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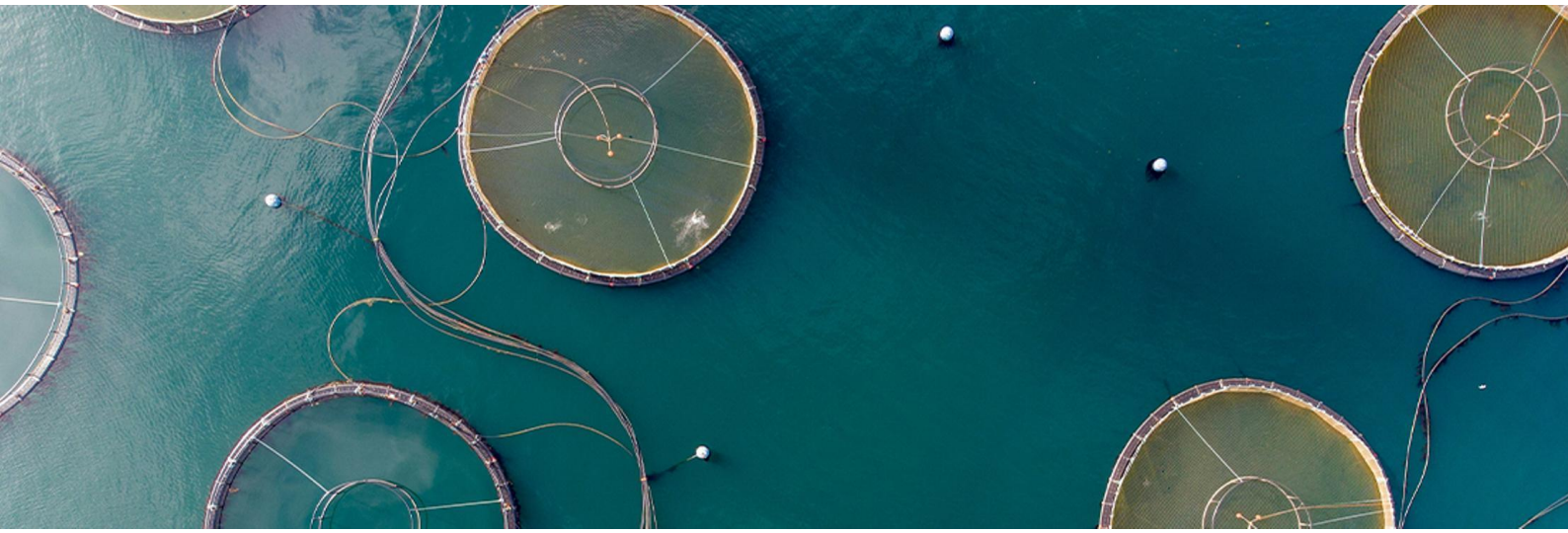

May 2026

D.3.2.2 AZA4ICE Action plan for the Palaio Lagoon Lefkada, Greece

Strategic document that outlines the key actions, stakeholders, timelines, and resources required to transition to a circular economy within the aquaculture

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Abbreviations

AZA	Allocated Zone for Aquaculture
C-AZA	Circular Allocated Zone for Aquaculture
C-AZAi	C-AZA Index
GES	Good Environmental Status
HAPO	Hellenic Aquaculture Producers Organisation
IMTA	Integrated Multi-Trophic Aquaculture
LiRRIE	Living Responsible Research & Innovation Ecosystems
NECCA	Natural Environment and Climate Change Agency
SAC	Special Area of Conservation
SiSI	Site Suitability Index
SPA	Special Protection Area

1. Executive Summary

This Action Plan has been developed within the framework of the AZA4ICE project to support the sustainable development of aquaculture in the Lefkada lagoon system through the adoption of circular aquaculture principles. The plan builds upon the results generated by the AZA4ICE methodology application, which integrates environmental suitability analysis, species selection and circular production assessment to identify opportunities for the implementation of circular aquaculture systems.

