Handbook of “Adriatic good practices” for ecological behaviours for the practice of aquaculture

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1 Introduction

Welcome to the Handbook of "Adriatic Good Practices" for Ecological Behaviours in Aquaculture. This handbook serves as a comprehensive guide to promote sustainable and environmentally responsible practices in the aquaculture sector within the Adriatic region. With its rich biodiversity and economic significance, the Adriatic Sea presents a unique setting where the principles of ecological stewardship and responsible aquaculture can be effectively implemented.

Aquaculture, or the farming of aquatic organisms, plays a vital role in meeting the increasing demand for seafood while relieving pressure on wild fish stocks. However, it is crucial to ensure that aquaculture operations are conducted in a manner that minimizes environmental impacts, protects native species and habitats, and fosters the long-term sustainability of coastal and marine ecosystems.

This handbook aims to showcase a collection of good practices that have been successfully implemented in the Adriatic region, highlighting innovative approaches, lessons learned, and practical strategies for achieving ecological balance in aquaculture operations. It serves as a valuable resource for aquaculture practitioners, policymakers, researchers, and other stakeholders seeking to enhance the ecological performance and social acceptance of aquaculture activities.

Throughout the handbook, you will find a diverse range of topics covered, including sustainable site selection, responsible feed management, efficient water and waste management, disease prevention and control, and the promotion of biodiversity conservation in and around aquaculture facilities. Each chapter presents a specific aspect of ecological behaviour in aquaculture, providing practical recommendations, case studies, and best practices that have demonstrated positive environmental outcomes.

It is our hope that this handbook will inspire and empower aquaculture operators to embrace ecological behaviours and implement sustainable practices that go beyond compliance. By adopting these good practices, we can contribute to the preservation and enhancement of the Adriatic ecosystem, ensure the economic viability of aquaculture enterprises, and promote the well-being of coastal communities that depend on these resources.

Together, let us embark on a journey of responsible aquaculture, where ecological balance, economic prosperity, and social harmony can coexist, shaping a more sustainable future for aquaculture in the Adriatic region and beyond.

2 Handbook of "Adriatic good practices" for ecological behaviours for the practice of aquaculture

2.1 Lessons learned from the project that contribute to fishermen and farmers when applying the Bottom-up approach in management and co-management

Project extracted instructions: Lessons Learned from the Project: Bottom-Up Approach in Aquaculture Management and Co-Management

1. Enhanced stakeholder engagement: The project emphasized the importance of involving aquaculture farmers and other stakeholders from the outset. By including their perspectives, knowledge, and expertise in decision-making processes, a sense of ownership and accountability was fostered. This bottom-up approach not only improved the effectiveness of management strategies but also strengthened the relationship between farmers and regulatory bodies.

2. Context-specific solutions: The project recognized the diverse nature of aquaculture operations and the need for context-specific solutions. Each farming site has unique environmental, social, and economic characteristics, which necessitate tailored approaches. By empowering farmers to contribute to the design and implementation of management measures, the project promoted the development of site-specific practices that address local challenges and opportunities.

3. Local ecological knowledge: The project acknowledged the valuable ecological knowledge held by aquaculture farmers. Farmers' practical experience and observations were considered vital sources of information for understanding local ecosystems, identifying potential risks, and implementing appropriate management actions. Integrating local ecological knowledge into decision-making processes resulted in more informed and effective management strategies.

4. Capacity building and knowledge exchange: The project prioritized capacity building initiatives that provided aquaculture farmers with the necessary skills and knowledge to actively participate in management and co-management processes. Training programs, workshops, and knowledge exchange platforms facilitated the sharing of best practices, lessons learned, and innovative approaches among farmers. This promoted a culture of continuous learning and improvement.

5. Adaptive management: The project emphasized the importance of adaptive management in the aquaculture sector. Recognizing that aquaculture systems and environments are dynamic, adaptive management allowed for ongoing monitoring, assessment, and adjustment of management strategies. This iterative approach, guided by feedback from farmers and stakeholders, improved the resilience and responsiveness of aquaculture practices to changing conditions.

6. Collaboration and partnership: The project highlighted the significance of collaboration and partnership among different stakeholders involved in aquaculture management. Engaging with government agencies, research institutions, environmental organizations, and local communities fostered collective decision-making and resource sharing. Collaborative efforts led to the

development of integrated management approaches, improved data collection systems, and more effective communication channels.

7. Sustainability as a shared goal: The project emphasized the common goal of achieving sustainable aquaculture practices. By promoting sustainability as a shared objective, it fostered a sense of collective responsibility among farmers and stakeholders. This shared vision facilitated cooperation, trust-building, and the development of long-term strategies that balanced environmental, social, and economic considerations.

8. Regulatory support and policy integration: The project underscored the importance of supportive regulatory frameworks and policy integration. Effective management and co-management require enabling policies that provide clarity, guidance, and incentives for sustainable aquaculture practices. The project advocated for policy reforms and collaboration between regulatory bodies and farmers to align objectives, streamline procedures, and ensure the implementation of environmentally sound practices.

The lessons learned from the project highlight the benefits of applying a bottom-up approach in aquaculture management and co-management. By engaging farmers, embracing local knowledge, fostering collaboration, and promoting adaptive management, the project contributed to more sustainable and inclusive aquaculture practices. These lessons can serve as valuable guidance for aquaculture farmers when adopting a bottom-up approach and striving for the long-term viability and environmental integrity of their operations.

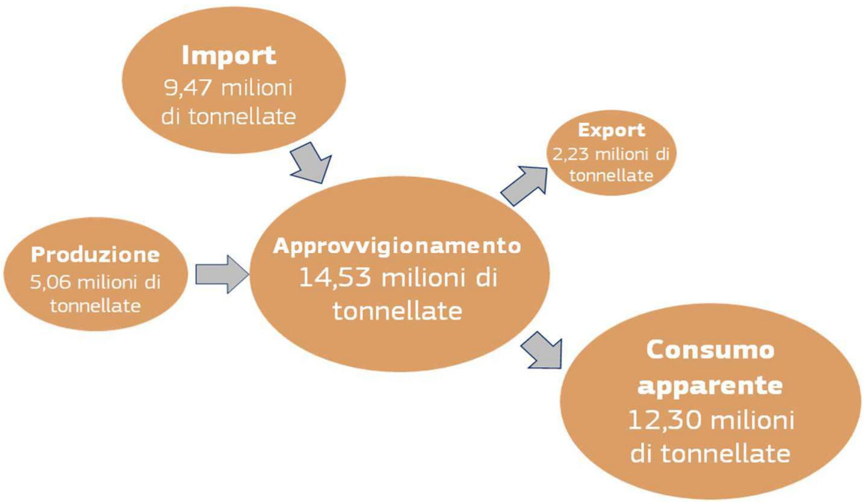


Figure 1 – EU Production, import and export of fishery and aquaculture products by product group in 2018 (equivalent live weight - for food use only). Source Eumofa.

<u>Notes from deliverables:</u>

The EU is the world's fifth largest producer of fishery and aquaculture products; in 2019, it covered about 3% of world production (5% of catches and 1% of farmed fish products). The catches of the EU fleet exceed 80% of the supply, while the remaining 20% is represented by aquaculture products

EU legislation defines aquaculture as the cultivation or cultivation of aquatic organisms using techniques designed to increase the production of those organisms beyond the natural capacity of the environment, where organisms remain owned by natural or legal persons during the breeding and production phase, up to and including the hunting phase. Aquatic organisms at any stage of the life cycle resulting from aquaculture activities or products derived therefrom (Reg. EU-1380/2013).

According to the new CFP, "Aquaculture should contribute to preserving the potential for sustainable food production throughout the Union by ensuring long-term food security, including food stocks, as well as growth and employment for Union citizens and contributing to growing global food demand from aquatic environment "(Reg. EU-1380/2013). The CFP directs aquaculture to increase competitiveness and innovation that would enable sustainable development, spatial integration and diversification of aquaculture products. Given that a regulated market is a precondition for the functioning of the Union, the new CFP introduces instruments for market regulation, such as: professional organizations; marketing standards; consumer information; competition rules; market research (Reg. EU.1379 / 2013)

The New Green Deal represents a strategy for the growth of the EU which, through a participatory process, aims to unite the actions of individual citizens, cities and regions by helping companies to use more eco-sustainable technologies for their activities, creating new jobs work and facilitating the transition to a circular and sustainable economy leading to zero emissions by 2050. To achieve this goal it will be necessary to act in all sectors of our economy. The first goal set is the 50% reduction of greenhouse gas emissions by 2030. The Green Deal includes 3 strategies that closely concern aquaculture and related aspects.

1. The Biodiversity Strategy for 2030 represents a long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on the path to recovery by 2030 by undertaking specific actions and commitments. This strategy also aims to strengthen the resilience of habitats and societies against future threats such as: climate change; forest fires; food insecurity; epidemics.

2. The Farm to Fork Strategy aims to accelerate the transition to a sustainable food system with a neutral or positive environmental impact. This should then help mitigate climate change, reverse biodiversity loss and ensure food security. The aim is to ensure that everyone has access to sufficient, safe, and sustainably produced food. The EU will support the global transition towards sustainable agro-food systems, such as aquaculture, through its trade policies and international cooperation instruments.

3. The Framework Directive 2008/56/EC on the strategy for the marine environment, transposed in Italy by Legislative Decree (LD) N. 190/2010, represents an innovative instrument for the protection of the seas since it constitutes the first law binding the States Members to consider the marine environment from a systemic point of view. The objective of the Directive is to develop the economic potential of the marine-coastal belt in harmony with the environment

Lack of space is often cited as an obstacle to the expansion of marine aquaculture in the EU. It is possible to remedy this shortcoming by identifying in advance the "most suitable sites for aquaculture". If not properly designed and monitored, aquaculture activities can significantly affect the environment. For this reason, certain environmental impacts of fish farming (such as nutrient enrichment or contamination by hazardous substances) are expressly governed by EU legislation. As for shellfish farming, on the other hand, this can cause an excess of organic matter on the seabed and changes in sedimentation or currents.

All these aspects are influenced by factors such as the type of organisms raised, the location of the plant and the vulnerability of the surrounding and underlying environment of the farm. According to a study by the European Parliament, the assessment of these environmental aspects as part of the spatial planning process can reduce the administrative burden for entrepreneurs and limit uncertainty in authorization procedures, thus favouring investments.

„The Commission aims at engaging all relevant stakeholders in the development of the EU aquaculture as a sector that supplies nutritious and healthy food with a low environmental and climate footprint that creates economic opportunities and jobs, and becomes a global reference for sustainability and quality. In particular, the guidelines have the following objectives building resilience and competitiveness of the EU aquaculture sector ensuring the participation of the EU aquaculture sector in the green transition fostering social acceptance and improved consumer information on EU aquaculture activities and products increasing knowledge and innovation in the EU aquaculture sector.“

https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/aquaculture/aquaculture-guidelines_en

New Strategic Guidelines have been adopted for the 2021-2030 programming period. The new strategic guidelines for more sustainable and competitive aquaculture in the EU, for Member States and all relevant stakeholders, seek to offer a common vision for the further development of aquaculture in the EU in a way that contributes to this growth strategy. In particular, it seeks to help build the EU's aquaculture sector:

- Which is competitive and resilient;

- Which ensures the supply of healthy food;

- reducing the EU's dependence on imports of seafood;

- In which economic opportunities and new jobs are created;

- Which is an example of sustainability worldwide

In order to achieve this vision, the Strategic Guidelines 2021-2030 identify four priority areas:

(1) Building resilience and competitiveness;

(2) Participation in the green transition;

(3) Social acceptance and consumer information; and

(4) Increasing knowledge and innovation.

Despite the aspiration to simplify procedures in setting up aquaculture, the legislative framework is extensive and complex. In this project, it was determined that Aquaculture management in the EU through the legislative framework includes 56 regulations, which relate to:

- General conditions for the setting up and for development of aquaculture,
- Aquaculture Financial support system,
- Environment and sustainable development,
- Locating aquaculture,
- Food safety,
- Health and well-being of cultivated organisms,
- Statistics and data collection from aquaculture.

