PHD 2021

Thesis title	**Predicting seagrass regional dynamics under climate change and human pressure using a hybrid modelling approach**
Department/Office	**IFREMER Department: Oceanography and Ecosystems Dynamics (ODE)** **Research Unit: Coastal Ecosystem Dynamics (DYNECO)** **Laboratory: Hydro-Sedimentary Dynamics (DHYSED**
Duty station	**Ifremer, Brittany Centre, Brest (France)** **Queensland University of Technology, Brisbane (Australia)**
Doctoral school	**The Marine & Coastal Sciences Doctoral School (SML)**
Thesis supervisor	**Romaric Verney**
Co-supervisors	**Héloïse Muller, Paul Wu, Martin Marzloff**
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The Institute and the recruiting department

- Presentation of the Institute

French Research Institute for Exploitation of the Sea, Ifremer, through its research work and expert advice, contributes to knowledge of the oceans and their resources, to monitoring of marine and coastal environments and to the sustainable development of marine activities. To these ends, Ifremer conceives and operates tools for observation, experimentation and monitoring, and manage the oceanographic databases. Created in 1984, Ifremer is a French public institute of an industrial and commercial nature. It is supervised jointly by the Ministry of Higher Education and Research and the Ministry of Ecology, Sustainable Development and Energy.
Ifremer undertakes research missions, offers expert advice and acts as a funding agency. Ifremer performs targeted applied research to address the questions posed by society (climate change effects, marine biodiversity, pollution prevention, seafood quality, etc.). Results include scientific knowledge, technological innovations, and systems for ocean observation and exploration. Partnerships may be public, private or a combination of both. Ifremer works in a network with the French scientific community, also collaborating with international partner organizations, in the frame of several national and international projects, including contractual activities.

- Presentation of the department, research unit and laboratory

The PhD student will mainly be hosted in the DHYSED Hydro-Sedimentary Dynamics laboratory with strong interactions with the coastal benthic ecology LEBCO laboratory within Ifremer's DYNECO research unit.

DYNECO (Dynamics of Coastal Ecosystems) research unit is one component of the "Oceanography and Ecosystems Dynamics" department. Its main objective is to study how coastal ecosystems respond to

anthropogenic or natural pressures. DYNECO conducts scientific and expert assessment activities in this field. The global approach rests on the analysis of physical and biogeochemical processes and is based on experimentations, in-situ observations and modelling. The main research areas concern: i) material flows in the human-land-coastal sea continuum, ii) spatial and temporal dynamics of human-habitat-biodiversity interactions and iii) methods for analysing ecosystems by crossing observation, experimentation and modelling.

Within DYNECO unit :

• the Hydro-Sedimentary Dynamics laboratory (DHYSED) studies hydro-sedimentary processes in interaction with the biotope and human activities at different spatial scales (ie from metropolitan facades to bays and estuaries) and temporal (from tidal to multi-decadal).
• The coastal benthic ecology (LEBCO) laboratory studies the diversity, structure and functioning of coastal marine ecosystems to understand species- and community-levels responses to environmental variability and anthropogenic pressures.

During this work, the PhD student will also spend some time at the Centre of Data Science at the Queensland University of Technology (QUT) in Brisbane (Australia). This centre is focused on developing new statistical tools and methods, and their application to varied domains including social systems, and environmental and natural systems.

Summary

Worldwide seagrass regression is alarming given the ecological role of this emblematic coastal ecosystem. Regional conservation initiatives, which have emerged over the past thirty years, have had limited success at protecting these habitats. Our ability to predict seagrass dynamics within a context of global change is critical to support the development and implementation of adequate conservation measures. However, the dynamics are complex and difficult to understand due in part to complex feedbacks between ecological dynamics, hydrodynamics and sediment processes. Modelling can help us to understand these complex dynamics within the ecosystem associated with the seagrass, but at present, combining ecological and hydro-sediment models to support management is both conceptually and technically challenging. This PhD project will tackle these challenges as it aims to develop an original modelling approach coupling a coastal hydro-sediment model with a dynamic Bayesian network model to understand and simulate long-term seagrass dynamics.

