Aquaculture Impact Mitigation and Octopus Reintroduction, Croatia Case Study

Introduction to the site

Driving factors, motivations, and goals for initiating restoration actions

The project was driven by the need to mitigate ecological impacts of marine aquaculture on benthic ecosystems, particularly the accumulation of organic matter beneath fish farms. Additionally, the common octopus (*Octopus vulgaris*), is overfished in much of the Adriatic, requiring support through habitat enhancement. The goals were to improve benthic habitat complexity, strengthen octopus resilience, and successfully transfer knowledge on artificial reef design, monitoring, and telemetry tagging to Croatian stakeholders.

Description of the restoration project location

The restoration project was carried out in the central eastern Adriatic Sea, beneath finfish farms near the island of Brač, Croatia. This location represents sedimentary soft-bottom ecosystems affected by aquaculture activities.

Assessment Phase

General description of the background and the Initial site assessment

The selected site consisted of soft sedimentary seabeds beneath and adjacent to aquaculture cages near Brač Island. These habitats had been subject to organic enrichment from fish farming, reducing environmental heterogeneity. Although the area is oligotrophic and capable of assimilating some organic matter, the long-term aquaculture pressures had degraded benthic conditions, which justified the restoration effort.

Planning and Design Phase

Permits applied for and from where

No formal permits were issued for this pilot project, as the activities took place within an area where an aquaculture company already holds a concession. Instead, an agreement was reached directly with the aquaculture operator, granting access and permission to deploy the artificial reefs and conduct monitoring activities within their concession area. This collaborative approach ensured smooth implementation of pilot project. However, if such practices become more frequent in the future, it will be necessary to establish clear procedures for the issuing of permits to ensure standardization, transparency, and wider applicability of restoration efforts.

Restoration objectives of the project

Overall, the aim of this pilot study was to promote the transfer of knowledge on reef design, implementation, and telemetry tagging of complex species such as the octopus between scientists from the Institute of Oceanography and Fisheries in Croatia and scientists from the CLIMAREST demonstration site from Universities of Vigo and Alicante.

Main objectives were:

1. Deploy artificial reefs beneath aquaculture farms to increase habitat complexity and provide shelters for octopus.
2. Test and refine methodologies for octopus habitat restoration in oligotrophic soft-sediment conditions.

3. Transfer practical knowledge on reef design, monitoring protocols, and telemetry tagging from Spanish demo sites to Croatia.
4. Raise stakeholder and public awareness of aquaculture impacts and restoration strategies.
5. Demonstrate scalable procedures applicable to other Adriatic or Mediterranean locations.

Protocol for the restoration project

1. Scale of the restoration project

The project was designed and implemented as a small-scale pilot, with the deployment of artificial reef modules beneath finfish aquaculture farms in the central Adriatic, near Brač Island. This scale was intentional, allowing researchers to carefully monitor the feasibility and ecological outcomes before considering wider application. While modest in size, the pilot represented a crucial first step for Croatia in testing habitat restoration within aquaculture concessions. The scale was also aligned with the available budget and resources, ensuring that the project could be completed effectively while generating reliable data for knowledge transfer and replication.

2. Selection of appropriate restoration techniques

The technique selected for restoration was the deployment of purpose-built artificial reefs designed specifically for octopus habitat enhancement. These reefs were created by the IOF research team to provide structural complexity and mimic natural rocky refuges within soft-sedimentary habitats. The reefs were adapted to local ecological and physical conditions, ensuring stability on sandy bottoms beneath fish farms while creating multiple cavities suitable for octopus sheltering. This approach provided both ecological benefits and practical feasibility for replication under aquaculture settings.

3. Control/reference sites

To ensure that the effects of reef deployment could be properly assessed, the project established control sites located in sandy habitats away from aquaculture influence. These reference sites provided a baseline for evaluating natural octopus presence and benthic conditions without the added pressure of organic matter sedimentation from fish farming. Comparisons between reefed sites under aquaculture farms and these control sites allowed researchers to distinguish the impacts of aquaculture, the benefits of artificial reef structures, and the interactions between the two. This experimental design was developed in accordance to experience with Spanish demonstration site.

4. Success/benefits indicators

The success of the restoration project is being assessed through several ecological and social indicators. Ecologically, key indicators include the colonization of artificial reefs by octopuses, evidence of site fidelity, reproductive behavior, and improvements in benthic habitat heterogeneity.

Acoustic telemetry tagging is currently providing insights into octopus movement patterns and their use of restored habitats, which is further strengthening the evaluation of ecological benefits.

Implementation Phase

Description of the Implementation of the protocol

The field implementation of the protocol is being carried out in close collaboration with the aquaculture company that holds the concession in the study area near Brač Island. Artificial reef modules, designed by the IOF research team to provide suitable cavities for octopus, are being deployed beneath fish cages on soft-sediment bottoms. The reefs are transported by boat and lowered into position using lifting equipment to ensure precise placement and stability on the seafloor.

Once installed, researchers are conducting regular dives and monitoring trips to document reef colonization and environmental conditions. In addition, part of the research team from the University of Vigo is supporting the implementation of acoustic telemetry tagging of octopus. This involves carefully capturing individuals, attaching telemetry devices using established protocols, and releasing them near the reef structures. An array of acoustic receivers is being deployed around the study site to record movement and habitat use.

Parallel activities at control sites located away from aquaculture influence follow the same deployment and monitoring procedures. This dual approach allows for direct comparison of ecological responses under aquaculture pressure versus more natural conditions, ensuring that the field implementation provides robust and transferable results.

Data collection, analysis, and assessments of ecological Indicators

At the study location, visual census techniques were conducted monthly by scuba divers. Besides octopuses, all other marine organisms around the reefs were recorded and quantified. All observations and findings were documented using under-water cameras. In addition, octopus monitoring was carried out using acoustic telemetry approach where 40 individuals were tagged and released in the study area. Array of receivers was deployed to track their movement and habitat use.

Ongoing Management, Monitoring, and Evaluation Phase

Final results of the demonstration site

The research is still ongoing, so final results cannot be expected at this stage. However, preliminary data indicate a positive impact of reefs on octopus' populations at sites affected by aquaculture. During each monitoring session, either live octopuses or remains of mollusk shells were observed, suggesting that octopuses are using the reef as their habitat. Additionally, many fish and benthic species have also been recorded around the reef, indicating that the structure in areas affected by aquaculture provides benefits to other marine life as well.

Major Issues and problems encountered

Although the implementation of the pilot project proceeded without major disruptions, several challenges, mainly of a logistical nature, were encountered. The reefs were primarily installed outside urban coastal areas, making them less accessible both for installation and monitoring, which requires significant material resources. Monitoring with divers is also highly dependent on weather conditions, which can be particularly challenging during the colder months. Control stations that are not located directly beneath fish cages and are therefore outside the direct oversight of the aquaculture company are unprotected, which could result in the illegal fisheries (i.e. removal of octopuses and other marine organisms). Additionally, ensuring consistent long-term maintenance and monitoring remains a challenge due to these logistical constraints and the need for sustained funding and manpower.

Sharing and Communication

Communication was established with the aquaculture company operating the fish cages where the restoration activity was implemented. In addition, the restoration concept and its associated benefits have been presented at both national and international meetings, including those organized by the General Fisheries Commission for the Mediterranean (GFCM CAQ, AdriaMed), focusing on aquaculture and marine environmental issues.