This is followed by national legislation that is harmonized with European regulations and forms the legal basis for aquaculture management at the national level. In order to simplify the aquaculture management system, continuous cooperation between producers and all levels of management, regional, national and European, is necessary. Perhaps it should be written that this is why it is necessary to develop regional centres where everything relevant to the development of aquaculture in the area will be monitored...

2.2 Ecological behaviours – aquaculture

Project extracted instructions: Ecological behaviours in aquaculture refer to practices and strategies that prioritize environmental sustainability, biodiversity conservation, and the minimization of negative impacts on ecosystems. These behaviours are essential for the long-term viability and ecological integrity of aquaculture operations. Here are some key ecological behaviours in aquaculture:

1. Site selection and design: Choosing appropriate sites for aquaculture facilities is crucial. Consideration should be given to water quality, hydrodynamics, local biodiversity, and potential interactions with sensitive habitats. Proper site design can minimize ecological disturbances and optimize natural resource utilization.

2. Water and waste management: Implementing effective water sources and waste management practices is essential to prevent pollution and maintain good water quality. This includes proper discover of open waters area for static cultivation, handling and treatment of effluents, minimizing nutrient and chemical inputs, and managing water circulation to maintain optimal conditions for aquatic organisms.

3. Responsible feed management: Developing and implementing responsible feed management practices can minimize the ecological footprint of aquaculture. This involves using nutritionally balanced and species-appropriate feeds, optimizing feed conversion ratios, reducing feed waste, and avoiding the use of unsustainable feed ingredients such as fishmeal derived from overexploited stocks.

4. Disease prevention and control: Adhering to sound biosecurity measures is critical to minimize the risk of disease outbreaks and the use of antibiotics or chemicals. Implementing strict hygiene practices, regular health monitoring, appropriate stocking densities, and selecting disease-resistant species can contribute to maintaining ecological balance and reducing the need for treatments.

5. Biodiversity conservation and habitat protection: Aquaculture operations should take measures to protect and enhance biodiversity. This includes minimizing impacts on local habitats, avoiding the release of non-native species that could become invasive, and implementing habitat restoration or creation initiatives that benefit native species.

6. Monitoring and data collection: Regular monitoring of water quality, ecosystem health, and the impacts of aquaculture activities is essential. Collecting and analysing data on key environmental parameters and biological indicators helps identify potential issues and guide adaptive management strategies to mitigate negative impacts.

7. Integration with ecosystem services: Recognizing and valuing ecosystem services is fundamental to ecological behaviours in aquaculture. Incorporating natural processes, such as nutrient cycling, into aquaculture systems can enhance ecological interactions, reduce external inputs, and promote self-sustainability.

8. Community engagement and social responsibility: Engaging with local communities, indigenous groups, and other stakeholders is important for promoting ecological behaviours in aquaculture. This includes respecting traditional knowledge, addressing concerns and conflicts, and fostering social and economic benefits for local communities.

9. Compliance with regulations and certification: Adhering to relevant regulations and obtaining certifications (e.g., Aquaculture Stewardship Council) demonstrates a commitment to ecological behaviours in aquaculture. Compliance ensures that operations meet specific environmental standards and promotes transparency and accountability.

By embracing these ecological behaviours, aquaculture can be transformed into a sustainable and environmentally responsible practice. Such practices help minimize ecological impacts, enhance biodiversity conservation, and contribute to the resilience and long-term success of aquaculture operations.

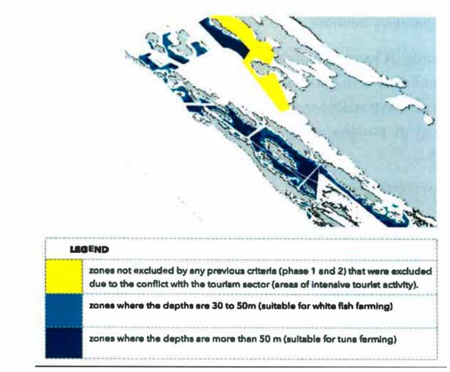


Figure 2. Aquaculture development zone in Zadar County

2.2.1 Compliance with protection measures in NATURA 2000 areas

Project extracted instructions: Compliance with protection measures in NATURA 2000 areas is of utmost importance in aquaculture to ensure the preservation of valuable ecosystems and species within these designated protected areas. NATURA 2000 is a network of protected areas established under the European Union's Birds and Habitats Directives, aimed at conserving biodiversity and maintaining the ecological integrity of these areas.

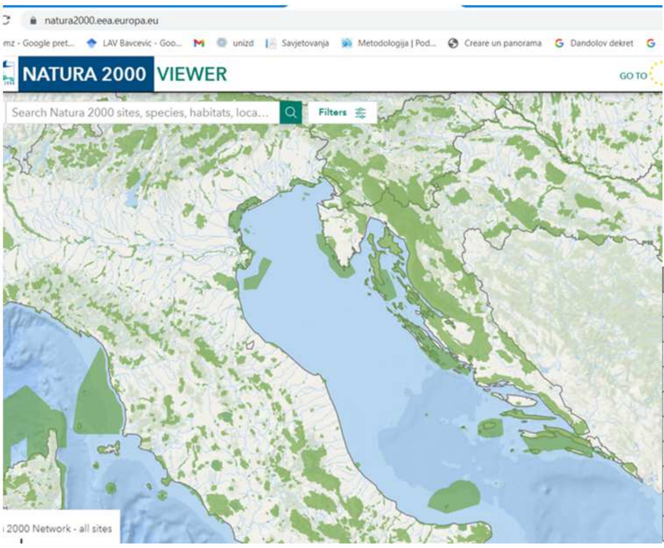
When conducting aquaculture activities in or near NATURA 2000 areas, it is essential to adhere to the following compliance measures:

1. Understanding the regulatory framework: Familiarize yourself with the specific regulations and guidelines applicable to aquaculture operations within NATURA 2000 areas. These may include restrictions on site selection, operational practices, and the protection of key species and habitats.
2. Environmental impact assessments: Conduct comprehensive environmental impact assessments (EIAs) prior to establishing or expanding aquaculture operations within or near NATURA 2000 areas. EIAs help identify potential ecological risks and inform decision-making processes to minimize negative impacts on protected species and habitats.
3. Species and habitat protection: Comply with regulations aimed at protecting species and habitats listed under the Birds and Habitats Directives. This may involve avoiding the introduction of non-native species, preventing damage to sensitive habitats, and implementing measures to minimize disturbance to protected species during aquaculture activities.
4. Monitoring and reporting: Establish monitoring programs to assess the ecological effects of aquaculture operations on NATURA 2000 areas. Regularly collect and report data on key indicators, such as water quality, biodiversity, and the presence of protected species. This

information helps evaluate the effectiveness of management measures and supports adaptive management approaches.

5. Collaboration with relevant stakeholders: Engage in active collaboration with relevant authorities, conservation organizations, and local communities to ensure compliance with protection measures. Seek their expertise, involve them in decision-making processes, and address any concerns or conflicts that may arise.
6. Sustainable practices: Implement sustainable aquaculture practices that minimize negative impacts on the environment. This includes responsible feed management, efficient waste management, water conservation, and the use of environmentally friendly technologies. By adopting sustainable practices, aquaculture operators can contribute to the conservation objectives of NATURA 2000 areas.
7. Training and awareness: Provide training and awareness programs for aquaculture staff to ensure they understand and comply with protection measures. Educate employees about the importance of NATURA 2000 areas, the species and habitats they protect, and the role aquaculture plays in their conservation.

By complying with protection measures in NATURA 2000 areas, aquaculture operators can contribute to the overall conservation and management goals of these important ecological sites. Responsible and sustainable aquaculture practices within these areas not only help preserve biodiversity but also maintain the ecological balance and contribute to the long-term sustainability of aquaculture operations.



Categories	Ia	Ib	II	III	IV	V	VI
High density fish cage culture	N	N	N	N	*	*	*
High density on-land close system fish culture	N	N	N	N	*	*	Y
Medium density on-land circulating system fish pond culture	N	N	N	N	*	Y	Y
High density shell fish culture (table, long-lines)	N	N	N	N	*	*	Y
Low density pond /lagoon fish culture	N	N	N	N	*	Y	Y
High density seaweed culture	N	N	N	N	*	*	Y
Low density shellfish culture	N	N	N	N	*	Y	Y
Medium density invertebrate (e.g. sea cucumber) culture	N	N	N	N	*	Y	Y
Integrated Multi-trophic culture	N	N	N	N	*	Y	Y
Restoration purpose aquaculture *	*	*	*	*	*	Y	Y

Figure3 and 4. Natura habitats in Adriatic and The IUCN categorisation and description of permitted activities.

Notes from deliverables:

With regard to interaction with forms of aquaculture, different considerations must be made:

- fish farms provide an artificial substrate that, together with the nutrient supply of feed, can increase the concentration of wild prey (acting as a fish concentrator) and facilitate their capture by dolphins, which in some areas of the Mediterranean tend to concentrate near the farms (Díaz López 2006, Piroddi et al. 2011, Bonizzoni et al. 2014, Bearzi et al. 2016).
- Mollusc farms can provide an enriched habitat in which dolphins can feed more efficiently (Díaz López and Methion 2017), but a negative effect of these facilities has been observed in some areas (Markowitz et al. 2004, Watson-Capps and Mann 2005, Pearson et al. 2012).

Many analyses that are usually carried out in the context of SCI protection areas are developed for the protection of specific habitats with which animal/vegetal species to be protected are associated. In the particular case of these two SCIs, however, it is not a specific environment that has led to the protection of the area (in fact, there is no valuable environment in the seabed) but the protection of the two target species bottlenose dolphin and turtle. If the activities that are developed within the area do not interfere with the two target species, there is no change to the activities currently in place and the establishment of the protection area is primarily aimed at protection against activities that might be established in the future (e.g. mining or aquaculture activities).

Fishing and aquaculture activities could encounter difficulties in a balanced coexistence with the protected areas, since fishing, both professional and recreational, tends to use spaces and resources that a SCI area aims to protect. Similarly, aquaculture, although it does not affect the stocks present, could produce boundary effects which could negatively interfere with the conservation objectives of the SCI.
The IUCN categorisation and description of permitted activities is therefore given below:

- Category **Ia** Integral Natural Reserve
- Category **Ib** Wild Area
- Category **II** National Park
- Category **III** Natural Monument
- Category **IV** Area of Habitat/Species conservation
- Category **V** Protected terrestrial/marine landscape
- Category **VI** A Protected area for sustainable resource management

The main purpose of the Marine Strategy Framework Directive (MSFD 2008/56/EC) transposed by the national Regulation is to achieve and maintain a good state of the marine environment by 2020 through the achievement of the general objectives of the protection of the marine environment, including:
1. Protection, preservation, enabling recovery and restoration of marine and coastal ecosystems and sustainable use of ecosystem services;
2. Preservation of protected areas in the sea and ecologically significant EU NATURA 2000 areas;

3. Reduction of pollution in the marine and coastal environment in order to preserve the health of people, the ecosystem and enable the use of the sea and coast;
4. Establishing and/or maintaining a balance between human activities and natural resources by applying an ecosystem approach.
The Habitats Directive and the Birds Directive together provide a framework for the establishment of the Natura 2000 network, and are applicable both on land and at sea, which may lead to limited use of technology that can be applied to aquaculture in Natura 2000 areas of aquaculture on marine habitats and species"- (ARGOS-S-03) pp 63

Birds Directive (2009/147/EC relates to the conservation of all species of naturally occurring birds in the wild state in the European territory of the Member States. It covers the protection, management and control of these species and lays down rules for their exploitation. This directive shall apply to birds, their eggs, nests and habitats.

The Annex to the Directive lists all the species that are protected by this Directive, including numerous species that are found in breeding grounds for aquatic organisms such as Gulls, Cormorants, Terns and Herons.

