Oyster Reef Restoration, France Case Study

The Bay of Brest and the Bat of Quiberon in the French region of Brittany have both historically been home to large populations of oyster beds. This coupled with a larval abundance and the strong restoration history in the area led to these areas to be chosen for rescaling the oyster population. Despite this history, the local oyster population *Ostrea edulis* is highly sensitive to the pressures of the restoration area, including the potential for overfishing, synthetic compound contamination, and introduction of microbial pathogens or parasites.

Introduction to the site

Driving factors, motivations, and goals for initiating restoration actions

Restoration actions have been initiated as a result of past experimental projects carried out in both sites and that have provided valuable insight into the local need for restoration, feasibility and acceptability, and relevant site-specific restoration practices. Historical data indicates the prior significance of the habitat throughout both sites and its severe decline over time. The reduction of some of the major pressures (including fishing) has not led to the natural restoration of the habitat, and the species and its habitat is estimated to be close to extinction in both areas. In this context, restoration is identified as course of action for the conservation of the species. Both territories are identified as priority areas of action due to the ecological and economic significance of the species both regionally, nationally and even at the scale of the EU. The Bay of Quiberon gathers strategic environmental conditions favouring natural reproduction and making it a European hotspot for spat collection of native oysters. The Bay of Brest hosts one of Europe's most active living labs for native oyster restoration in Europe, generating unique practice based scientific knowledge. Finally, the local socio-economic environment is such that several of the ecosystem services that could result from upscaling the restoration of native oyster reefs, could generate significant benefits and contribute to more resilient coastal communities in both sites.

Description of the restoration project location

The actions carried out within the CLIMAREST project for the restoration of *Ostrea edulis* are taking place in the region of Britany, France. Two sites were selected: the "Banc du Roz" in the Bay of Brest, and the "Banc de Penthièvre" in the Bay of Quiberon.

Assessment Phase

General description of the background and the Initial site assessment

The term "Banc", present in both site names, is a historical term used in France to designate the presence of an oyster bed, usually either fished or farmed. Both sites therefore historically hosted dense oyster beds. The two sites are close to the shore (several hundred meters distance), in the subtidal zone, and are both included in Natura 2000 sites, setting a framework for conservation and restoration efforts. The environmental conditions are contrasted in between sites. The "Banc du Roz" is set in a sheltered shallow inlet benefiting from oceanic incursions at each tidal flow and regular supply of freshwater. The last oysters are found scattered over a seabed consisting mainly of maerl (*Lithothamnium corallioides*) and attach themselves to shell fragments. The "Banc de Penthièvre" is set in a more open and exposed bay and the seabed is dominated by a mosaic of different types of sediment. The last oysters are found scattered over the seabed and attach themselves to small stones, shell fragments and residues of clay tiles inherited from past oyster farming practices. According to Pouvreau et al. (2019), the natural oyster density in both sites is generally below 1 individuals/m, but some clumps of oysters can be occasionally found, which ranks this population in a critical, but restorable state.

Planning and Design Phase

Permits applied for and from where

The native oyster restoration undertaken in CLIMAREST is set out in areas in which prior experimental work was already ongoing. As a result, and from a permitting perspective, the implementation of the restoration actions was simplified in comparison to what could have been required in areas not benefiting from similar past dynamics. In the Bay of Quiberon, restoration occurs within a marine plot managed by the regional representative committee of shellfish farmers. The spatial perimeter of this plot overlaps with part of the historical oyster bed as mapped in the early 1900s, and was leased by local state authorities to the committee to sustainably manage this specific natural resource. CLIMAREST partners signed a partnership agreement with the committee to carry out restoration on a sub-plot in this area. Authorizations for the restoration actions were also required from the managing institution of the local Natura 2000 site in which the site is set. Due to the small depth of the site, individual signalization of each equipment deployed on the seabed through specific marker buoys was required by state authorities to guarantee navigation safety in the area. In the Bay of Brest, actions were carried out in a plot already managed by one of the CLIMAREST partners, Ifremer, and dedicated to practical research on the restoration of *Ostrea edulis*. For this site as well, no additional permits than those already in place were required. The experimental work operated in this plot is aligned with the research objectives and practices that are defined by Ifremer in close collaboration with local public and professional institutions, including the French Office for Biodiversity which oversees the management of the Natura 2000 site in which the plot is located.

