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Abstract. For more than fifty years, Artificial Reefs (AR) have been deployed in France to respond to the decline in fish stocks with a high deployment on the Mediterranean coast. However, from 40 sites listed, less than a quarter have not been the subject of any known published ecological or socio-economic monitoring reports, over the past five years. The lack of data on the evaluation of these structures therefore raises questions about their interest, both from an ecological and social point of view. By relying on the theory of organizations and more specifically on the translation resulting from the sociology of innovation applied to the environment, we will develop an original socio-ecological approach intended to meet this need for evaluation, in particular for managers. Based on two case studies on the coasts of the French Channel (Etretat and Cherbourg), we will highlight the interests and roles of human and non-human actors in an AR immersion process. The analysis will highlight the social and ecological objectives of these two projects from an analytical framework designed to verify the adequacy between the socio-ecological network "artificial reefs" formed and the objectives initially expected by the actors, especially decision-makers and funders. The limits posed by these approaches to improve the evaluation of artificial reefs will finally be discussed.

1. Introduction

Due to overexploitation and decrease in fish stocks [1], new tools for the management of the coastal zone have emerged around the worldwide ocean. Artificial reefs (ARs) are human structures voluntarily deployed for the objectives of fixing, concentrating, increasing or regenerating marine fauna [2]. They are used in many countries around the world for the purposes of fish production (such as in Japan, China or Portugal), development of recreational activities (such as in Australia, United States or Israel) or protection against illegal trawling actions (such as in France, Spain or Italy). Scientific research on ARs applies to these three main objectives.

In France, since the 1960s, ARs deployment have increased considerably. On all French metropolitan coastlines, the number of ARs sites reaches 44 in 2020. Historically, the main objective of French ARs is to support the production of artisanal fisheries. Indeed, in the Mediterranean Sea, over 2/3 of the ARs sites have a fisheries production objective [3]. However, the distribution of the number of ARs sites between French maritime coast is very heterogeneous. When the Mediterranean Sea has about 30 ARs sites in 2020, North Brittany and the English Channel have only four ARs sites and the Bay of Biscay nine.

For more than 50 years that ARs have been used in France, their assessments remain unusual or incomplete [2 -7]. The studies carried out often target indicators such as the abundance and the species richness of or focus only on a specific fish community or on some species [8]. These studies, although

they have shown the direct effect of ARs on the increase of local primary production [9 -10], provide only a partial answer to the problem of assessing the contribution of ARs within a socio-ecosystem point of view. Indeed, the socio-economic dimension is often forgotten [11 -12]. To compensate this lack, some studies have focused on landing data, experimental fisheries, calculations of biological production of ARs from the selling prices of species at the harbour markets. Others have integrated the social dimension by studying users' perception of the usefulness of ARs [6;13]. Nevertheless, no study considered the entire socio-ecological network to assess the overall contributions of ARs.
A socio-ecological approach applied to ARs sites seems relevant to understand the overall functioning of the ARs system but also to compare the social-ecological contributions of ARs with the initial expectations of the actors of the territory. The use of this innovative approach is part of a multidisciplinary approach linking nature and culture within a territory.
Based on two case studies on the French English Channel (Etretat and Cherbourg), we highlight in this paper the interests and roles of human and non-human actors in an ARs project.

2. Materials and Methods

2.1. Study sites

The study sites chosen are located in the English Channel, off Etretat and in the harbour of Cherbourg (Figure 1).
In 2008, 450 m^3 of the ARs were deployed off Etretat by the Chamber of Commerce and Industry (CCI) of Fécamp/Bolbec. The 25-ha site is located 2.4 km from the coast and on depths of -17m. It is composed of a central module of 54 m^3, a first belt of heap of cubic reefs and a second belt of protective reefs. The concrete used is composed of synthetic fibber that favours fauna and flora colonization. The project was financed by European funds dedicated to fisheries, the Haute-Normandie Region and the Seine-Maritime Department. The objective of the ARs site is to support the fishing industry by targeting species with fisheries interest such as sea bass [14].
The second study site is located in the Cherbourg harbour on shallow depths up to 5m deep. The ARs were deployed in 2015 and was design during the European RECIF project. The modules are composed of 72 experimental shell concrete blocks, spread over three levels of 24 units for a total volume of approximatively 100 m^3. The objective is to improve the biodiversity and production of the English Channel marine ecosystems. The RECIF project was selected within the framework of the European Cross-border Cooperation Programme INTERREG IV A France (English Channel) / England, co-financed by the European Regional Development Fund (ERDF). It brings together eight French and British partners and was supported by the ‘Conseil Régional de Basse-Normandie’. The RECIF project is part of the opportunities and actions carried out for the improvement of the ecosystem of the English Channel and for a better management of marine resources [15].