The Habitats Directive (92/43/EEC) is aimed to contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States. Measures taken pursuant to this Directive shall be designed to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora of Community interest. In addition, the measures to be taken should shall take account of economic, social and cultural requirements and regional and local characteristics.

The concept of nature conservation includes necessary protection measures aimed at maintaining and reconstructing a favourable state of preservation of natural habitat types and species that are of interest to the EU.

The conservative status of a natural habitat will be taken as 'favourable' when:

- its natural range and areas it covers within that range are stable or increasing,
- the specific structure and functions which are necessary for its long-term maintenance exist and are likely to continue to exist for the foreseeable future,
- the conservation status of its typical species is favourable

The conservation status will be taken as 'favourable' when:

- population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats,
- the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future,
- there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis

In many large areas of the Adriatic Sea, special NATURA 2000 areas have not yet been established, for example in the coastal area of Molise region According to ISPRA (Environmental Yearbook 2019), there are no protected areas (Natura 2000 Network, Ramsar, Protected Marine Areas). However, the Regional Site indicates that some areas have been proposed but probably not yet approved. Such approval is subject to a series of required characteristics for recognition, which will also be investigated based on the environmental data proposed by the Molise Region in the context of the Natura 2000 Network, as well as other justifying aspects for approval. For this reason, the declaration of new NATURA 2000 areas in the Adriatic Sea is expected. In order for farmers to carry out aquaculture in accordance with the law and in accordance with good production practice, which includes a responsible attitude towards the environment and nature, they should be constantly informed about possible changes in the legislative framework.

The information system has been improved with digital technology and the necessary information about Natura 2000 areas can be found on the official portals:

- Natura 2000 Viewer (https://natura2000.eea.europa.eu/)
- Cartografie Rete Natura 2000 e Aree Protette - "Progetto Natura" (http://www.pcn.minambiente.it/viewer/index.php?project=natura)
- Natura 2000 Biopportal (https://www.bioportal.hr/gis/)

The maps on the official portals are interactive, so you can get detailed information about protected Hab. Many areas in the Adriatic Sea are more or less isolated from open waters. Due to their peculiarities and ecological importance, they are included in the Natura 2000 areas (Laghi di Lesina e Varano; Valli di Comacchio; Sacca di Goro, Po di Goro, Valle Dindona, Foce del Po di Volano; Delta del Po; Laguna di Venezia; Valli Zignago; Valle Vecchia - Zumelle - Valli di Bibione; Laguna di Marano e Grado; Lim channel; Novigrad and Karin seas; Krka estuary; Maloston Bay). Aquaculture is traditionally carried out in these areas and, due to increased natural productivity, shellfish are most often grown there. Due to the vulnerability of the habitat, protection through the Natura 2000 network represents an opportunity, which on the one hand enables the recognition and value addition of aquaculture products. On the other hand, protection provides the possibility of more effective management of activities that have an impact on traditional aquaculture. The establishment of cross-border cooperation through a network that connects farmers, science and regional authorities can significantly contribute to adding value to these habitats and the aquaculture carried out in them.

Fish farming in cages (white fish and tuna) can lead to increased sedimentation of organic matter, the source of which is unconsummated food and feces as well as pseudo faces of cultivated organisms. In addition to the emission of organic matter from the cage, it is also possible the emission of drugs if they are used in a particular phase of cultivation. The presence of cage farming provides a source of food as well as an area of protection from predators and a fishing area for certain species of wild fish population in the wider area of cultivation.

From the perspective of the positioning of the cage structures, it can be considered that there is no impact on the habitat types „1110 Sandbanks which are slightly covered by sea water all the time“, then „1140 Mudflats and sand flats not covered by seawater at low tide“ as well as „*1150 Coastal lagoons“. It is only possible to influence the biocenosis of coastal detritus bottoms (NKS code G.4.2.2.) which is a part of habitat type „1110 Sandbanks which are slightly covered by sea water all the time“ and is located at depths of 30 m and deeper. Flooded or partially flooded sea caves (Natura 2000 code 8830) are sites of extremely small area, and if fish farms are in the vicinity or above this habitat, change in its quality is possible. Bird disturbance is possible during the maintenance and operation of fish farms, and thus reducing good nesting areas.

From the aspects of cultivation of rainbow trout, there are no sufficient data of its cultivation, as there are no data related to the assessment of the impact of the cultivation on Natura 2000. When locating such fish farms, it is necessary to pay attention to the habitat types „1170 Reefs“(NKS code G.4.3.4. Biocenosis of pit type vrulja) and „*1150 Coastal lagoons“(NKS code G.3.1.1.11. Submerged submarine vrulja) which are more numerous along the coast of the Velebit channel to optimally position the fish farms regarding the position of habitats in question.

Farmers who in any way come into contact with protected species and habitats in the context of Natura 2000 protection should adapt their management to avoid or mitigate the effects of their activities on habitats and species. This is most often foreseen through the process of assessment of aquaculture on the environment and nature, which also includes the assessment of aquaculture on habitats and species determined by the Natura 2000 network.

The situation related to birds that temporarily reside in breeding areas is particularly sensitive. Birds that temporarily inhabit breeding grounds (especially fish) are covered by the "Birds Directive". Considering that the birds around the breeding grounds cause harm to the breeders, whether it is direct predation, damage to the breeding installations or the transmission of diseases. In order to mitigate the unwanted effects caused by birds that are also protected, it is necessary to reduce the "benefit" for which birds visit breeding grounds. This implies investments that should be evaluated in accordance with the expected effects of the applied method to deter birds from breeding grounds

Systems for interfering with the predatory behaviour of birds use wires, ropes, curtains, fences and other systems that prevent access to birds. The wires should be of high strength, galvanized or stainless steel, arranged as a mesh or in one direction as parallel lines. The distance between the wires depends on the type of bird that is to be prevented from approaching the water surface. The strings are best used against predators that attack from the air such as sea swallows, gulls, cormorants and the ospreys. Pond birds can reach the pond by landing on the shore and walking to the water. They should be prevented by a fence surrounding the pond with electric fences or wires with a charge which must not be lethal to humans or birds.

2.2.2 Contribution to Data collection

Project extracted instructions: Aquaculture farmers and stakeholders can make valuable contributions to data collection, which plays a crucial role in improving the understanding and management of aquaculture operations. Here are some ways in which they can contribute:

1. Monitoring environmental parameters: Aquaculture farmers can regularly collect data on key environmental parameters such as water temperature, salinity, dissolved oxygen levels, and nutrient concentrations. These measurements help track changes in the aquatic environment and identify any potential impacts of aquaculture activities.
2. Species performance and health data: Farmers can contribute by recording data on the performance and health of the cultured species. This includes growth rates, feed conversion ratios, disease incidence, and mortality rates. Such information helps identify trends, assess the effectiveness of management practices, and detect any emerging health issues.
3. Water quality monitoring: Farmers can assist in monitoring water quality parameters within and around aquaculture sites. This includes measuring parameters such as pH, turbidity, ammonia levels, and nutrient concentrations. Monitoring water quality helps identify potential sources of pollution, evaluate the effectiveness of waste management practices, and ensure compliance with regulatory standards.
4. Disease monitoring and reporting: Timely reporting of disease outbreaks and health-related incidents in aquaculture facilities is crucial. Farmers can play an active role in monitoring and reporting disease occurrences to relevant authorities and research institutions. This data contributes to early detection, prevention, and control of diseases, benefiting both the farming operations and the overall health of the aquaculture sector.
5. Data sharing and collaboration: Farmers and stakeholders can contribute by sharing their data and experiences with research institutions, governmental agencies, and industry associations. Collaborative data sharing facilitates a more comprehensive understanding of aquaculture practices, helps identify emerging trends and challenges, and supports evidence-based decision-making.
6. Genetic and breeding data: In cases where selective breeding programs are implemented in aquaculture, farmers can contribute by providing data on genetic traits, breeding performance, and genetic diversity. This data can aid in improving breeding programs, enhancing the quality and productivity of cultured species, and ensuring the long-term sustainability of aquaculture operations.

7. Participating in research initiatives: Farmers and stakeholders can actively participate in research projects and surveys related to aquaculture. By providing access to their facilities and sharing data, they contribute to scientific knowledge, technological advancements, and the development of innovative solutions that address industry challenges.

8. Supporting data collection infrastructure: Farmers and stakeholders can support the establishment and maintenance of data collection infrastructure. This includes installing monitoring equipment, such as water quality sensors or data loggers, within aquaculture facilities and assisting in their regular maintenance and calibration.

By actively participating in data collection efforts, aquaculture farmers and stakeholders contribute to a broader and more accurate understanding of aquaculture practices and their environmental impacts. The availability of robust and comprehensive data supports evidence-based decision-making, facilitates the development of sustainable practices, and enhances the overall management and governance of the aquaculture sector.

Figure5. An image taken by interviewer Pansini during the survey activity at the port of Manfredonia 03.03.2022

Notes from deliverables:
Comprehensive and responsible aquaculture management aims at socio-economic efficiency, environmental sustainability and political stability. For practical reasons, aquaculture management can be divided into strategic management and operational management where:

<u>Strategic management (governance) includes</u>:

i. Management of aquaculture policies

ii. Aquaculture management through the legislative framework

iii. Regional strategic management

Operational management refers to:

i. Investment management

ii. Management of technological processes

iii. Standards management

iv. Product management

Effective management implies the collection and analysis of relevant data. Therefore, a data collection system was established that does not differ significantly in Croatia and Italy. For example, in Croatia, the data collection system can be divided into:

- (Fisheries Information System) The Marine Aquaculture Log-book – production data in accordance to the specific technologies (Licensee, Ordinal number, Location of the farm, Reporting period, Type of environment, Breeding system)
- Annual collection of socio-economic data – (managing authority)
- Data collection to manage farmed organism health and food safety – obligatory to keep records. (All movements of aquaculture animals and their products to or from the farm, deaths on the farm by type of production, results of health status monitoring, deaths during transport, farms, mollusc production areas and processing facilities into which the means of transport entered, any water change during transport.)
- Environmental monitoring program- prescribed following the environmental impact assessment procedure
- Monitoring the quality of the sea and shellfish in production areas and areas for the re-laying of live shellfish

In principle the collected data are sufficient for the establishment of Aquaculture Zones, but agglomeration of data and reporting of results based on collected data are only partially aligned with the goal of sustainable development. Actually a large number of authorized legal entities collect and store data related to aquaculture in an uncoordinated manner. The main challenge for the integral management of aquaculture based on collected data is the formation of a unique database at the local level.

In addition to official protocols for data collection, data is collected through various scientific research, projects, through the activities of non-governmental organizations and observations of technologists at the farm and citizens. These data are not agglomerated and are not linked to official data, so there are hasty estimates that can harm the sustainable development of aquaculture and in the final consequences always come at the expense of the producers themselves.

The operational/adaptive management of aquaculture in the terms of public control of the effects of aquaculture, on long-term sustainability can only be established on the basis of the rapid availability of data that are necessary for making management decisions. The establishment of adaptive aquaculture management is in the public interest as well as in the interests of producers and management bodies.

In this sense, in addition to technological data (intake of organisms and food, fishing of organisms and removal of waste...) and general environmental data (temperature, salinity, oxygen, benthic impact indicators, lightning storms...) it is necessary to expand organized and purposeful data collection to:

- Anthropogenic impact on the environment and aquaculture (tourism, noise, selective protection, waste management…)
- Biotic factors (gathering of predators, fouling, animal welfare, fish escape from aquaculture facilities, and release of microplastics.)
- Data on local aquaculture knowledge
- Aquaculture business data that indicate the state of the sector

The update of information on the status of shellfish enterprises operating in the waters facing the coast of the Marche region was carried out in February-March 2023, with reference to the year 2022. The preformed analysis were based on highly articulated questionnaire. The interest of producers was great, which indicates their interest in cooperation in the development of sustainable aquaculture. Compared to the usual data collection protocols, this data collection is significantly expanded and provides insight into a number of details that may be important for the sustainable development of mussel farming in the region and the Adriatic Sea in general. Data collection has been extended to: current status of shellfish farms, structure of enterprises, production and marketing, breeding plant, vessels, processing equipment, schooling, acceptability of aquaculture, aggregation, training, investments, product distribution, innovation, recent innovation adoption, future needs in terms of innovation, effectiveness of existing measures in adopting innovation and European Union integrated maritime policy and funding tools for its development. Application of the same data collection form on shellfish farming in all Adriatic regions/counties and their comprehensive analysis can contribute to the development strategy of this branch of aquaculture in the Adriatic Sea.