The Lefkada lagoon represents a characteristic Mediterranean coastal ecosystem where traditional lagoon aquaculture practices coexist with valuable wetland habitats and a range of coastal economic activities. Historically, aquaculture production in the lagoon has been based on extensive systems that rely on natural fish migration and low-intensity harvesting techniques. These systems are functionally closer to fisheries than to conventional aquaculture, as they depend on natural ecological processes and passive fish capture dynamics rather than controlled production conditions. This characteristic represents both a constraint and an opportunity for the development of circular aquaculture approaches adapted to lagoon environments. While these traditional practices generally maintain a low environmental impact, they also present limitations in terms of production diversification, economic resilience and resource efficiency. The AZA4ICE analysis indicated that the Lefkada lagoon presents a moderate but promising suitability for the development of circular aquaculture systems. In particular, the integration of different trophic levels within aquaculture production, through IMTA approaches, offers opportunities to enhance nutrient recycling, improve ecosystem functioning and diversify aquaculture production.

The Action Plan therefore proposes a strategic framework aimed at supporting the gradual transition towards circular aquaculture practices adapted to lagoon environments. The proposed approach combines environmental monitoring, technical innovation, stakeholder engagement and institutional coordination. Key actions include strengthening environmental monitoring programmes to better understand lagoon ecological dynamics, promoting knowledge transfer and capacity building among aquaculture operators, and exploring the feasibility of pilot IMTA systems combining fed species with extractive organisms, in particular oysters and halophytic plants. These initiatives are designed to test circular production concepts while maintaining compatibility with the ecological characteristics of the lagoon ecosystem.

Governance and stakeholder participation represent another central component of the Action Plan. The implementation of circular aquaculture practices requires effective collaboration among regional and local authorities, research institutions, aquaculture operators and civil society organisations. The LiRRIE participatory

framework developed within the AZA4ICE project provides a platform to facilitate dialogue among these actors and support shared decision-making processes.

The monitoring and evaluation framework proposed in this Action Plan will allow the assessment of environmental, technical, economic and social aspects of circular aquaculture implementation. Through a combination of environmental indicators, operational performance metrics and stakeholder engagement indicators, the monitoring system will support adaptive management and ensure that aquaculture development remains aligned with sustainability objectives.

Overall, the Action Plan provides a roadmap for exploring innovative aquaculture practices in the Lefkada lagoon while preserving the ecological integrity and cultural heritage of this coastal environment. The proposed actions aim to strengthen the long-term sustainability and resilience of lagoon-based aquaculture systems and contribute to broader regional efforts to promote circular and environmentally responsible aquaculture development in the Mediterranean.

2. Introduction

Scope and Objectives

This Action Plan aims to support the sustainable development of aquaculture in the Lefkada lagoon system through the application of the Circular Allocated Zones for Aquaculture (C-AZA) framework developed within the AZA4ICE project. The document translates the technical assessments, spatial analyses and stakeholder engagement activities carried out during the project into a structured set of strategic orientations and operational recommendations designed to facilitate the gradual implementation of circular aquaculture approaches in the pilot area.

The Plan is intended to bridge scientific knowledge, policy frameworks and practical aquaculture management by providing a coherent pathway for integrating circular economy principles into lagoon-based aquaculture systems. Particular attention is given to ensuring that production activities remain compatible with the ecological characteristics of the lagoon ecosystem while at the same time strengthening the socio-economic viability of the sector. More specifically, the Action Plan seeks to promote the integration of circular economy principles into aquaculture development strategies, encouraging production models that minimise waste, enhance resource efficiency and promote nutrient recycling within the ecosystem. In this context, Integrated Multi-Trophic Aquaculture (IMTA) systems represent a promising approach capable of combining fed and extractive species in order to optimise nutrient flows and improve environmental performance.

Another important objective of the Plan is to strengthen coordination among the different actors involved in aquaculture governance and management. Public authorities, research institutions, aquaculture operators and civil society organisations all play complementary roles in shaping the development of the sector. Improved coordination among these actors is essential to ensure coherent decision-making processes, transparent governance mechanisms and effective implementation of sustainable aquaculture strategies.

The Action Plan also emphasises the importance of improving environmental monitoring and data availability in order to support evidence-based planning and adaptive management. Reliable information on water quality conditions, ecosystem dynamics and species performance is fundamental for ensuring that aquaculture development remains compatible with environmental protection objectives.

Finally, the document seeks to facilitate knowledge transfer and capacity building among stakeholders involved in lagoon aquaculture. By strengthening technical knowledge, promoting the exchange of experiences and encouraging participatory governance processes, the Plan aims to create favourable conditions

for the progressive adoption of circular aquaculture practices within the Lefkada lagoon system.