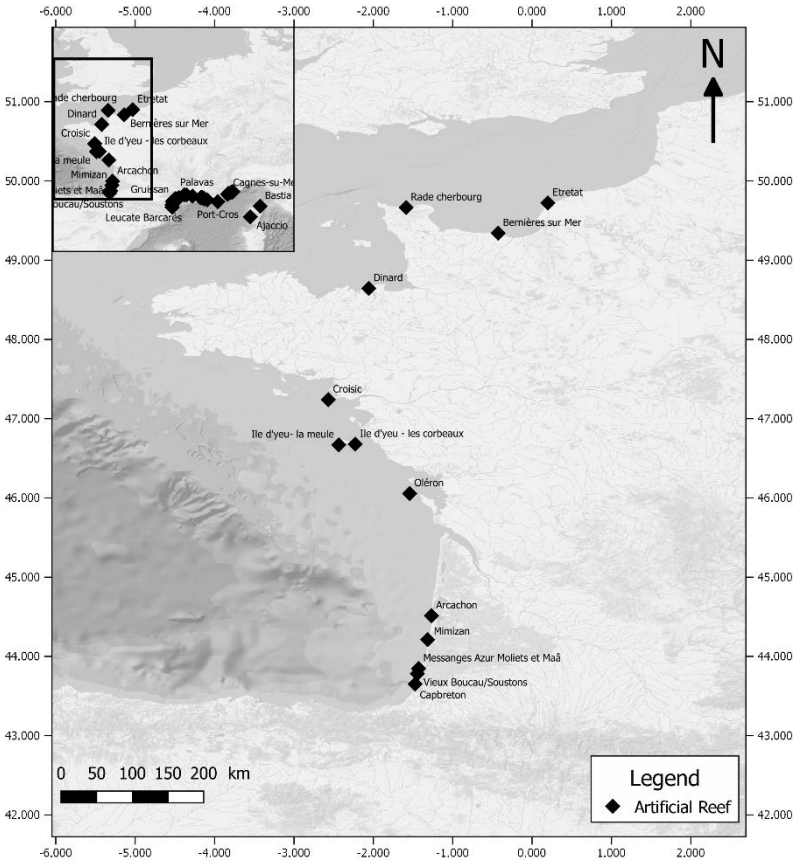

Figure 1. Location map of the artificial reef sites in the English Channel

2.2. The Translation concept

The concept of translation had been developed by Callon [16] and Latour [17] and based on the Actor Network Theory [18]. This concept is used to describe each step of the actor network construction to understand the process of collective action [17]. The particularity of this concept is to consider the non-human actors who can be both technical objects and living beings as part of the definition of actors. This particularity makes it possible to consider marine fauna and flora as an actor in the ARs socio-ecosystem analysis.

The translation concept is defined by four steps [16;19;20]:

1. Problematization, which defines the issues and the obligatory passage point for collective action (the common solution responding to the challenges identified);
2. Interessement, which expresses the interests of each actor;
3. Enrolment, which assigns roles to each actor;
4. Mobilization of allies, which makes it possible to extend the network and gather other actors to collective action.

2.3. Data acquisition

In order to understand how the ARs network was created, qualitative open-ended interviews were conducted. This methodology does not seek to cover representativeness but the diversity and complexity of social reality [21]. During the first interview campaigns, a model is built and is constantly modified by the contribution of the following interviews. Then the model is consolidated until the new interviews no longer provide new information. The model then called "saturated", validates the results obtained [22].

The choice of the actors interviewed follows the "snowball effect" method which consists of starting from a central actor of the study case, in our case the ARs site manager, then all the actors mentioned

during the interview of the central actor. These actors identified (level 1) directly by the central actor are also interviewed and the new actors mentioned are integrated in the network (level 2).
Human actors have been grouped defining three categories of actors according to their social function [23]:
-The State;
-Local government;
-Civil society.
The non-human actors, who could not be questioned directly, were represented by scientists as experts of the marine fauna.