Report on the collection of alternative data on mussel cultivation in the Krka estuary in Šibenik-Knin County indicates differences between the production results based on the official data collection system and those obtained through the conducted survey. A comparison of the national sales value data and the data collected through this Report at the local level at first glance shows a significant disparity, which may be the result of various factors: different data collection methodologies, credibility, interest of the respondent, understanding the question, the fact that the farming business is taken care of by authorized, third persons (e.g. accountants).

The most important result of involving farmers in data collection is gaining public trust and a better understanding of production opportunities. It is essential that by collecting data at the local level, the risks factor are determined. In cooperation with local authorities and farmers as actors, science should identify and characterizes these risks through an evidence-based approach. This indicates the necessary additional efforts in obtaining relevant official data on shellfish production in Croatia.

An overview of the collected data on the impact of fish aquaculture on the environment in Zadar County confirms the thesis that good planning in setting up fish farms is the basis for sustainable aquaculture. Among other things, the monitoring program compares the concentrations of organic carbon and organic phosphorus under the cages with fish and at reference locations (without the impact of aquaculture). Despite the significant increase in breeding volumes, as well as the displacement of cages, the impact is not great or even not measurable.

In today's time of available technologies for measuring the parameters of the growing environment, farmers should regularly (daily) measure and store data on the growing environment:

The temperature of the sea at three depths - the surface, the depth where the growing organisms are found, and the bottom. Dissolving oxygen outside and in the cages, before feeding and after feeding and in zones of variable salinity – Salinity at three depths...

It would be very good to establish records of data collection in the local product market, to re-educate the producers that they should be educated in the interpretation of the results of the collected data in order to improve their production based on this findings.

2.2.3 Biosecurity: animal transport, non-native species, diseases,

Project extracted instructions: Biosecurity is a critical aspect of aquaculture that aims to prevent and manage risks associated with animal transport, non-native species, and diseases. Implementing effective biosecurity measures helps protect the health and welfare of farmed aquatic animals, prevents the spread of diseases, and minimizes the introduction and establishment of non-native species. Here are key considerations for biosecurity in aquaculture:

1. Animal transport protocols: Establish strict protocols for the transport of live aquatic animals, including proper hygiene practices, quarantine procedures, and health certification. These protocols help prevent the introduction and spread of pathogens during transportation and ensure that only healthy animals are moved between facilities.

2. Quarantine and health screening: Implement robust quarantine procedures for new stock entering aquaculture facilities. Quarantine periods allow for the observation and testing of animals to identify any signs of diseases or infections before introducing them to existing populations. Health screening, including laboratory testing, is an essential component of quarantine protocols.

3. Non-native species management: Take measures to prevent the introduction and establishment of non-native species in aquaculture systems. This includes avoiding the use of non-native species in aquaculture, maintaining secure facility design to prevent escapes, and regularly monitoring and removing any non-native species that may inadvertently enter the system.

4. Disease surveillance and monitoring: Establish regular disease surveillance programs to monitor the health status of aquatic animals. This involves conducting routine inspections, health assessments, and laboratory testing to detect the presence of pathogens and emerging diseases. Prompt reporting of any signs of disease allows for timely intervention and control measures.

5. Hygiene and disinfection practices: Promote and enforce strict hygiene and disinfection practices within aquaculture facilities. This includes proper cleaning and disinfection of equipment, infrastructure, and vehicles used in aquaculture operations to prevent the transmission of pathogens. Implementing and maintaining bio secure facilities and equipment minimizes the risk of disease introduction and transmission.
6. Biosecurity training and education: Provide biosecurity training and education to aquaculture farmers, workers, and stakeholders. This includes raising awareness about the importance of biosecurity, providing guidance on best practices, and ensuring that all individuals involved in aquaculture operations understand their role in preventing the introduction and spread of diseases and non-native species.
7. Collaboration and information sharing: Foster collaboration among aquaculture farmers, industry associations, regulatory agencies, and research institutions to share information and best practices related to biosecurity. This includes disseminating information about disease outbreaks, emerging threats, and effective control measures to facilitate proactive response and prevention.
8. Regulatory compliance: Adhere to applicable biosecurity regulations and guidelines set by governmental agencies or industry standards. Compliance ensures that aquaculture operations meet specific biosecurity requirements, such as disease testing, health certification, and reporting obligations.

By implementing robust biosecurity measures, aquaculture operators can minimize the risks associated with animal transport, non-native species, and diseases. This proactive approach helps safeguard the health and productivity of aquaculture systems, supports sustainable industry growth, and protects natural ecosystems from the negative impacts of disease outbreaks and the introduction of invasive species.

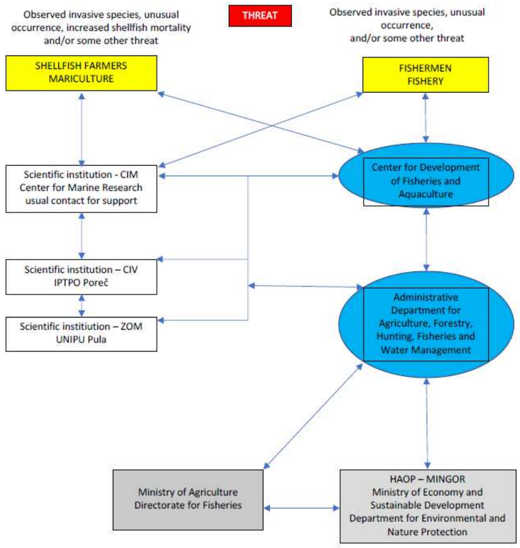


Figure 6 and 7 in 2015, a new invasive species of the ascidian tunicate Clavelina oblonga was observed in the Bay of Trieste and in the Savudrijska Vala (D.Mioković, 2016)

Figure 8 Schematic representation of the Protocol - how to proceed in the case that the area of interest of the Region of Istria is affected by threats in aquaculture.

Notes from deliverables:

In accordance with the Law on Veterinary Medicine, health care measures for bred organisms are implemented on farms, which include good breeding practice, ensuring conditions for animal welfare and veterinary supervision and control. There are very rigorous measures in the system of supervision and control of transport and stock of organisms from different production areas, but no control over the health status of organisms in the environment has been established, especially no control of possible parasites. Therefore, it is necessary to establish measures to monitor the presence of microorganisms and parasites in the species of organisms that aggregate in the area of the farm.

When we talk about aquaculture in open systems, we should keep in mind the risks posed by the establishment of other activities in the aquatorium that are shared with the farming of organisms. It is particularly important to ensure that the risk of disease and poisoning of cultivated organisms and/ or humans consuming the cultivated organisms is reduced. In this sense, integrated management and spatial planning of space use should identify possible risks and interactions that will result in risks arising from the use of the same space. Risk reduction or its complete elimination can be established

Control of diseases in aquaculture and measures to combat them are regulated by Regulation (EU) 2016/429 of the European Parliament and of the Council of 9 March 2016 on transmissible animal diseases and amending and repealing certain acts in the area of animal health ('Animal Health Law'). The regulation specifically emphasizes that diseases occurring in wild animal populations may have a detrimental effect on the agriculture and aquaculture sectors, on public health, on the environment and on biodiversity. That is why registration and approval of aquaculture establishments is necessary in order to allow the competent authority to perform adequate surveillance and to prevent, control and eradicate transmissible animal diseases. Disease prevention and prophylaxis are additional objectives (use of drugs limited to particular cases- Reg. (EU) no. 2018/848) of aquaculture. Operators should keep records on the health status of cultivated organisms shall only move aquaculture animals if they are accompanied by an animal health certificate issued by the competent authority of the Member State. Disease prevention and prophylaxis in aquaculture is a professional and specialist issue and therefore it is recommended to leave the health supervision to the competent services. In order to reach the optimal level of control and supervision, the producer should adopt the skill of recognizing when the cultivated organisms are in good condition, that is, they should recognize the appearance of individuals that are not in good condition and inform the competent services about it. Through practice and professional assistance, the breeder increases the necessary knowledge, which facilitates cooperation with specialists, which ultimately contributes to the goals of sustainable aquaculture.

"Non-indigenous species introduced by human activities are at such levels that they do not harm ecosystems" is one of the descriptors of the good state of the marine environment according to the MFSD, and is defined by the following criteria:

D2C1 – Primary:

The number of new non-indigenous species introduced into the wild as a result of human activity, per assessment period (six years), measured from the reference year from the initial assessment based on Article 8 paragraph 1 of Directive 2008/56/EC, has been reduced where possible and reduced to zero.

D2C2 – Secondary:

The number and distribution of established non-indigenous species, especially invasive species, which greatly increase the harmful effects on certain groups of species or broad types of habitats.

D2C3 - Secondary:

The proportion of a species group or area of a broad habitat type that is adversely affected by non-native species, particularly invasive non-native species.

Regulation (EU) No 1143/2014 of the European Parliament and of the Council on the prevention and management of the introduction and spread of invasive alien species establishes rules for preventing, minimizing and mitigating the harmful effects of intentional and unintentional introduction and the spread of invasive alien species on biodiversity in the Union. It also applies to species covered by Council Regulation (EC) no. 708/2007 on the use of foreign and locally absent species in aquaculture. As part of the integral system for monitoring and assessing the state of the Mediterranean Sea and the coast (IMAP IG.22/7), the Republic of Croatia implements a monitoring program for the continuous assessment of the environmental state of marine waters under its sovereignty as part of the Marine Strategy Framework Directive (MFSD) and the Reference Canter for Sea of the Environmental Protection Agency (https://acta.izor.hr/wp/novost/referentni-centar-za-more/). Collection of nonindigenous species in Italy is centralized through the Central Information System for Monitoring Data and is under the responsibility of the Ministero della Transizione Ecologica (http://www.db-strategiamarina.isprambiente.it/app/#/). In many isolated coastal areas in the Adriatic Sea, such as the Italian lagoons or, for example, the Krka estuary, it is important to preserve habitat conditions that support the cultivation of autochthonous shellfish species.

The appearance of invasive species that colonize farmed shellfish (fouling), reduces water exchange and thus limits the flow of food and oxygen can threaten the development of aquaculture. In 2015, a new invasive species of the ascidian tunicate Clavelina oblonga was observed in the Bay of Trieste and in the Savudirjska Vala (Mioković, 2016)

Few years later, it was obvious that the intensive C. oblonga fouling is affecting only mussel production areas and spreading at shellfish farms along western and southern coast of Istria. With some exceptions, shellfish farmers avoid addressing this issue for fear of negative information and potential negative impact on the sale and distribution of their products. Apart from individual cooperation between shellfish farmers and regional scientific institutions and mariculture operators, there is generally no official information and no systematic data collection Instead of a direct link between farmers and scientific institutions, the newly established Center for the Development of Fisheries and Aquaculture of the Istrian County is envisioned as an important intermediary action on the occurrence of invasive species and other threats in aquaculture in the Istrian region.

Cultured bivalve species in the Adriatic Sea have been known to be sporadically transferred between locations, mainly to kick-start or renew production of a certain species and/or when local production was not able to meet market demand. This continues to be a dangerous practice as it has proven to be a vector for spreading bivalve pathogens and biofouling organisms, including non-native species of which some have proven to be invasive. These kind of practices can have devastating consequences for the ecosystems and the industries that depend on them, such as bivalve farming. Bivalve translocation often involves the movement of people, equipment, live shellfish and sometimes substrate materials between sites and as such provides numerous opportunities for the unintended transfer of accompanying species as well. Whilst such movements are by no means the only vectors for non-native species or diseases, efforts to transfer bivalve populations must adopt rigorous biosecurity protocols in order to reduce the risk that an action with an intended positive commercial and/or ecological benefit results in a negative impact.

