude intégrée du Bassin d’Arcachon, Ifremer report, FR, 129 pages.
- Cayocca (1996): Modélisation morphodynamique d’une embouchure tidale : application aux passes d’entrée du Bassin d’Arcachon, PhD, University of Bordeaux 1, 426 pages.
- Ganthy, Sottolichio and Verney (2013): Seasonal modification of tidal flat sediment dynamics by seagrass meadows of *Zostera noltii* (Bassin d’Arcachon, France), *Journal of Marine Systems*, ELSEVIER, vol. 109-110, pp. s233-s244.
- IPBES (2019): Biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, Settele, Díaz, and Ngo (editors). IPBES secretariat, Bonn, Germany, 1148 pages.
- James, Birkhead, Jordanova and O’Sullivan (2012): Flow resistance of emergent vegetation, *Journal of Hydraulic Research*, TAYLOR & FRANCIS, vol. 42:4, pp. 390-398.
- Lesser, Roelvink, van Kester, Stelling (2004): Development and validation of a three-dimensional morphological model, *Coastal Engineering*, vol. 51(8–9), pp. 883-915.
- Schrijvershof, van Maren, Torfs and Hoitink (2023): A Synthetic Spring-Neap Tidal Cycle for Long-Term Morphodynamic Models, *Journal of Geophysical Research: Earth Surface*, WILEY, vol. 128:3, pp. 1-18.
- van Ledden (2003): Sand-mud segregation in estuaries and tidal basins, PhD, Delft University of Technology, 248 pages.
- van Rijn and Kroon (1993): Sediment transport by currents and waves, *Coastal Engineering*, ASCE, pp. 2613-2628.
- van Rijn, Walstra and van Ormondt (2007): Unified view of sediment transport by currents and waves. IV: Application of morphodynamic model, *Journal of Hydraulic Engineering*, ASCE, vol. 133:7, pp. 776-793.