Table 1. Number and type of actors interviewed

Type of actors interviewed	Number
State	2
Local government	1
Civil society	12
Wildlife Representative	6

3. Results

3.1. A favourable socio economic context to deploy artificial reefs

During the 1990-2000, ARs is democratized in the Mediterranean Sea and the Atlantic coast. Many projects were born during this period.
The materials used are mainly recycled elements such as electric poles, nozzles, blocks... Since 1999, ARs projects are eligible to receive European funds in France. This financial assistance, along with the reduction in costs through the use of recycled materials, makes ARs projects more affordable for local government such as townships. Acceptance of ARs is also social. At this time, the fisheries sector is facing a decrease of fish catches [24]. In consequence, the professional fishermen, seeing in this tool a manner to fix the resource and manage conflicts between inshore fishermen and trawlers, requested ARs deployment. The media also take up the subject and relay the deployment through reports on national TV channels such as Thalassa. From a scientific point of view, after an experiment carried out in 1990s, the reports conclude that it is difficult to assess the real benefits for the fisheries sector [5;25].
This socio-economic context favourable to the ARs deployment have allowed to continue to experiment and improve scientific knowledge on the contribution of ARs to the socio-ecosystem. The two study projects have emerged in this context.

3.2. The English Channel, a territory of research and development

The origin of the Etretat ARs project, located in the eastern part of the English Channel, is multiple and responds to various actor's interests (Figure 2):

- **The industry sector** is interested in experimenting and designing new materials, resistant in the corrosive marine environment.
- **The harbour manager** considers ARs project as an opportunity to increase harbour activity and enhance the harbour value through innovative projects.
- **Professional fishermen organizations** are attracted by the possibility of increasing the coastal fishery resource. However, the location of the project is essential and must not impact existing activities. The choice of the project area can then influence their support for the project.
- **Other marine users** such as divers are interested in developing more diving sites.
- **Marine fauna and flora** are interested in the possibility of having a specific and additional habitat to feed and reproduce.

Thus, all these actors and their interests converged around a common project of experimentation of form and materials of ARs, making this project the 1st in the English Channel.

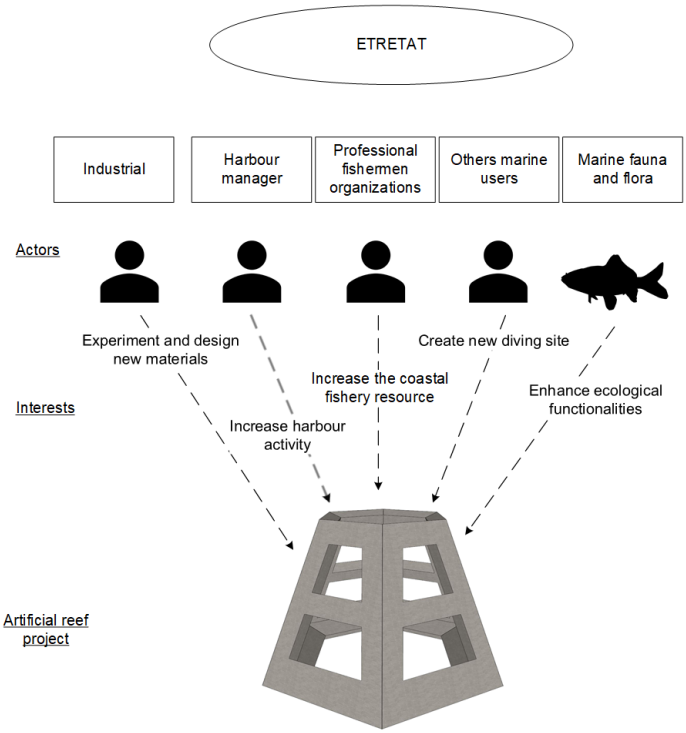

Figure 2. Actors interests in the context of the Etretat study site

The deployment of ARs in the Cherbourg harbour is an example of a convergence of several interests which can be divided into two main steps.
Firstly, the European INTERREG program entitled RECIF which has been able to federate scientific and industrial actors around a project to recover shellfish waste in the manufacture of concrete (Figure 3) :

- **The industry sector** continues their research and development approach. The evolution of the regulatory context (compensatory measure), economic context (offshore wind turbine project) and mentalities in favour of ecology, suggests that ARs project could be promising subject.
- **The scientific community** is also interested by study human pressures on the environment, both in terms of increasing industrial waste such as shells and the increase in activities in the marine environment. Through a research program, researchers are interested in developing new materials, monitoring protocols and acquiring data on the flora and fauna of hard substrates that had previously been neglected in terms of their biodiversity and ecological functioning at the scale of the French side of the English Channel.
- **Marine fauna and flora** are interested in the possibility of having a specific and additional habitat to feed and reproduce.

Secondly, a consultation around the Cherbourg harbour development project invites users to give their opinion and express their interests. The deployment of ARs appears as an interesting ecological action to compensate the harbour extension which can have a negative effect of the coastal biodiversity. The idea then reached a consensus among users of the Cherbourg harbour.