On the other hand, in the face of direct and indirect anthropogenic effects that are steadily increasing in scope and intensity and pose a threat both to cultured and natural populations of bivalves, translocation of certain species can have numerous benefits. It is an essential tool for restoring devastated production sites and/or natural populations of certain species and habitats. However, given the dangers associated with these activities, it is imperative that translocation procedures are properly managed and follow strict biosecurity guidelines. The biosecurity guidelines produced through the Argos project are heavily based on the Native oyster restoration alliance (NORA) publication "European Guidelines on Biosecurity in Native Oyster Restoration".

Diseases and their biosecurity management

The media that bivalves are cultured in, in this case seawater, is often transferred with the animals as well, and even if this only refers to the seawater captured within the mantle cavity once the shell is closed. This seawater can contain pathogens and/or non-native species that could be transferred to the sites to which the bivalves are being introduced. Thus, non-native species and pathogens can be moved between sites whenever people and equipment are moved as well as the bivalves themselves and any accompanying substrates that they are attached to. As such, it is important that all people participating in bivalve translocation, including farmers, scientists, technical personnel and others, comply with both standard 'Check, Clean, Disinfect, Dry' protocols.

When working in shellfish growing waters, consideration should also be given to the possible transmission between bivalve species. Some pathogens, such as Marteilia refringens (including the recently proposed species M. parafringens sp. nov.) can be transmitted between European flat oysters and blue mussels (Mytilus edulis), and there are indications that OsHV-1 µvar can be transmitted between Pacific oysters (Magalana gigas) and European flat oysters.

There are several diseases which are of particular note in the context of European flat oysters. These include the listed diseases (and the agents) of bivalves to the World Organisation for Animal Health (OIE) and/or to the European Commission (EC) (The Council Directive 2006/88/EC):

Bonamiosis – Bonamia ostreae (OIE/EC – present in Europe),

• Bonamiosis – Bonamia exitiosa (OIE/EC – present in Europe),

• Marteiliasis – Marteilia refringens (OIE/EC – present in Europe),

• Herpes-like infection – Herpes virus OsHV-1-µvar (present in Europe) (notifiable in few zones in Ireland and UK only).

In the context of the Mediterranean mussel, the most common disease is:

• Marteiliasis – Marteilia refringens (OIE/EC – present in Europe).

In the case of the suspicion of the presence of a disease or non-native species, the practitioner must follow these steps:

1. Report immediately to the competent authority

2. Adopt a precautionary approach – do not carry on operations that might contribute to further dispersal

3. Carry out risk assessmens

4. Seek and follow advice from the relevant authorities. This may include not moving any material

It is important for stakeholders to be aware not only of the listed diseases and the requirements to follow the rules on translocations that apply locally and internationally, but also to be mindful that there are a range of other parasites, pathogens and epibionts to which bivalves are susceptible, or may be a vector of. The following is a non-exhaustive list of known pathogens and parasites affecting commonly farmed bivalve species:

- Boccardia (genus of)
- Cliona celata
- Cliona viridis
- Gyrodinium aureolum
- Haplosporidium armoricanum
- Herrmannella duggani
- Hexamita inflata
- Mytilicola intestinalis
- Nocardia crassostreae
- Ostracoblabe implexa
- Papovaviridae (family of)
- Perkinsus mediterraneus
- Polydora (genus of)
- Pseudoklossia (genus of)
- Vibrio spp. (e.g. V. alginolyticus, V. anguillarum, V. coralliilyticus, V. neptunius, V. ostreicida, V. tubiashi)

Haemic neoplasia may also affect oysters. In this case, no disease agent is observed, but the neoplastic cells may be infectious and cause significant mortalities.

Screening for diseases is usually carried out by national reference laboratories or other national institutions, depending upon the jurisdiction. OIE reference laboratories can be found on the World Organisation for Animal Health website.

Biosecurity guidelines for translocation of bivalves

Before translocation

It is critical that when considering translocating bivalves the following questions are addressed:
- Is translocation necessary? Consider why translocation is the best option. If possible, do not translocate bivalves.

- Is it possible to source the bivalves more locally? If not, try to obtain hatchery-reared spat.

If translocating, use the following general hierarchy in selecting donor material to minimize risk:

- Do not consider donor sites with high-risk invasive species or diseases that are not present at the receiving site. The ecological and socioeconomic risk of introducing either a disease or high-risk **invasive non-native species** (INNS) into an area is unacceptable, given the possible impacts such an action could result in.
- Minimize the physical distance between the donor and receiving site. To reduce the risk of unknown diseases or INNS being introduced to an area, it is best to reduce the physical distance between the donor and receiving site. This will also allow for maintaining local or regional genetic structure in bivalve populations.
- Avoid movements across latitudinal gradients. Bivalves can be infected by a large number of pathogens. Within their co-evolved range and the local temperature regime, pathogens may have limited impact on their host. There is, however, a risk that pathogens may become more virulent when moved to a different environment. As it is not possible to know which diseases may have an impact in the novel environment, and it is in any case challenging to screen for all known diseases, movement of bivalves to a largely different environment is not recommended.
- Never consider donor sites outside of the natural range of the species. Reintroducing species from outside their native range should be avoided at all costs in order to avoid the potential introduction of non-native species and diseases associated with the translocated bivalves. As an illustration of the risk, the European presence of more than sixty species, native to the Pacific Northwest USA, can be attributed to movements of the Pacific oyster since the 1960's alone.

<u>Translocating live bivalves</u>

If translocation is indeed deemed necessary and potentially appropriate donor material has been identified, the next step is to undertake thorough biosecurity measures, under advice from the relevant authorities, to reduce the risk of accidental transfer of hitchhiking species. Initial risk assessments should be undertaken in order to understand the risk and map out the appropriate action. Assessment of risk should include consideration of ongoing activities in both the donor and receiving site.

Undertaking a risk assessment: The first steps in any risk assessment is risk identification or mapping and analysis. The identified risks should then be analysed regarding likelihood and consequence. Moreover, to rank risks, they must first be comparable. In the current document, the characteristics of each production site along the Adriatic coast will be covered in detail in order to have a better understanding of the risks and benefits involved with translocation between individual sites. Even though many factors can be taken into account, the main ones should be presence of bivalve diseases (primarily bonamiosis and marteiliosis) and potential INNS.

Survey the donor site: Once a potential donor site has been identified, the current disease status of the site should be confirmed through further testing. Although a profile of individual production areas in Croatia will be provided, disease testing and especially biodiversity surveys take place at insufficient frequency to ensure that the current disease/INNS status of a site is accurately reflected in available information. If possible, dedicated field surveys and testing to ensure that the risk assessments are undertaken with the most current and relevant information should be performed for each individual translocation activity.

Screening for diseases: Pathogen screens should be done using recommended methods as specified in the OIE aquatic manual and as recommended by the EU legislation (Commission Implementing Decision (EU) 2015/1554 of 11 September 2015 laying down rules for the application of Directive 2006/88/EC as regards requirements for surveillance and diagnostic methods (notified under document C(2015) 6188).

This should at least include the diseases:

- Bonamiosis (B. ostreae and B. exitiosa)
- Marteiliosis (M. refringens)

Sample sizes should follow or exceed those recommended in the OIE aquatic manual and EU legislation. In the aforementioned decision there are specific recommendations about the surveillance and diagnostic of B. ostreae and M. refringens.

In addition to screening listed pathogens, general screening based on histology and bacteriology should be implemented. Consideration should also be given to diseases which are not listed. Attention should therefore be paid to the general health of the bivalves and the recent history of mortality at the donor site.

Surveying for INNS: When undertaking a biodiversity survey to inform the translocation risk assessment, particular care should be paid to potential and high-risk INNS. As INNS include a full range of species with differing life histories, no one sampling protocol will be best suited to all potential species of interest. Stakeholders should therefore consider using a range of methods that cover: species that are likely to have low densities and are dispersed and species that are likely to have higher densities and/or be less patchily distributed. These should at least cover biofouling organisms and planktonic organisms present at the donor site

A critical aspect of biosecurity relating to disease management is monitoring of increased and unexplained mortality. During monitoring, stakeholders may notice changes in bivalve growth, absence of larval settlement or increased or unexplained mortality. These may not have an immediate or obvious explanation and therefore require investigation.

Disease is not the only cause of unexpected mortality. Pulse events, such as heavy rainfall can cause fluctuations in temperature, salinity, and turbidity, and may contribute to adult and spat mortalities, loss of planktonic larvae and cessation of reproductive activity. Storms can also increase pollution, horizontal advection and abrasion, which can negatively impact bivalve condition and possibly influence the prevalence of diseases such as infection with Bonamia ostreae where it is present. Because of the risk posed by disease, translocators should always seek advice from the relevant authority regarding actions required in the event of an increased and unexpected mortality event.

Currently, there is no 100% accurate method of disease-screening for all translocated organisms in a consignment.

1. Any biosecurity for the translocation of live bivalves runs the risk that not all individual INNS will be eliminated because, inevitably, the system must allow for the survival of the oysters.

2. Third-party activities in the area may have introduced a disease or INNS at or around the time of the translocation event.

3. The disease or INNS may have already been present and undetected in other biological reservoirs.

2.2.4 Reduction of impact on biodiversity

Project extracted instructions: Reducing the impact on biodiversity in aquaculture is crucial for the long-term sustainability and ecological integrity of aquaculture operations. Here are some key strategies and practices to minimize the impact on biodiversity:

1. Site selection and design: Choose aquaculture sites that minimize impacts on sensitive habitats, endangered species, and biodiversity-rich areas. Conduct thorough environmental assessments to identify suitable locations and avoid areas of high ecological value.
2. Integrated multi-trophic aquaculture (IMTA): Implement IMTA systems that maximize resource utilization and minimize environmental impacts. By combining the cultivation of multiple species with different ecological roles, such as finfish, shellfish, and seaweed, IMTA systems can enhance nutrient recycling, reduce waste, and promote ecosystem balance.
3. Species selection: Choose species that are native to the local ecosystem or have a low risk of becoming invasive. Native species are generally better adapted to the local environment and are less likely to cause negative ecological interactions or disrupt natural food webs.
4. Escape prevention: Employ effective measures to prevent escapes of farmed species into natural habitats. This includes secure enclosure designs, regular maintenance and inspections of infrastructure, and proper protocols for handling and transporting animals.
5. Feed management: Optimize feed management practices to minimize ecological impacts. Use sustainable and responsible feed ingredients sourced from certified and traceable sources. Develop feeds with optimal nutrient profiles to reduce waste and nutrient discharge into the surrounding environment.
6. Waste management: Implement efficient waste management practices to minimize the release of organic and nutrient-rich effluents into surrounding ecosystems. Employ appropriate treatment technologies, such as sedimentation ponds, biofilters, or constructed wetlands, to remove or reduce waste before discharge.
7. Disease prevention and control: Implement stringent biosecurity measures to prevent the introduction and spread of diseases in aquaculture facilities. This includes regular health

monitoring, vaccination programs, proper quarantine procedures for new stock, and the use of disease-resistant species or strains.

8. Habitat protection and restoration: Take measures to protect and restore habitats affected by aquaculture activities. This may involve avoiding sensitive areas, implementing habitat restoration initiatives, and participating in conservation programs to enhance biodiversity and ecosystem health.
9. Monitoring and research: Establish comprehensive monitoring programs to assess the ecological impacts of aquaculture on biodiversity. Collect data on water quality, biodiversity indicators, and interactions with wild species to evaluate the effectiveness of mitigation measures and inform adaptive management strategies.
10. Stakeholder engagement and collaboration: Engage with local communities, indigenous groups, environmental organizations, and regulatory agencies to ensure transparency, dialogue, and collaboration in addressing biodiversity concerns. Incorporate traditional knowledge and scientific expertise to develop mutually beneficial solutions.