Restoration objectives of the project

The general objective of the project is to contribute to the safeguard and possibly restoration of the European native oyster (*Ostrea edulis*) and its reef habitat.

The native oyster restoration actions undertaken within the CLIMAREST project were developed according to three main objectives:

- contribute to the development of best practice for upscaling native oyster restoration by experimenting protocols adapted to contrasted sites and evaluating their efficiency,
- model and measure ecosystem benefits associated to large-scale restoration scenarios,
- support to local stakeholders in defining and implementing ambitious roadmaps for upscaled restoration.

In this sense, the project was not operated in the purpose of actually restoring the native oyster reefs in both demonstration sites, but rather in the purpose of experimenting and hopefully validating protocols and approaches that could be deployed and replicated at a larger scale after the project's end. In a similar manner, demonstration of restoration benefits could not be envisaged

in this project as a direct measurement of effects associated to large scale restoration, the projects actions being limited in both time and scale. Coupling of in-situ measurement of small-scale effects and modelling was used to evaluate and quantify possible benefits associated to scenarios of larger restoration efforts. Prior demonstration of benefits specific to each site was seen as necessary to mobilize stakeholders and funding efforts for future upscaling.

Protocol for the restoration project

The technique used for native oyster restoration in this project relies on the deployment of substrate to enhance the local settlement of naturally occurring larvae and initiate the formation of native oyster biogenic reefs. This substrate is designed and implemented considering several key aspects including limiting predation of juvenile oysters in the first years of reef formation, maximizing larval settlement through material composition and timing of deployment, and ensuring substrate compatibility with habitats and species already present in the restoration site.

In Quiberon Bay, the scale of restoration trials was set to 1000 m². This surface was estimated as a relevant milestone, between the scale of past experimental trials (a few square meters) and the surface of the historical oyster bed that could be restored over the long term (several hectares). The form of oyster habitat targeted for restoration is that of large oyster reef aggregates of several meters in diameter. Restoration techniques were developed in the aim of being transferable to local oyster farmers who represent a major task force in this bay, and who are pioneers in the safeguard of the species locally. Ecosystem service evaluation in Quiberon Bay focuses on contribution of restoration to erosion control through wave attenuation. The perimeter of the historical oyster bed is adjacent to the Penthièvre isthmus, a natural heritage site supporting key regional transportation infrastructure, and subject to critical erosion dynamics.

In the Bay of Brest, restoration trials are not focused on scale but on effectiveness and compatibility with the presence of sensitive habitats such as maerl beds. The objective is to develop and test restoration techniques with the smallest environmental footprint possible. The form of oyster habitat targeted for restoration in this site is that of small oyster clumps scattered on the seabed at a density of approximately one clump per square meter. Restoration techniques were developed in the aim of being deployable by divers and transferable to leisure and professional practitioners. Ecosystem service evaluation in the Bay of Brest focuses on biodiversity enhancement and water quality improvement. The Bay of Brest is subject to degraded freshwater inputs from local rivers that significantly alter local marine ecosystems.

Finally, both sites also serve to develop and test monitoring protocols aimed at measuring the effect of native oyster reefs on carbon fluxes. The capacity of such habitats to store carbon is still under evaluation. Demonstration of carbon storage capacity could lead the way to direct carbon offset funding to native oyster restoration projects.

Implementation Phase

Description of the Implementation of the protocol

The restoration protocol begins with a thorough monitoring of the reproductive activity of local adult oysters starting at the end of the month of May. Peak reproduction in Brittany occurs when water temperatures reach 17°C, between mid-June and mid-July. During this time, adult oysters are fished from the area and observed. Water samples are also collected, and oyster larvae are counted. Comparison of this data to that of previous years enables the anticipation of the larval peak during which substrates must be deployed. Most years, this peak lasts only a couple of weeks. Getting the timing of deployment right is critical to guarantee optimal substrate colonization and to set optimal conditions for oyster reef development.

Substrates are deployed on the seabed during larval peak. Their design and materials may vary from one site to another depending on local objectives and environmental conditions of the sites. The effectiveness of over 50 materials has been tested since 2020 in Ifremer's underwater laboratory in the Bay of Brest. Three new materials were tested as part of CLIMAREST.