Overall, this Action Plan is intended to serve as a strategic reference for local authorities, aquaculture operators, research institutions and other stakeholders engaged in the management and development of aquaculture activities in the Lefkada lagoon. By combining scientific evidence, stakeholder perspectives and practical recommendations, the document contributes to the long-term sustainability and resilience of lagoon-based aquaculture systems.

Context

Aquaculture plays an increasingly important role in supporting food security, economic development and coastal livelihoods across the Mediterranean region. As demand for aquatic products continues to grow, the sector is expected to expand further in the coming decades. However, the development of aquaculture activities must be carefully managed to ensure that production systems remain compatible with environmental protection objectives, biodiversity conservation and the sustainable use of coastal resources. In this context, circular aquaculture approaches have emerged as an innovative pathway for reconciling production objectives with environmental sustainability. By promoting nutrient recycling, ecosystem integration and efficient resource use, circular aquaculture systems seek to minimise environmental impacts while improving the overall resilience and productivity of aquaculture operations.

The AZA4ICE project contributes to this broader policy and scientific context by developing a methodological framework for identifying Circular Allocated Zones for Aquaculture (C-AZA). This framework builds upon the concept of Allocated Zones for Aquaculture (AZA), which has been widely promoted as a spatial planning tool for supporting sustainable aquaculture development. The AZA4ICE methodology extends this concept by integrating circular economy principles, ecosystem-based management approaches and participatory governance mechanisms. The methodological framework developed within AZA4ICE combines environmental suitability analysis, species compatibility modelling, circularity assessment and stakeholder participation in order to identify areas where aquaculture activities can be developed or strengthened in an environmentally responsible and socially acceptable manner. Through the integration of spatial analysis and participatory processes, the methodology supports evidence-based decision-making and encourages collaborative planning among stakeholders.

The Lefkada lagoon system was selected as one of the pilot sites for testing this methodology due to its ecological importance, the presence of long-established lagoon aquaculture practices and the potential for exploring innovative circular aquaculture approaches adapted to coastal wetland environments. The Lefkada

pilot site is located within the Lefkada lagoon complex, a coastal wetland system situated on the north-eastern side of Lefkada Island in the Ionian Sea in western Greece, close to the city of Lefkada. The lagoon complex consists of two hydrologically connected water bodies, namely the Paleo Lagoon and the Avlémonas Lagoon. The AZA4ICE pilot case focuses specifically on the Paleo Lagoon, where the aquaculture activities addressed in this Action Plan are currently located. The Lefkada lagoon complex forms part of a wider coastal wetland system of considerable ecological value. The area is included in the Natura 2000 network, being designated both as a Special Area of Conservation (SAC) and a Special Protection Area (SPA) and is also recognised as a Ramsar wetland of international importance. These conservation designations highlight the ecological significance of the lagoon and underline the need for careful management to ensure compatibility between economic activities and environmental protection objectives. The lagoon's fish community includes species typical of brackish environments, including grey mullet (*Mugil cephalus*), European eel (*Anguilla anguilla*), gilthead seabream (*Sparus aurata*) and European seabass (*Dicentrarchus labrax*).

Coastal lagoons such as the Lefkada lagoon system constitute transitional ecosystems that are closely interconnected with the surrounding coastal zone and marine environment. These ecosystems play an important ecological role as nursery and feeding grounds for numerous fish species that spend part of their life cycle within lagoon habitats before migrating to adjacent marine waters. The maintenance of effective hydrological connectivity between the lagoon and the sea is therefore essential for ensuring both water circulation and the seasonal migration of fish populations. In lagoon aquaculture systems, the management of water exchange points and fish-trap installations requires careful consideration in order to facilitate fish movement while maintaining the ecological functioning of the lagoon ecosystem.

Human use of the lagoon has historically been closely linked to its natural resources and cultural heritage. The area has long supported artisanal fishing activities based on traditional lagoon management practices. In particular, the Paleo Lagoon hosts a traditional fish-trap system locally known as *ivari*, which has been operating since the mid-1980s. This system represents a form of extensive lagoon aquaculture based on fixed structures that guide naturally migrating fish into trapping enclosures. Production includes species typical of lagoon environments as well as high-value products such as bottarga, produced from processed fish roe. Although historically managed by a larger number of operators, the workforce involved in the system has gradually declined over time due to demographic changes and institutional constraints. Nevertheless, the lagoon continues to support a low-intensity and environmentally compatible aquaculture management regime in which fish harvesting relies on fixed fish-trap installations positioned at strategic points of water exchange between the lagoon and the canal.