By implementing these practices, aquaculture operators can minimize the impact on biodiversity and promote the coexistence of aquaculture and natural ecosystems. The responsible management of aquaculture systems not only supports the conservation of biodiversity but also contributes to the long-term sustainability and social acceptance of the industry.

Figure 9: Gilthead breams near the cage, Source; Katavić, I. Šegvić-Bubić, T. Grubišić, L.Talijančić, I. Žužul, I., Predation of shellfish farms along the eastern Adriatic coast -recent

<u>Notes from deliverables:</u>
Cultivation, by definition, implies the keeping of desirable types of organisms, the quality and yield of which ensure economically sustainable food production. A direct consequence of this is the reduction of

biodiversity in the area of aquaculture. Biodiversity can be further reduced due to the emission of substances and energy into the environment.

Depending on energy sources used to produce biomass, mariculture could be divided into:

a) Autochthonous organic-based or “natural” trophic systems, such as kelp culture, and raft culture of mussels or oysters. Such culture practices derive their energy from solar radiation or nutrient sources already available in natural ecosystems, and tend to have fewer negative effects on biodiversity. In some cases, their impact on biodiversity may even be positive;

b) Allochthones organic-based or “artificial” trophic systems, such as net and pond culture of fish and shrimps, derive energy mainly from feeds supplied by growers and are more likely to disrupt the natural ecosystems

While mariculture has a variety of adverse effects on biodiversity, many of these effects can be mitigated or eliminated. In some cases, it is even possible to produce some positive biodiversity related effects. It is important to mention that mariculture based on allochthons feed (most finfish and crustaceans) could have larger and more significant adverse effects than mariculture based on autochthonous feed (filter feeders, macro algae, deposit feeders). The areas offering the most promise for avoiding adverse biodiversity effects of mariculture include reducing waste by better management, changes in nutrition (reformulation of feeds, reduction in use of animal protein, improving utilization) and technological improvements such as “enclosed systems”. In such enclosed tanks or ponds, it is possible to treat the effluent in order to avoid outflow of chemicals, antibiotics, diseases, as well as excess nutrients.

Various guidelines and application of best practices that contribute to biodiversity conservation provide a number of concrete suggestions for conservation measures that should be adopted for all aquaculture systems:

- in marine cage farming, controlling and limiting breeding density can reduce potential impacts from organic waste particles, while improving feed digestibility and food waste reduction systems can also mitigate these impacts;
- appropriate placement of rafts and ropes for shellfish aquaculture in areas with good water exchange, as well as appropriate sizing of aquaculture facilities using predictive models that allow assessment of the footprint of benthic loading, can reduce the most significant potential impacts of these systems;
- For systems with onshore marine tanks, a potential mitigation measure is to allow the source water to be micro filtered, treated, and purified by a treatment system prior to discharge to the lagoon-sea connection channel to allow microalgae to take up nutrient particles.

Better management practices for non-enclosed systems, include:

- Most importantly, proper site selection. The location of cages, pens, rafts, etc., should ensure proper water circulation to satisfy both the needs of mariculture and the flushing of nutrients and wastes;

- Optimal management, including proper feeding to decrease conversion ratios. Proper feeding requires proper training and a good knowledge of the behaviour of organ- isms to be fed. Often workers feeding finfish or crustaceans have poor knowledge of what they do, and the basis of feeding practices. This is true in particular in developing countries. It should be noted that cheap labour often works against biodiversity simply because the lack of proper management knowledge and training investment.

Other mitigation measurements include culturing different species together (polyculture) to make better use of available resources (such as fin fish and bivalve culturing) and coupling mariculture with other activities such as artisanal fisheries and sport fishing. However, all such forms of mitigation are effective only if chemicals and antibiotics are avoided in intensive production. The reduction of the use of antibiotics and chemicals is achieved through good practice based on the optimization of breeding conditions and disease prevention, such as appropriate stocking and vaccination of farmed fish.

In practice, however, one of the greatest threats of cage fish farming to the environment is its impact on benthic communities. Control of the impact of aquaculture on Posidonia meadows or other benthic settlements is achieved by proper placement of breeding grounds and adaptive management of breeding processes. Adaptive farming management depends on conducting regular monitoring of benthic habitats in the vicinity of breeding sites, on establishing clear indicators and reference values, and on measures to mitigate the effects of farming on biodiversity. Operators should sometimes come to terms with the fact that it is necessary to take measures that are not in line with the current maximization of profits. The state of the environment can be improved by introducing innovative technologies (continuous monitoring - digital technologies) and management of cultivation based on the ecosystem. If the measures taken cannot achieve the desired results, the assessment of the reduction of breeding capacity remains the last option. Now actually it is not possible to impose a reduction of farm capacity, because the contract allows the producer, unconditionally, to produce a certain amount of organisms. On the other hand, operators can and should adapt the breeding design to knowledge and new technological achievements. For this purpose, The European Maritime, Fisheries and Aquaculture Fund (EMFAF) for 2021-2027. (REGULATION (EU) 2021/1139) has the priority of fostering sustainable aquaculture activities through operations supporting innovative products, processes or equipment in fisheries, aquaculture and processing.

Escape of fish from cages occurs and farmed organisms come into contact with wild populations. There are adverse comments about the possible impacts of breeding on the genetic structure of wild populations and on the reduction of genetic biodiversity within the European Union, escape is perceived as a threat to natural biodiversity in Europe's marine waters. Therefore it is necessary to apply a precautionary approach and prevent or maximally reduce the probability of escape of farmed fish into the environment. Escapes are most often caused by technical and operational failures such as cage breaks in storms, holes in nets caused by wear and tear of materials, and operational errors during farm work. Holes in nets can also be caused by predators, or farmed fish can bite through the cage mesh. The release of cage farms to the open sea mitigates many of the environmental impacts of farming, but increases the likelihood of farmed fish escaping.

<u>Escape prevention measures</u>:

- Standardization of structural features of morning lines and grid system
- Cage netting material adapted to the environmental conditions at the farm location and to the farmed species (according to risk assessment)
- Control and maintenance plan for equipment, cages and nets (according to risk assessment)
- Timely maintenance and repairs of equipment

Mitigating the consequences of escape:

- Breeding of fish that cannot produce offspring (sterilisation, triploids…)
- A breeding program that promotes desirable traits, but also maintains a relatively large genetic biodiversity of the parent stock.
- Monitoring the occurrence of escaped fish
- Catching escaped fish

2.2.5 Contribution to native stock recovery

Project extracted instructions: Aquaculture can contribute to the recovery of native stocks in several ways, promoting the conservation and restoration of wild populations. Here are some contributions that aquaculture can make towards native stock recovery:

1. Stock enhancement and supplementation: Aquaculture can produce juvenile individuals of native species for stock enhancement programs. These individuals are reared in controlled environments and released into the wild to supplement existing populations or aid in the recovery of depleted stocks. By increasing the number of individuals in the wild, aquaculture can enhance the reproductive potential and genetic diversity of native stocks.

2. Broodstock management and selective breeding: Aquaculture facilities can maintain broodstock populations of native species and implement selective breeding programs. By selecting individuals with desirable traits, such as disease resistance, growth performance, and genetic diversity, aquaculture can produce offspring with improved fitness and adaptability for reintroduction or restocking efforts.

3. Conservation breeding programs: Aquaculture can play a vital role in the conservation of endangered or threatened native species through captive breeding programs. By maintaining and breeding individuals in controlled environments, aquaculture facilities can ensure the survival and genetic diversity of these species, providing a potential source for future reintroductions and recovery efforts.

4. Research and monitoring: Aquaculture facilities can contribute to scientific research and monitoring efforts focused on native species. By participating in research projects, aquaculture operators can provide data and insights into the biology, behaviour, and ecology of native stocks. This information helps inform conservation strategies, population assessments, and management decisions.

5. Collaboration with conservation organizations: Aquaculture operators can collaborate with conservation organizations, government agencies, and research institutions to develop and implement native stock recovery programs. Such partnerships can facilitate the exchange of knowledge, resources, and expertise, resulting in more effective conservation measures and increased success rates of native stock recovery initiatives.
6. Habitat restoration and protection: Aquaculture operations can contribute to habitat restoration and protection efforts that benefit native species. This includes initiatives such as the creation of artificial reefs, the establishment of marine protected areas, and the implementation of sustainable aquaculture practices that minimize habitat degradation and water pollution.
7. Public awareness and education: Aquaculture facilities can raise public awareness about the importance of native species and the need for their recovery. By educating the public, visitors, and local communities about the value of native stocks, aquaculture operators can foster support for conservation initiatives and promote responsible stewardship of aquatic ecosystems.

It is important to note that the contribution of aquaculture to native stock recovery should be done in collaboration with scientific experts and regulatory bodies. Careful consideration should be given to genetic integrity, disease risks, and the potential ecological impacts of released individuals. The goal is to ensure that aquaculture-based interventions are well-designed, evidence-based, and align with broader conservation objectives to effectively support the recovery of native stocks.

Figure 10. Aerial view of Mali Ston bay interior (source: https://www.vecernji.hr/vijesti/akcijaciscenja-malostonskog-zaljeva-okupila-je-50-ronilaca-160)- Argos source

<u>Notes from deliverables:</u>

The Biodiversity Strategy for 2030 represents a long-term plan to protect nature and reverse the degradation of ecosystems. The strategy aims to put Europe's biodiversity on the path **to recovery** by 2030 by undertaking specific actions and commitments. This strategy also aims to strengthen the resilience of habitats and societies against future threats such as: climate change; forest fires; food insecurity; epidemics.

Fishing activities have been identified as one of the major anthropogenic pressure on biodiversity and on marine ecosystem structure. Certain common fishing practices in Europe not only directly impact biomass through harvesting, but also have negative consequences for productivity, population dynamics of non-target species, and key habitats. These habitats may require many years to recover and regain a healthy status once altered.

Shellfish farming is most often initiated in areas where the habitats of natural populations of the same species or at least trophically identical species are known. It should not be forgotten that shellfish farming in the Adriatic Sea is still based on catching in the wild. That is why when exploiting shellfish from nature, there is a thin line that separates farming from fishing. In this sense, it is important to preserve the reproductive potential of the species that is exploited through farming and gathering. It is therefore crucial to identify the minimum required natural stocks of exploited species that will ensure sufficient reproduction required for its sustainable exploitation

To preserve the productivity of shellfish production areas, it is necessary to establish zones of prohibition of shellfish collection from natural shellfish beds in the wider area of the farm determining the prohibition zones for the exploitation of natural populations of bivalves should be applied as a priority in Natura 2000 areas.

Mariculture could also be considered as having positive effects when, under certain circumstances, it provides seed for sea-ranching and recovery of wild stocks, endangered species, or even improves productivity and biodiversity.

The development of mariculture has enabled the production of species in the sea that are in "bad condition". Acquired knowledge and skills in the reproduction of marine animals and plants enable possibility for the recovery of wild stocks, endangered species, or even improves productivity and biodiversity.

The harvesting of bivalve molluscs in natural habitats has an impact on the state of natural populations, and then also on reproduction, which is a source of spats for aquaculture. Recovery of natural populations is based on catch control. However, the acquired knowledge and skills in mariculture give the possibility of developing technology of controlled reproduction, which is already in operation for some commercially important species.

Reproduction and controlled cultivation of European flat oyster is the focus of developing mariculture for the production of quality food, which also allows for the recovery of natural habitats. When it comes to the recovery of fish species, the technology of reproduction of commercially interesting species has been developed, while there is a lack of knowledge about the controlled reproduction of numerous species that are not in the focus of the market, but the state of their populations can indirectly affect the continued exploitation of commercially important populations.

Although there are many references in the literature about the successful reproduction of oysters, spawn production is not stable and additional work needs to be done to improve spawning and breeding technology. This is especially important when the principles of biosecurity are desired and when autochthonous ecotypes are planted in the marine environment.

The results achieved through pilot projects encourage the continuation of research into the development of shellfish reproduction technology as well as other commercially interesting invertebrates (e.g. sea urchins), which will enable not only stable production in aquaculture but also the possibility of recovery of natural populations.