In Quiberon Bay, 55 large steel domes around 2.5m in diameter and 0,7m in height were deployed between 2023 and 2024. Coating the steel with lime prior to deployment has led to a significant gain in oyster larvae colonization. In the Bay of Brest, the preferred technique consists in using small cubes (approx. 10cm in diameter) of biobased mortar fixed on small wooden sticks planted in the seabed. The domes and cubes are elevated from the seabed around 0.3m to limit colonization by benthic predators such as oyster drills or sea stars. This is a key aspect to optimize juvenile oyster survival during the first years.

Reference substrates are also deployed using a standardized protocol. They allow a better interpretation of colonization results and observations and permit interannual comparison. Periodic removal of predators (mainly oyster drills) is carried out on the restoration sites by divers.

Data collection, analysis, and assessments of ecological Indicators

Two categories of monitoring are operated in the demonstration sites. The first consists in monitoring the colonization of the substrates by flat oysters and monitoring their survival over time. The second consists in measuring the effect of the presence of oyster reefs on various parameters of the environment.

The monitoring of oyster colonization of substrates consists in counting the number of oysters per surface unit. Live and dead oysters are differentiated as well as their size. This allows a better understanding of the growth and mortality dynamics of the reef. For dead oysters, specific predation marks are noted (holes made by oyster drills for example). Quantitative monitoring campaigns are carried out yearly. More frequent qualitative observations are made more

frequently, at least every 3 months. The observations made on the restoration substrates are confronted with those made on the surrounding seabed as well as reference areas nearby. Juvenile mortality being the main cause of oyster reef decline today in both sites, the efficiency of restoration is made by comparing oyster size distribution between restoration and reference areas, as well as live oyster density averaged per square meter.

For the evaluation of ecosystem benefits and support to modelling, some specific measures have been made during the project on biodiversity (identification of species associated to oyster aggregates), water filtration (measurement of chlorophyll concentrations upstream and downstream of a reef), sedimentation (observation of sediment accumulation and/or erosion around the substrates) and carbon fluxes (carbon content in underlying sediments, and dissolved carbon concentration in the water column).

Ongoing Management, Monitoring, and Evaluation Phase

Final results of the demonstration site

The restoration trials undertaken within the CLIMAREST project have resulted in very positive results. In both sites, the deployed techniques have led to the development of densities of between 10 to over 30 oysters per square meter, reaching the status of functioning oyster beds and reefs as stated in the classification proposed by Pouvreau et al. 2021 et Zu Ermgassen et al., 2021, and used as reference for evaluation by the Native Oyster Restoration Alliance. Densities prior to restoration in both sites as well as in reference areas are 0 to 1 individual per square meter, corresponding to the most degraded state of conservation of an oyster bed and indicating risk of disappearance.

Results to come before the end of the project for associated ecological benefits.

Major Issues and problems encountered

The major issue faced in the process of restoration in Brittanny is the management of predation during the first years of growth of the oyster reef. In their aggregative form, oysters are less vulnerable to fish such as seabream but remain highly vulnerable to benthic predators, oyster drills being a significant cause of mortality. Elevation from the seabed of settlement substrates helps reduce exposure to benthic predators but is not sufficient to completely eliminate this pressure. Periodic inspection of the substrates to remove predators is necessary to optimize success of restoration. The design, deployment logistics and periodic inspections required to manage this pressure have a significant impact on cost and technical efficiency of restoration operations, in comparison to directly “seeding” the seabed with settlement substrates.

It should be noted that both sites have a rather unique spatfall. The possibility of directly replicating these techniques to other sites rests on the capacity of these sites to provide sufficiently significant

concentrations of larvae in the water column during the reproductive season. Where this is not the case, different methods should be applied.

Sharing and Communication

Examples of Sharing and Communication activities from the demonstration site include the following.

- Public Outreach
    - Support to local website development for raising awareness
    - Community talks
    - School visits
    - University lectures
    - Stands and demonstrations
- Collaborative Efforts
    - Meetings with NGOs
    - Meetings with local authorities
    - Stakeholder workshops
    - Meetings with dive centres
- Media Presence
    - Film at SER international film festival
    - Radio interviews
    - Promotional videos
    - Social media
    - Newspaper articles
- Production of Scientific Works
    - Academic theses
    - Scientific publicans
    - Oral presentations
    - Poster presentations

References

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2. zu Ermgassen PSE, Bos O, Debney A, Gamble C, Glover A, Pogoda B, Pouvreau S, Sanderson W, Smyth D, Preston J (2021) European Native Oyster Habitat Restoration Monitoring Handbook. The Zoological Society of London, London, UK