Aquaculture practices in lagoon environments such as Lefkada present specific characteristics that distinguish them from conventional aquaculture systems. In

these transitional ecosystems, production is strongly dependent on natural processes and follows extensive management approaches, making it more closely comparable to fisheries than to intensive aquaculture. Lagoon aquaculture relies on the natural productivity of the ecosystem and on traditional management practices, often involving passive capture systems rather than controlled farming conditions. This distinction is particularly relevant in the Greek context, where lagoon-based production systems have historically developed within a fisheries management framework. As a result, they are governed by regulatory, ecological and socio-economic dynamics that differ significantly from those of marine aquaculture. In contrast, marine aquaculture represents the main component of intensive production in Greece. This is especially evident in the Ionian Sea, where environmental conditions are highly favourable, including deep waters, the presence of naturally sheltered areas and limited exposure to strong winds. These conditions support the development of offshore and coastal aquaculture systems characterised by higher levels of technological input and production intensity.

Within this context, the AZA4ICE project provides an important framework for exploring how traditional lagoon aquaculture systems can be strengthened and adapted to respond to contemporary environmental, economic and governance challenges. The application of the C-AZA methodology at the Lefkada pilot site aims to assess the environmental suitability of the lagoon for aquaculture activities, identify opportunities for circular production models and support participatory governance processes involving local stakeholders. Through the integration of environmental data, spatial analysis, circularity assessment, and stakeholder engagement under the LiRRIE framework, the AZA4ICE approach contributes to the development of evidence-based strategies capable of maintaining the ecological integrity of the lagoon while supporting the long-term sustainability of its traditional aquaculture practices.

3. Roles and Responsibilities of Key Actors

The development and implementation of circular aquaculture systems requires the coordinated involvement of a wide range of actors operating at different institutional, scientific and operational levels. Sustainable aquaculture governance relies not only on appropriate regulatory frameworks but also on effective collaboration among public authorities, research institutions, private operators and local communities. Each of these actors contributes specific knowledge, responsibilities and capacities that are essential for the successful implementation of circular aquaculture strategies.

Public authorities play a central role in defining the institutional and regulatory context within which aquaculture activities are developed and managed. Their responsibilities include establishing policy frameworks, issuing licences, regulating access to aquatic resources and ensuring that aquaculture operations comply with environmental protection standards. Public authorities are also responsible for

spatial planning processes, environmental monitoring programmes and the coordination of sectoral policies related to fisheries, aquaculture, environmental conservation and coastal development. Through these functions, governmental institutions contribute to creating the enabling conditions necessary for the development of sustainable aquaculture systems.

Research institutes and scientific organisations provide the scientific knowledge and technical expertise required to support evidence-based decision-making. Their work contributes to improving the understanding of ecosystem dynamics, evaluating environmental carrying capacity and developing modelling tools capable of assessing species suitability and system interactions. In addition, research institutions play an important role in supporting innovation by testing new production models, evaluating environmental performance and providing technical guidance for the implementation of circular aquaculture approaches such as IMTA systems.

Aquaculture operators represent the actors directly responsible for the implementation of production activities. Their experience and practical knowledge of local environmental conditions are fundamental for translating scientific recommendations into operational practices. The willingness of operators to adopt new technologies, diversify production systems and participate in collaborative governance processes plays a crucial role in determining the feasibility and long-term success of circular aquaculture initiatives.

Local communities and civil society organisations also contribute significantly to the governance of aquaculture activities. Their perspectives help ensure that development strategies are aligned with local social expectations, cultural values and environmental priorities. In coastal areas where multiple economic activities coexist, including tourism, fisheries and environmental conservation, community involvement is essential for maintaining social acceptance and preventing potential conflicts over resource use.

The stakeholder engagement process conducted within the AZA4ICE project highlighted the importance of maintaining open and continuous dialogue among these different actors. The LiRRIEs participatory framework developed within the project provides a platform for facilitating this dialogue, allowing stakeholders to share knowledge, discuss potential challenges and collaboratively identify solutions that support sustainable aquaculture development in the Lefkada lagoon system.