2.2.6 Measures to mitigate the environmental impact of aquaculture activities

Project extracted instructions: To mitigate the environmental impact of aquaculture activities, several measures can be implemented. These measures aim to minimize negative effects on water quality, habitats, and surrounding ecosystems. Here are some key measures to mitigate the environmental impact of aquaculture:

1. Site selection and carrying capacity: Choose aquaculture sites carefully, considering factors such as water quality, hydrodynamics, and ecological sensitivity. Assess the carrying capacity of the site to ensure that aquaculture activities can be conducted without exceeding the natural assimilative capacity of the ecosystem.

2. Effluent management: Implement effective waste management practices to minimize the release of nutrients, organic matter, and other pollutants into the surrounding environment. This can include measures such as using sedimentation ponds, bio filters, or constructed wetlands to treat effluent before it is discharged.

3. Nutrient management: Optimize feed formulations and feeding practices to reduce nutrient waste and improve feed conversion efficiency. This can help minimize the discharge of excess nutrients, which can lead to eutrophication and other water quality issues. Implementing feeding protocols that match the nutritional requirements of the cultured species can help reduce nutrient inputs and improve overall environmental performance.

4. Integrated multi-trophic aquaculture (IMTA): Implement IMTA systems that utilize multiple species to enhance nutrient cycling and reduce environmental impacts. By combining the cultivation of finfish, shellfish, and seaweed, IMTA can help utilize excess nutrients, mitigate eutrophication, and promote a more balanced ecosystem within aquaculture sites.

5. Habitat protection and restoration: Take measures to protect and restore habitats affected by aquaculture activities. This can include avoiding sensitive areas, minimizing physical disturbances during infrastructure installation, and implementing habitat restoration initiatives to enhance biodiversity and ecosystem health.
6. Disease prevention and control: Implement robust biosecurity measures to prevent the introduction and spread of diseases within aquaculture facilities. This can include regular health monitoring, vaccination programs, and quarantine procedures for new stock. Effective disease management helps minimize the use of antibiotics and reduces the risk of disease transmission to wild populations.
7. Water management: Implement efficient water use practices to minimize the extraction of freshwater resources and reduce the discharge of excess water. Technologies such as recirculating aquaculture systems (RAS) can help optimize water usage, improve water quality control, and minimize the environmental footprint of aquaculture operations.
8. Monitoring and research: Establish comprehensive monitoring programs to assess the environmental impacts of aquaculture activities. This includes monitoring water quality parameters, biodiversity indicators, and interactions with wild species. Regular monitoring helps identify potential issues and supports adaptive management approaches for continuous improvement.
9. Compliance with regulations and certifications: Adhere to applicable regulations and standards set by governmental agencies and certification programs. Compliance ensures that aquaculture operations meet environmental requirements, such as water quality standards, effluent discharge limits, and sustainable practices.
10. Stakeholder engagement and transparency: Engage with local communities, indigenous groups, environmental organizations, and regulatory agencies to foster transparency and collaboration. Involve stakeholders in decision-making processes, seek input, and communicate the measures taken to mitigate environmental impacts. This helps build trust, address concerns, and promote responsible and sustainable aquaculture practices.

By implementing these measures, aquaculture operators can minimize the environmental impact of their activities, promote sustainable practices, and contribute to the conservation and protection of aquatic ecosystems. Continuous monitoring, research, and innovation are essential to further improve environmental performance and ensure the long-term sustainability of the aquaculture industry.

Figure11. Wave impact on the coast of Komiža (web source- Božanić T)

Notes from deliverables:

Aquaculture, like most activities, depending on whether it is breeding that uses autochthonous organic-based or natural trophic systems or breeding that relies on allochthons organic-based or artificial trophic systems (chapter - Reduction of impact on biodiversity), leaves an environmental footprint. The environmental footprint also depends on the characteristics of the location where aquaculture is planned or implemented. That is why mitigating the environmental impact of aquaculture activities should be carried out before setting up the farm in a certain location and after establishing aquaculture in the allocated zone for aquaculture (AZA).

Determining zones suitable for aquaculture should be carried out through marine spatial multi- criteria analysis and planning. It takes into account all relevant mutual influences of the coastal area: user functions (human interests), natural system (includes all subsystems that are not influenced by humans and interact through biotic, abiotic and chemical processes), climatic changes and infrastructure. The criteria are well known and lessons have been learned from good examples, including the experiences of the Adriatic Sea. However, due to changes in knowledge, people's interests, changes in nature and new technologies, this procedure needs to be periodically repeated and improved.

Aquaculture requires good environmental conditions including good water quality. Certain types of aquaculture such as shellfish farming, algae farming and the breeding of invertebrates can offer numerous ecosystem services. These services include: the absorption of excess nutrients and organic substances from the environment; the conservation and restoration of ecosystems and biodiversity through the creation of reefs where many marine species find refuge; the protection of the coasts from erosion thanks to the mitigation effect of the wave motion. Once aquaculture is started, the fact remains that it is an anthropized area in which aquaculture leaves a footprint. Therefore, measures to mitigate the impact of aquaculture on the environment should be taken constantly. Nowadays, the focus of public interest on the Adriatic Sea is the impact of fin-fish aquaculture and poses many challenges for science and industry.

Fish aquaculture can potentially affect the ecosystem by emitting substances, energy and living organisms into the environment. The substances emitted are:

• Nutrients that support plant growth (phytoplankton, algae, and sea flowers)

• Organic particles from faeces and uneaten food, which are rich in energy, and which are most often broken down by microorganisms

• Substances used to maintain farming installations

• Substances used to treat cultivated organisms

• Maintenance of the farm results in the generation of waste and the producer is obliged to properly dispose in order to avoid pollution.

The problem fecal emission poses an important challenge to a sustainable breeding technology management ecosystem. New cultivation technology enables cultivation in submerged cages at greater depths. which allows greater dilution of emitted substances and less competition with other activities. Some of the characteristics of the most advanced offshore systems are:

- High-density cages: Offshore mariculture systems use high-density cages, which are usually made of GRP and covered with polyurethane mesh to prevent the entry of predators.

- Automated feeding and monitoring systems: The most advanced offshore systems include sophisticated feeding systems that use sensors to monitor feed levels and automatic feed dosing systems. Also, monitoring systems help monitor water quality and maintain fish breeding conditions.

- Water temperature and quality monitoring systems

- Renewable energy sources

- Environmental monitoring and control systems

Bivalve culture takes nutrients away from the marine food web, but only affects biodiversity adversely if the carbon and nitrogen removed from the water column becomes excessive, leaving less for other herbivores and phytoplankton, thereby affecting the growth and reproduction of zooplankton and other herbivorous marine animals. Bivalves do take suspended seston (particulate matter suspended in water) and change it into denser particles that fall to the bottom.

Permanent extensive bivalve culture may bring about changes in the coastal food web causing eutrophication.

Due to the use of organic polymers for cage netting and tubular nets in mussel farming, aquaculture contributes to the introduction of microplastics into the environment. The influence of drugs and chemicals can significantly affect the environment, but their use is decreasing and more and more operators are switching optimization of growing conditions to and disease prevention (chapters:

Reduction of impact on biodiversity: Biosecurity: animal transport, non-native species, diseases).

It is difficult to fully predict all the consequences of the environmental impact of aquaculture activities. In addition, there are other possible sources of influence on the condition in the AZA that can negatively affect breeding results. Cultivated organisms are regularly very demanding in terms of the quality of the farming environment, so farming itself is a constraint for their own growth in production intensity. To establish the stability of good farming conditions, it is necessary to take in all input parameters in terms of their impact on the sustainable stability of farming conditions.

Therefore, in addition to the stationary criteria according to which the suitability of farming sites was determined, it is necessary to establish adaptive and ecosystem-based management of aquaculture.

Adaptive and ecosystem-based management of aquaculture is based on:

- Continuous data collection
- Decision-making system based on the results of measurements and observations
- Implementing good practices and experiences
- Continuous education of operators

Adaptive and eco based farming management is needed only for the preservation of biodiversity, but also for the preservation of the quality of the growing environment, which significantly reduces the risks related to organisms in the environment not only for the preservation of biodiversity or biosecurity, but also for the preservation of the quality of the environment, which also significantly reduces the risks related to wild organisms in the surrounding marine area.

Adaptive and eco based farming management can be initiated based on continuous monitoring of several basic abiotic parameters such as seawater temperature, dissolved oxygen concentration, cultured fish growth and feed conversion. Inconsistencies in production results (weaker growth, frequent diseases, and increased feed conversion) accompanied by significant oxygen oscillations in the cages and outside of them already indicate necessary changes in the technological pattern being implemented. If there are no inconsistencies in production results and the concentration of dissolved oxygen is stable and good (preferably always above 4 mg/l), the scope of continuous environmental monitoring related to long-term changes in the environment can be expanded.

The environmental monitoring program (EMP) is the tool for the collection, documentation, and communication of environmental data and information, useful for understanding and better managing the interactions between aquaculture and the environment and to mitigate potential impacts. The environmental monitoring activities envisaged in the EMP are the responsibility of the company that has the concession for the maritime state-owned area in which the production plant is installed. The concessionaire will be responsible for transmitting the results of the EMP, in the form of an environmental report, to the Competent Authority.

Objectives of the EMP:

- Minimize the impact of aquaculture on the environment and biodiversity;

- Ensure compliance with legislation and the maintenance of the GES (Good Environment Status);

- Ensure compliance with Quality Standards Environmental (QSE), when establishes;

- Respect the ecological services provided from the ecosystem;

- Ensuring the sustainability of the activities productive in the long run;

- Ensure an environment suitable for the needs of several species relieve;

- Verify the effectiveness of good practices applied management;

- Communicate to civil society and stakeholders the quality of the marine environment in the AZA

Additional monitoring should include data collection on:

- fish immunization activities at sea-cage farms and other farming facilities;

- feed ingredients and biochemical composition;

- feed conversion ratios per species/age/type of diet/densities.

Additional data collection that reflects and describes the impact of local farms on marine ecosystem

should include:

- water quality parameters in respect to the organic pollution;

- impact of organic waste on Posidonia beds;

- state of natural ichthyopopulations associated with sea-cage farms;

- occurrence and frequencies of disease transmission between farmed and wild fish;

- occurrence and frequencies of parasite transmission between farmed and wild fish;

- shellfish production losses caused by fish predation.

To gain insight into the impact of aquaculture on the marine ecosystem through escaped fish, future monitoring programmes should focus on:

- monitoring of spatio-temporal distribution of escaped fish;

- development of genetic traceability tool for farmed escapees and hybrids detection into the wild

Effective management implies that measurement results should be followed by appropriate management measures. Frequent interventions in planned technological procedures due to the mitigation of problems such as diseases or hypoxia indicate a redesign of breeding technology or breeding capacity. The selected corrective measures should be aligned with the goals and, accordingly, determine the success of changes in management. Due to the specificity of AZA, there are no universal forms for implementing corrective measures. This is why education and the involvement of responsible managers in the achievement of set objectives is important.

In addition to measures related to corrections in farming technology, management should also be adapted with regard to changes in the environment that are not a consequence of aquaculture activities. These are various natural and anthropogenic sources of influence on the cultivation process. Climate change mitigation measures have been in the focus of interest in recent years. The breadth of the problem can often exceed the resources of the operators, so for the successful adaptation of aquaculture to the environmental conditions, it is necessary to openly cooperate with scientific institutions and management bodies at the local and national level.

2.2.7 Create a recovery-reuse of shellfish shells

Project extracted instructions: Creating a recovery and reuse system for shellfish shells can provide several benefits, including waste reduction, resource conservation, and the development of value-added products. Here's an overview of the process and potential uses for shellfish shells:

1. Shellfish shell collection: Establish a system to collect shellfish shells from seafood processing facilities, restaurants, or aquaculture operations. These shells typically come from oysters, mussels, clams, and other shellfish species.