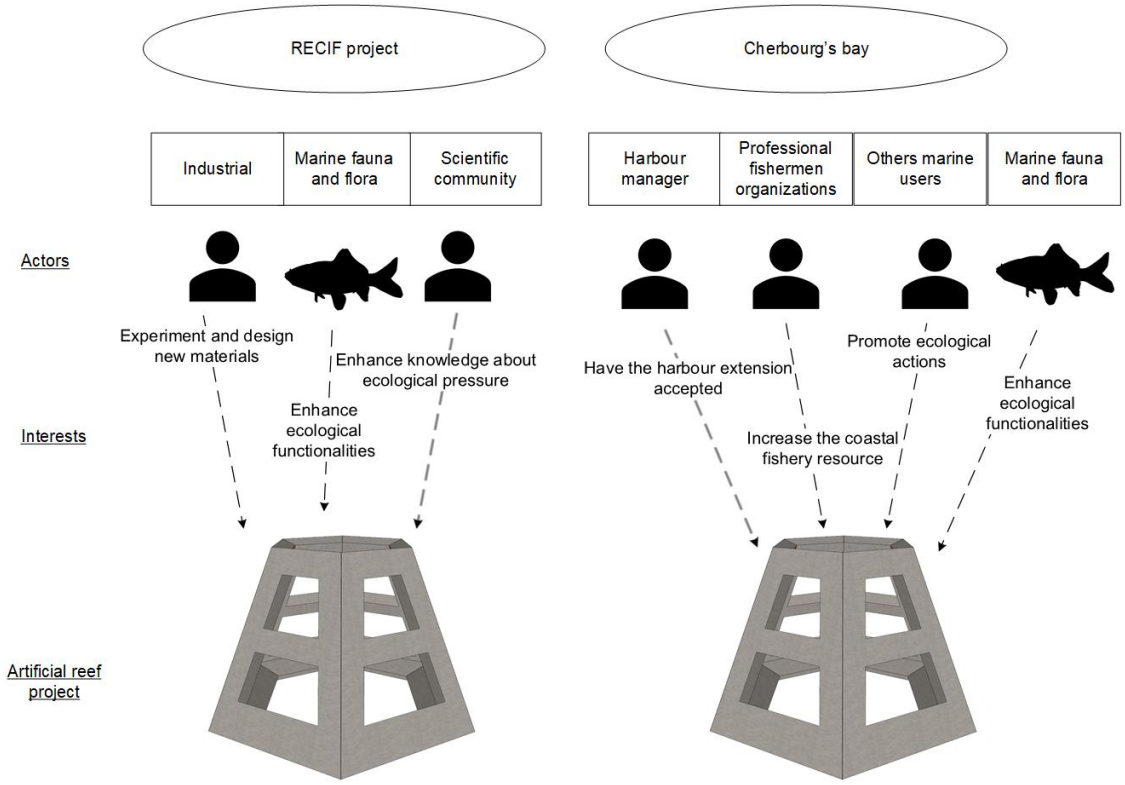

Figure 3. Actors interests in the context of the Cherbourg study site

3.3. Actors enrol in AR's immersion project

In order to carry out ARs projects, the previously federated actors are involved in their deployment and also mobilize other actors necessary for the project. The needs for the deployment of ARs are numerous. First of all, there is an administrative need for authorization to use the maritime French public domain, then a need for financing the project and finally a need to define the technical aspects of design, deployment and monitoring of the structures.

For the Etretat project, the actors involved will fill the roles of project holder (legal project leader for the administration), project manager, operator and marine user (concerted for the define the location and the management measures). The interests of marine fauna are considered at this stage of the project, through scientific monitoring and a preliminary study to determine the best location of the ARs. For funding, the actors will request European funds and local authorities support. Regarding the need of authorization, it is given by the administrators of maritime and land affairs (DDTM).

The RECIF program and the reef project in the harbour of Cherbourg are not on the same temporalities. While the RECIF project is concretized from a technical and financial point of view, the Cherbourg harbour manager carries out a preliminary study in order to choose the ARs location. The needs and interests of these two projects will then converge to form a single ARs project. Indeed, while the RECIF project encounters administrative difficulties (duration of instruction exceeding the temporality of the European program), the project leader of the Cherbourg harbour has administrative facilities. The merger of the two ARs projects then brings together all the administrative, financial, technical and scientific needs to implement ARs (Figure 4). Finally, the monitoring of the ARs deployed in Cherbourg harbour continues today as part of a new European INTERREG MARINEFF project and bringing together the actors of the RECIF project as well as other partners including the Cherbourg harbour manager for the deployment of new reefs in the Cherbourg Bay.

