Developing a Companion modeling approach to support sustainability in Marine social-ecological systems – application to the red lobster fishery in Iroise Sea

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Abstract. Marine socio-ecosystems are complex systems characterized by strong interactions between natural resources exploited, human activities and governance. Many human activities rely on the resources that the ecosystem can provide. However, natural resources are common and variable and thus require particular management and adaptation from human activities. In addition, marine environments and activities are difficult to observe, assess or control. Supporting management of marine SES therefore requires the use of participatory integrated approaches such as the ComMod (Companion Modeling) approach. This approach builds simulations and gaming with the stakeholders of the territory to help sharing a common vision of the SES and its future and thus empowering stakeholders towards sustainable trajectories. Within the framework of the HOPOPoP project, a ComMod approach has been developed in the Iroise Sea red lobster fishery which is characterized by a biomass increase providing incentives to target this species in a context of a decrease observed in a number of other fish stocks. In a first step, the co-construction of a conceptual model with the stakeholders of the fishery will be built through interviews and workshops. This model will be used, in a second step, to create an agent-based simulation model which combines classical biological and socio-economic simulations of scenarios and role playing in order to help stakeholders explore consequences of decisions on the management of their activity. Stakeholders will be able to make virtual decisions and see how they impact the different elements of the socio-ecosystem.

Keywords: Companion Modeling, fisheries management, Iroise Sea

Complex systems are systems composed of a large number of entities and interactions which create emerging properties. A complex system is characterized by a high difficulty to anticipate how the system will evolve (Ottino, 2004). Socio-ecological systems (SES) are complex systems (Berkes et al., 1998). A SES is composed of an ecological part where several species share the same space and interact between them and with the other components of the ecosystem. In addition, a SES includes human activities which depend on or exploit some of these common resources and are often characterized by distinct temporal and spatial dimensions.

In a marine SES, understanding interactions between exploited living resources, maritime uses, governance and science support are particularly challenging to disentangle, thus hampering the emergence of effective management strategies and adaptations to local and global changes (Cheung, 2018). Given the particular complexity of coastal regions, the sustainability of marine living resources and human activities should thus rely on integrated approaches considering the entire SES (Weatherdon et al., 2016). Managing marine SES towards sustainability in a changing world would require to (i) integrate diverse sources of knowledge, (ii) account for interactions between resources, users and governance (iii) explore future options, and (iv) support social learning and development of sustainable options with stakeholders and society (Mackinson et al. 2010, Macher et al., 2018, 2021).

The COMpanion MODeling (ComMod) approach is an integrated approach combining various sources of knowledge from and outside academia while taking into account the interactions between resources, users and governance through modeling and simulation processes

(ComMod, 2003, 2005, Etienne et al. 2011). It aims at providing a better understanding of interactions in a SES (Etienne et al. 2011) and promote a shared knowledge to collectively explore future options, support social learning and identify sustainable management methods with stakeholders. To this end ComMod approach uses participatory and collaborative methodologies based on gaming and computer simulations (Becu, 2021). This approach has been mainly used in terrestrial SES, and there are a few applications to support fisheries management (Becu et al., 2016, Worrapimphong et al., 2010).

We aim at implementing a ComMod approach in a marine environment with strong sustainable management issues, where there is a tension between actors and resources. We chose Iroise Sea (Figure 1) to explore the efficiency of this type of approach to tackle sustainability challenges in Marine SES. It is characterized by a diversity of habitats supporting the activity of various emblematic commercial fishing fleets as well as other small scale fishery units. In addition, the Iroise Sea is home of the Iroise Marine Natural Park, the first French marine natural park created in 2007. This park adds a new administrative layer to the area in addition to the traditional governance of French coastlines (Iroise sea park).

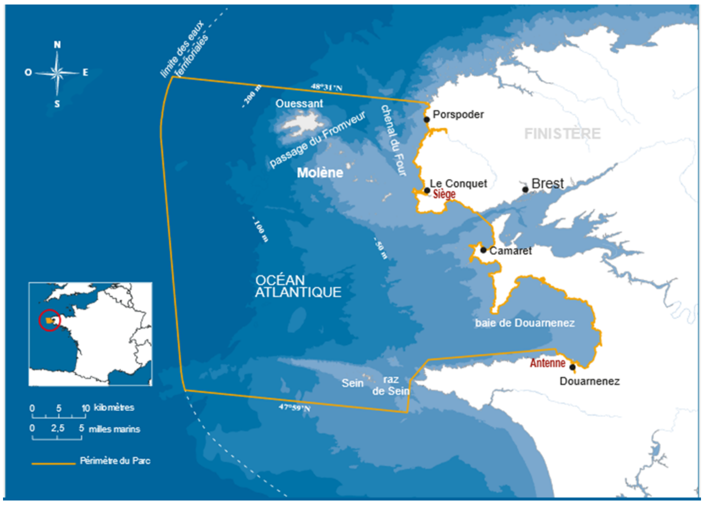

Fig. 1. Map of the Iroise Sea and the Natural Marine Park. Sources: Office Français de la biodiversité

The application of this approach is being implemented as part of the HOPOPoP project (2022-2026). To support the exploration of sustainable futures in the Iroise Sea, the project combines various integrated and innovative approaches based on simulation, gaming and virtual or augmented reality. We decided to implement a ComMod approach in 3 steps: (i) scoping of the case study, (ii) create a conceptual model of the SES and (iii) implement an agent-based model combining simulation and gaming.