2. Shell cleaning and processing: Once collected, the shells need to be cleaned and processed to remove any organic matter and prepare them for reuse. This can involve thorough washing, soaking, and sanitization to ensure they are free from contaminants.

3. Composting and soil amendment: Shellfish shells can be composted and used as a valuable soil amendment. The high calcium carbonate content in the shells helps to balance soil pH, improve soil structure, and provide essential nutrients to plants. Crushed or ground shells can be added to compost piles or directly applied to agricultural fields, gardens, or landscaping areas.

4. Calcium supplements in animal feed: The calcium-rich composition of shellfish shells makes them suitable for use as a calcium supplement in animal feed. Ground or powdered shells can be incorporated into animal feed formulations to provide additional calcium for livestock, poultry, or aquaculture species.

5. Aquaculture applications: Shellfish shells can be used in aquaculture systems as substrate materials or in biofiltration processes. The shells provide a surface for the attachment of beneficial

bacteria, which help in water filtration and the removal of nitrogenous waste. They can also be used as a substrate for oyster or mussel cultivation, providing attachment surfaces for spat settlement and growth.

6. Construction materials and road surfaces: Crushed or ground shellfish shells can be used as a component in construction materials, such as concrete, plaster, or asphalt. The shells' hardness and durability make them suitable for enhancing the strength and performance of these materials. Additionally, shells can be used as a decorative element in landscaping or as a component in road surfaces for improved traction.
7. Art and craft applications: Shellfish shells can be used in artistic and craft projects. They can be cleaned, polished, and used as decorative pieces, jewellery components, or incorporated into sculptures, mosaics, or other creative works.
8. Shell recycling programs: Establish shell recycling programs in collaboration with local communities and businesses. Educate the public about the importance of shell recycling and provide designated collection points where individuals can drop off their shellfish shells for proper processing and reuse.

By creating a recovery and reuse system for shellfish shells, we can minimize waste, conserve resources, and explore various applications that add value to these discarded materials. Additionally, such initiatives contribute to a more sustainable and circular approach to shellfish production and consumption.

Figure 12 Mussels on the mesh socks- Argos source

2.2.8 Reduction of microplastic emissions

Project extracted instructions: Reducing microplastic emissions in aquaculture is crucial for maintaining the environmental integrity of aquatic ecosystems. Microplastics, which are tiny plastic particles less than 5mm in size, can have detrimental effects on marine life and pose potential risks to human health. Here are some measures that can be taken to mitigate and reduce microplastic emissions in aquaculture:

1. Source control and waste management: Implement practices to minimize the use of plastic materials in aquaculture operations. This includes reducing the use of single-use plastics, such as plastic bags, packaging, and equipment. Opt for alternative materials that are less likely to generate microplastic particles, such as biodegradable or compostable materials.

2. Improved feed management: Evaluate and improve feed formulations and production processes to minimize microplastic contamination. Microplastics can be present in feed ingredients, such as fishmeal or fish oil. Working with feed manufacturers to ensure the sourcing of clean and low-contaminant feed ingredients can help reduce the presence of microplastics in aquaculture systems.

3. Water treatment and filtration: Implement effective water treatment and filtration systems to remove microplastics from the water used in aquaculture operations. Filtration technologies, such as sand filters, microfilters, or advanced treatment systems, can help capture and remove microplastic particles from the water before it is released back into the environment.

4. Proper waste disposal: Ensure proper disposal of waste materials generated during aquaculture activities. This includes appropriate management of plastic waste, such as proper recycling or disposal in designated waste management facilities. Avoiding the release of plastic waste into water bodies helps prevent the fragmentation and generation of microplastics.

5. Research and monitoring: Conduct research and monitoring programs to assess the presence and impact of microplastics in aquaculture systems. This includes monitoring microplastic concentrations in water, sediments, and aquatic organisms to understand the sources, distribution, and potential risks associated with microplastic contamination. This information can guide the development of targeted mitigation strategies.

6. Education and awareness: Raise awareness among aquaculture farmers, industry stakeholders, and consumers about the issue of microplastic pollution and the importance of reducing its emissions. Promote sustainable practices, encourage the use of alternatives to plastic, and educate about proper waste management to prevent microplastic contamination.

7. Collaboration and policy support: Foster collaboration among aquaculture operators, industry associations, researchers, and regulatory bodies to develop and implement guidelines and best practices for reducing microplastic emissions in aquaculture. Support policy initiatives that promote sustainable aquaculture practices and address the issue of microplastic pollution.

By implementing these measures, aquaculture operators can contribute to the reduction of microplastic emissions and protect the health of aquatic ecosystems. The prevention and mitigation of microplastic pollution require a multi-faceted approach involving source control, improved waste management, technological advancements, and increased awareness throughout the aquaculture industry.

Figure 13 Plastic pollution-Hakai magazine-Coastal science and communities (web source)

Notes from deliverables:

The result of industrial development is microplastic that is already found in seawater and animals in accumulate it in their digestive system. When consuming most species of fish, their digestive system is removed, thus avoiding contamination of humans with microplastics.

The origin of microplastics in the sea is mostly from wastewater and inadequate disposal of plastic waste that ends up in the sea and degrades and decomposes into small pieces. Although significantly less than fishing, plastic structures on farms also degrade over time and release microplastics into the surrounding sea. Degradation is accelerated by fouling organisms, for example isopod shrimps that drill holes in plastic buoys.

Shellfish are a particularly risky food category because they are filter feeder animals and therefore, accumulate various substances in their body, including bacteria, viruses, biotoxins, heavy metals, other toxic substances, and even microplastic particles.

However, shellfish, unlike fish, are consumed whole and are thus one of the main ways of ingesting microplastic in humans. By consuming one serving of mussels (225g) according to some research, a person would intake 7µg of plastic into his body, which is negligible (<0.1%) in relation to the total daily exposure to chemical compounds such as PBT (Persistent, bioaccumulative and toxic substances) and plastic additives (source: Microplastic in seafood). This calculation is based on the assumption that the largest measured amount of microplastics in shellfish from China averages 4 pieces of microplastics/g of meat.

225g of meat has about 900 pieces of microplastics, and according to the dimensions and density of polyethylene, it is calculated that 900 pieces have a mass of 7µg. However, in the work of C. L. Murphy from 2018, is stated that 5 to 650 pieces of microplastic per gram of shellfish meat were measured, which indicates that the amount of microplastic in a portion of shellfish can be significantly higher (650pcs x 225g x 0.007 = 1,137µg). This study also demonstrated significantly higher concentrations of microplastics in farmed mussels and oysters compared to wild individuals.

Release of microplastics from farming installations

The origin of microplastics in the sea is mostly from wastewater and inadequate disposal of plastic waste that ends up in the sea and degrades and decomposes into small pieces. In addition, all the plastic structures that make up the farm itself also degrade over time and release microplastics into the surrounding sea. Fouling organisms accelerate degradation, like isopod shrimps that drill holes in buoys. To minimize microplastic pollution, the farm should replace plastic structures with metal or wood, and ropes and nets with biodegradable materials (cotton and coconut fibres).

In order to minimize microplastic pollution, the farm should replace plastic structures with metal or wood, and ropes and nets with biodegradable materials (cotton and coconut fibres). Given that, materials require a new cycle of change.

3 List of deliverable as a source for handbook

D3.2.1. Analysis for the harmonisation of legal framework between the regulation on fisheries and aquaculture between Italy and Croatia, within the general EU regulatory framework

WP3 Governance framework

Activity 3.2. Maritime Spatial Planning assessments

PP3 - Marche Region

D3.2 Additional study for the protection of marine resources and fisheries and aquaculture activities of the Molise region

WP3 Governance framework

Activity 3.2. Maritime Spatial Planning assessment

PP4 - Molise Region

D3.2.2. N. 1 comprehensive study by P6, P7 and P10 on the possibilities of Croatian aquaculture development and innovation of farming processes, biodiversity conservation due to setting of fish aggregating devices and necessary changes in spatial planning for fishery and aquaculture areas

WP3 Governance framework

Activity 3.2. Maritime Spatial Planning assessment

PP7 - Primorje Gorski Kotar County, involved partners - PP6, PP10

D3.2.3. Study on maritime intra-sectorial interactions analysis as a deepening of the spill over effects of the establishment of Natura 2000 areas in the upper Adriatic sea

WP3 Governance framework

Activity 3.2. Maritime Spatial Planning assessment

PP1 - Veneto Region, partners involved - LP, PP1, PP2, PP3, PP6, PP7, PP8, PP12

D3.2.5. Analysis of interactions between different typologies of aquaculture practices and the trends of Adriatic fish stock, highlighting both positive and unwanted effects of aquaculture on marine habitats and species

WP3 Governance framework

Activity 3.2. Maritime Spatial Planning assessments

PP8 - Zadar County

D4.1. and D4.2. Research and comparison of existing data and databases and design of protocols for monitoring invasive species in fisheries and aquaculture

WP4 Knowledge-based decision-making process

Activity 4.1. Survey and comparison of existing data and databases

Activity 4.2. Common scheme for the management of fishery activities at local level

PP2 – Emilia-Romagna Region

PP6 – Istrian Region

D4.1.2 Agenda for the standardization of data as a basis for a shared approach in the management of Adriatic biological resources and economic activities

WP4 Knowledge-based decision-making process

Activity 4.1. Survey and comparison of existing data and databases

PP13 - IOF

D4.2.1 Num. 1 technical-scientific common scheme for local data collection on fish and fish related data at very local level

WP4 Knowledge-based decision-making process

Activity 4.2. Technical-scientific common scheme for local data collection on fisheries and fish related data at very local level

PP13 - IOF

D4.2.2. Protocol on aquaculture data collection at very local level

WP4 Knowledge-based decision-making process

Activity 4.2. Common scheme for the management of fishery activities at local level

PP3 - Marche Region

D4.2.2. Protocol to collect data at local level PGK

WP4 Knowledge-based decision-making process

Activity 4.2. Common scheme for the management of fishery activities at local level

PP7 - Primorje Gorski Kotar County

D4.2.2. Report on the collection of alternative data on mussel cultivation in the Krka estuary

WP4 Knowledge-based decision-making process

Activity 4.2. Common scheme for the management of fishery activities at local level

PP9 - Development Agency of Šibenik County – Knin

D.4.2.2 Common scheme for the management of fishery activities at the local level

WP4 Knowledge-based decision-making process

Activity 4.2. Common scheme for the management of fishery activities at local level

PP2 – Emilia-Romagna Region

D4.2.2 Collection of Apulian fishery and aquaculture data at local level

WP4 Knowledge-based decision-making process

Activity 4.2. Common scheme for the management of fishery activities at local level

PP5 - Apulia Region

D5.3.1. Mariculture modelling study in the restriction area of protected coastal area in Primorje – Gorski Kotar County with a climate impact assessment

WP5 Sectoral know-how development and pilot project implementation

Activity 5.3 Improvement of aquaculture operator's behaviours

PP7 - Primorje-Gorski Kotar County

D5.3.1. Common set of protocols and guidelines for sustainable production and added value in rearing of common interest shellfish species

WP5 Sectoral know-how development and pilot project implementation

Activity 5.3 Improvement of aquaculture operator's behaviours

PP7 - Primorje-Gorski Kotar County, partners involved - PP8, PP9, PP11

D5.1. Additional deliverable - Establishment of a local and cross-border network for training and education of all stakeholders of the fisheries sector for the purpose of environmental protection and sustainability

WP5 Sectoral know-how development and pilot project implementation

Activity 5.1 Network for the training and education of operators towards environmental sustainability

PP11 - Dubrovnik - Neretva County

D5.3.4. N. 1 Set of pilot guidelines for biodiversity protection related to marine aquaculture science

WP5 Sectoral know-how development and pilot project implementation

Activity 5.3. Improvement of aquaculture operator's behaviours

PP6 - Istrian Region

D5.3.3. Protocol for sustainable integrated aquaculture in long-line mussel farms

WP5 Sectorial know-how development and pilot project implementation

Activity 5.3. Improvement of aquaculture operator's behaviours

PP4 - Molise Region