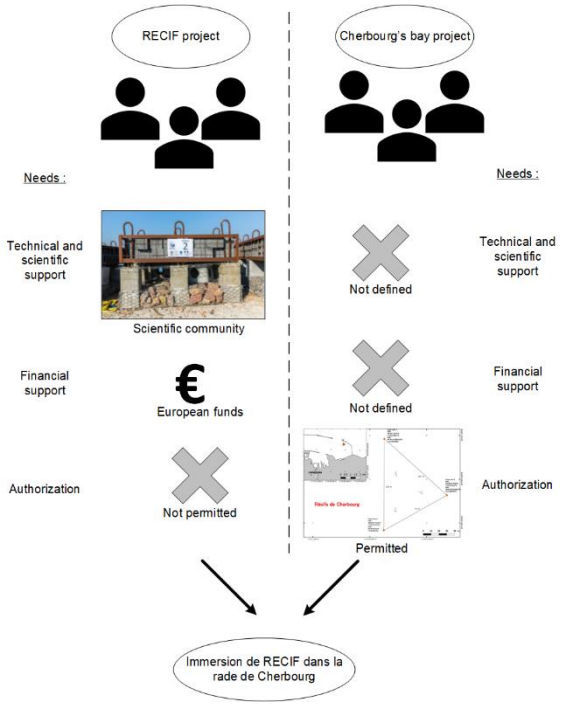

Figure 4. Mobilization of actors in the context of artificial reefs deployment in the harbour of Cherbourg

3.4. The continued mobilization of actors

A project is defined as a success when all actors enroll in the project to achieve the ARs deployment [16]. The continued mobilization of actors ensures the achievement of the results expected by each actor.

In the case of the Etretat ARs, the actors involved have different economic, social or ecological expectations. After ten years of deployment, the feedbacks from the actors involved in the project are:

- **The industry sector**: it has succeeded in promoting the experimentation of a formulation of new materials for which a patent has been filed.
- **The harbour manager:** despite a lack of interest of wind project leaders in artificial reefs, the harbour has been able to position as a logistics platform for the installation of wind farms, harbour activity has increased accordingly. However, the influence of the ARs project on this increase is difficult to determine.
- **Professional fishermen organizations** don't have specific benefit related to the ARs deployment and subsequently lost interest in the subject.
- **Others marine users** : divers benefit from a partnership with the harbour manager. They carry out annual photographic monitoring on the ARs.
- **Marine fauna and flora**: it colonized the AR with a preference for cubic reefs, compared to the large central module. Despite the destabilization of the central module, the diversity of the fauna increases.

In the case of the RECIF project in Cherbourg harbour, after five years of immersion, the feedback of deployment, the feedbacks from the actors involved in the project are:

- **The industry sector:** they continue their research and development approach in the new MARINEFF research program.
- **The harbour manager**: it was able to carry out the harbour extension and compensation. He joined the new MARINEFF research program as a partner.
- **The scientific community**: it has promoted research work through the realization of a scientific symposium. In addition, it is continuing to acquire biological data within a new INTERREG programme called MARINEFF.
- **Others marine users**: they accepted the ARs project. The area being forbidden to all activities, they lost interest in the subject. Only one diving structure has become a technical partner of the scientific community.
- **Marine fauna and flora**: The flora has strongly colonized the reefs and the fauna is also present.

4. Conclusion

Through the translation concept, the process of building ARs projects is described. Initially isolated actors with their own interests will federated in a common project of ARs deployment. The ARs appear as the tools that permit to meet the expectations of all the actors involved. This approach makes it possible to describe the social expectations of the actors involved in the projects but also to integrate the ecological aspects of the projects by integrating the marine fauna and flora as an actor in its own right. A network of actors is then created around ARs projects.

The difficulty of assess an ARs project lies in the complexity of the socio-ecosystem formed during its deployment. Indeed, the translation concept highlights the diversity of actors interests. These interests, if the project is settled, can be used as goals to reach in order to measure the success of AR projects. There is therefore not one clearly defined objective but a variety of expectations depending on the actors initially enrolled and mobilized later.

The limits of the assessment by this approach are that it is a qualitative method and that the ecological dimension appears as minor in the process. Indeed, the interest of the ecosystem is considered through a single group that represent the marine fauna as a whole that is a very simplified analysis.

To go further in the understanding and assessment of the socio-ecosystem, the analysis could propose a modelling of the sociological and ecological ARs network. These models would bring quantitative indicators to the assessment and restore symmetry between human and non-human actors. By comparing the number of interactions before and after ARs deployment, it would be possible to characterize the network evolution over the life time of ARs.

5. Acknowledgments

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