The first step is to select the case study. We conducted preliminary interviews and workshops with the park and a fishermen's representative to scope the stakes in Iroise. The case study was chosen for the stake, the interest of the stakeholders (fishermen, manager of the Iroise park, fishmonger), the spatial scale (Iroise sea) and the available data and experts. On this basis, we selected the red lobster fishery. The red lobster case is an important issue because after several years with a small population size, the lobster stock is increasing while other fish populations are decreasing in Iroise. The fishery is mainly managed by conservation measures while access regulation is based on uses and habits. Expected changes in strategies towards red lobster can also have consequences on other species in Iroise depending on which gear is used (Figure 2).

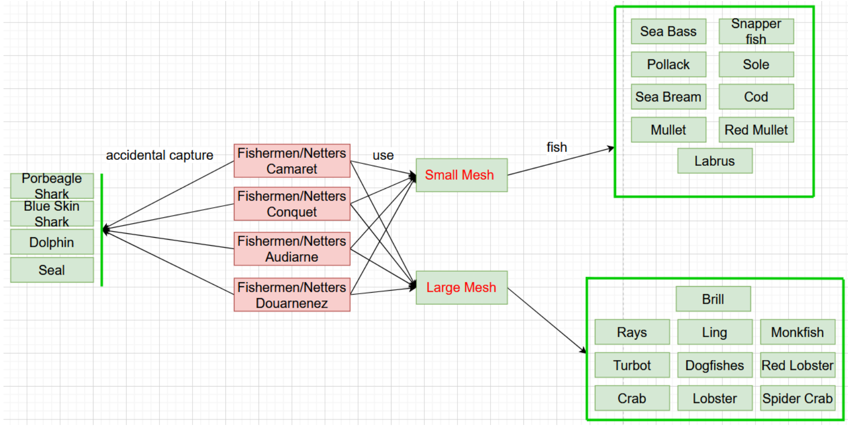

Fig. 2. Conceptual diagram of the netters in the Iroise Sea and the species impacted. Sources: Elaborated from the first scientific focus group workshop of HOPOPoP Project

The second step is to create a conceptual model of the red lobster fishery in the Iroise Sea. We decided to use the ARDI method (Etienne, 2011). The ARDI method stands for Actor, Resources, Dynamics and Interaction. It is one of the main methods used in ComMod approaches to create a shared conceptual model of an SES. This method aims to list all the actors and resources of the SES linked to an issue (here: how the red lobster fishery works in the Iroise Sea? Figure 2). We will then explicit the dynamics (e.g. biology of the red lobster, fishery activity) of the SES linked to this issue. Eventually, we will further construct with stakeholders a diagram representing the interaction between the actors and the resources which govern the SES.

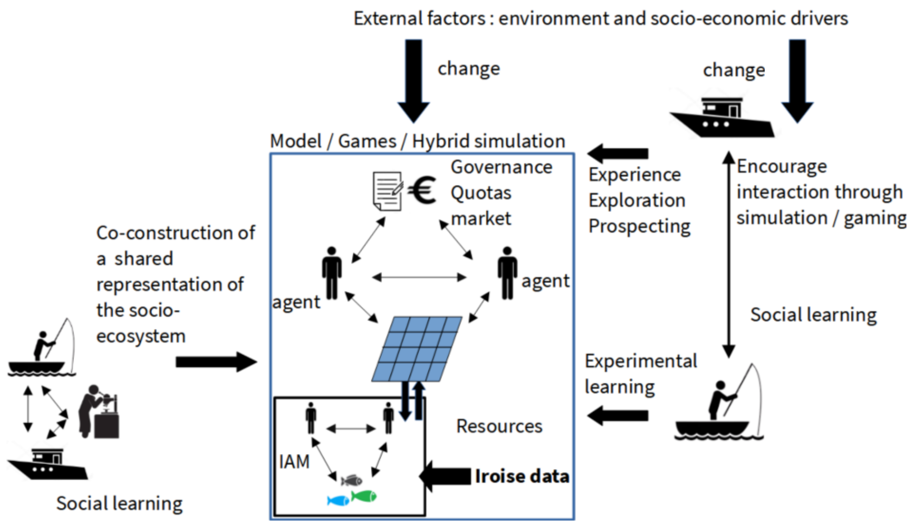

Fig. 3. Representation of the conceptual framework based on a hybrid game/simulation model. Sources: diagram presented during the kick-off of the HOPOPoP project.

In a third step, we aim at implementing a hybrid simulator which combines a role playing game with computer simulation (see conceptual framework proposed in Figure 3). The objective is to integrate several components of the SES into an agent-based model (using the conceptual model created during step 2) including interactions between harvesting strategies of fishermen, resource dynamics, biophysical evolution and management. To help realism, the model will also use other existing models which prove to be efficient such as the IAM model (Merzéréaud et al, 2022; Macher et al, 2018). The IAM model aims to simulate the dynamics and interactions between fish stocks, the vessels or fleets which exploit them, fisheries governance and the market. This will give stakeholders an opportunity to explore potential ecological, economic or social impacts of alternative choices encouraging experimental and social learning. On this basis, the stakeholders will take virtual decisions which will be integrated into the simulator in hybrid game sessions. Lessons learned will allow to explore and debate the possible futures of the Iroise Sea.

We are currently completing the second step of the project.

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