Context

Seagrasses form coastal habitats of high ecological and patrimonial value as they play the role of ecosystem engineer for instance by supporting high levels of biodiversity, or by contributing to water quality as well as coastal protection from erosion, storms and floods, or even carbon trapping (United Nations Environment Programme 2020). They have been declining for nearly one century with an estimated annual global loss of 7% (United Nations Environment Programme 2020). France is highly concerned with a critical hotspot in Arcachon bay in southwestern France, where total surface area of *Zostera spp.* seagrass beds drastically declined between 1988 and 2008, by 33% for *Z. noltei* and by 72% for *Z. marina* meadows, respectively (Plus et al., 2010). The drivers of such a dramatic decline are not well known but potential suspects include

eutrophication pollutants, pesticides, turbidity, metallic pollutants, diseases and maybe climate warming. In Arcachon bay seagrass regression may have been initiated by combined effects of heat waves and herbicides. Moreover, recent works identified that seagrass resilience to these stressors is largely conditioned by complex feedback between hydrodynamics, suspended particulate matter concentration and seagrass extent (Ganthy 2017, Cognat et al., 2018a, and 2018b).

As a result, seagrasses are classified as sentinel species because they clearly indicate marine environmental changes at local, regional and global scale. Thus, they are considered as an indicator of the quality of the water body in the Water Framework Directive. Moreover they are the subject to several conservation initiatives (Flora Fauna Habitat Directive, OSPAR Convention,…) and research projects whose purpose is to design tools that will help to prevent their degradation. Limited understanding of seagrass dynamics within an integrated ecosystem approach motivates the development of efficient models to understand the drivers of seagrass local decline.

Two complementary modelling approaches are developed in Australia by Queensland University of Technology (QUT) and in France by Ifremer: data-driven and expert-elicitation probabilistic model (Wu et al., 2017) and deterministic process-based model ((Plus et al., 2003, 2010; Ganthy et al., 2013; Kombiadou et al., 2014) respectively. Ifremer has a strong experience in modelling seagrass dynamics using deterministic approaches that capture key processes and interactions between different compartments (hydrodynamics, sediment dynamics, bio-geochemical cycles and seagrass growth). However even if such approaches are very accurate as they explicitly account for a number of detailed processes, they have high computational cost and are site-specific. QUT and Edith Cowan University (ECU) have collaborated to develop a Dynamic Bayesian Network (DBN) from observations and expert judgment that captures seagrass dynamics and the effect of different dredging periods/regimes at a meadow scale.

The proposed PhD project will directly build on and benefit from the research collaboration initiated between QUT and Ifremer in January 2019 to develop a seagrass dynamics model using a hybrid framework with a co-supervision strategy. This PhD project proposes to combine both institutes modelling approaches in order to simulate long-term seagrass extent and biomass in a global change context.

Objectives

The objective of this PhD proposal is to evaluate and anticipate seagrass-system evolution and resilience in response to global change and conservation/restoration scenarios, based on the development of an innovative hybrid modelling strategy. It implies to understand the functioning of the ecosystem associated to seagrass as a whole: across scales (individual, patch, local, regional, global) and across dimensions (physical, ecological, economic, social/cultural, management) (Melbourne-Thomas et al., 2017). The hybridization between the process-based hydro-sediment model MARS-MUSTANG 3D developed at Ifremer and the seagrass resilience DBN developed by QUT and ECU will enable to parameterize the interactions between seagrasses and their multi-dimensions environment. It can tremendously extend our capacity to simulate scenarios of spatio-temporal seagrass evolution (biomass and spatial distribution) over long-term periods (horizon2100), in relation to anthropogenic as well as natural stress factors. The impact of IPCC scenarii (temperature increase and seal level rise) and scenarii of local realities (issued from ARCADE project's data analysis) and actions like seagrass replanting could be analysed through this hybrid modelling approach. The Arcachon bay will be the pilot site because of the availability of an extended databases (physical data such as currents, temperature, light and biological data relative to seagrasses). It also benefit from a validated and calibrated hydrodynamical model configuration.

Scientific interests

The originality of the PhD consists of the development of a hydric model coupling process-based, data-driven and statistical approaches, including expert judgment. This method will enable to model partially resolved or even unknown processes and also to make long-term predictions. Indeed, we are not able to parameterized all the processes describing an ecosystem and deterministic process-based-models are quickly limited by computational time. The coupling of such approaches will also provide the standard deviation associated to the seagrass variables as extent, biomass, etc… Moreover the structure of the DBN will enable easily to integrate management measures and model their impact on the whole ecosystems. One huge valuable outcome of this work will be the availability of an efficient decision support tools.

Partnership

The project will be a partnership between IFREMER/DYNECO DHYSED and LEBCO, the LERAR Arcachon, QUT and ECU. Moreover the co-supervision with QUT will imply at least a 10-month stay for the PhD student to adapt the DBN to the Arcachon bay and convert the DBN outputs to MARS3D MUSTANG and vice versa with Paul Wu.

References

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