Regional and National Authorities

At the national level, aquaculture governance in Greece is primarily coordinated by the Ministry of Rural Development and Food, which holds the main responsibility for the regulation, strategic planning and development of the aquaculture sector through its Directorate of Aquaculture and Fisheries. This ministry is responsible for defining national aquaculture policies, implementing the national strategic plan for

sustainable aquaculture development, and supervising licensing procedures for aquaculture establishments. In addition, it coordinates the implementation of relevant European Union policies, including the Common Fisheries Policy and funding instruments supporting the development of the blue economy. The regulatory framework for aquaculture also involves several other national ministries whose competences intersect with coastal and marine management. The Ministry of Environment and Energy plays a key role in environmental permitting procedures and spatial planning policies, particularly through the implementation of environmental impact assessment requirements and the management of protected areas. At the same time, the Ministry of Maritime Affairs and Insular Policy is involved in matters related to maritime space management, navigation safety and coastal infrastructure. These multiple administrative responsibilities reflect the inherently cross-sectoral nature of aquaculture governance in Greece, where environmental protection, maritime management and economic development must be coordinated across different institutional domains.

At the regional level, administrative responsibilities are exercised by the Region of the Ionian Islands (Perifereia Ionion Nison), which constitutes one of the thirteen administrative regions of Greece and includes the regional units of Corfu, Lefkada, Kefalonia, Zakynthos and Ithaca. The regional administration plays an important role in implementing national policies at the territorial level, particularly with regard to regional development planning, environmental management and the coordination of sectoral activities such as fisheries, aquaculture and coastal tourism. In addition, a significant role is played by the Decentralized Administration of the Peloponnese, Western Greece, and the Ionian Islands, which operates as a deconcentrated state authority. This body is responsible for key administrative functions, including the approval of environmental terms, supervision of spatial planning instruments, and oversight of compliance with national legislation. Its role is particularly relevant in licensing procedures and environmental governance, acting as a critical link between central government and regional/local authorities. Within the region, the Regional Unit of Lefkada represents the main territorial authority responsible for local administrative coordination. Regional authorities contribute to supervising aquaculture activities through regional fisheries services, participating in environmental monitoring programmes and supporting regional development initiatives that affect coastal and lagoon ecosystems. They also act as intermediaries between national ministries, local municipalities and sectoral stakeholders, facilitating the implementation of regulatory frameworks and development strategies at the local scale.

In areas designated as environmentally protected, additional governance responsibilities are exercised by specialised environmental management bodies. In the case of the Lefkada lagoon system, conservation and environmental management tasks are coordinated by the Natural Environment and Climate Change Agency (NECCA) through its regional management units responsible for Natura 2000 sites. These bodies oversee the implementation of conservation measures, monitor ecological conditions and ensure that human activities within protected areas remain compatible with biodiversity protection objectives.

Finally, the Municipality of Lefkada plays a particularly strategic role in the governance of lagoon systems. Beyond its general responsibilities in local planning, infrastructure development and coastal management, the municipality holds a unique dual function as both owner and operator (aquaculturist) of the Lefkada lagoons. This dual role makes it a central actor in decision-making processes related to lagoon management, directly influencing both production practices and environmental stewardship. Municipal authorities are also involved in promoting local economic development strategies, supporting tourism and cultural heritage initiatives, and facilitating dialogue between local communities and sectoral stakeholders.

Through this multi-level governance structure, aquaculture management in Lefkada involves a complex interaction between national ministries, regional administrations, decentralised state authorities, environmental management bodies and local authorities. Effective coordination among these actors is therefore essential to ensure that aquaculture development remains environmentally sustainable, socially accepted and aligned with broader coastal management objectives.

Research Institutes and Scientific Organizations

Scientific institutions play a fundamental role in supporting sustainable aquaculture development in Greece by providing the technical knowledge and analytical tools necessary for ecosystem-based management. Universities and research institutes contribute to the study of coastal ecosystems, the assessment of environmental carrying capacity and the development of innovative aquaculture production systems adapted to Mediterranean conditions. Several academic institutions have developed specialised expertise in fisheries science, aquaculture technology and marine ecology. These include departments of fisheries and aquaculture at Greek universities, as well as national research organisations that support applied research and innovation in the aquaculture sector. Through scientific projects, environmental monitoring programmes and collaborative research initiatives, these institutions generate the knowledge required to inform policy development and support evidence-based planning.

Beyond research activities, scientific organisations also play an important role in capacity building and knowledge transfer. Training programmes, technical workshops and collaborative research initiatives provide opportunities for aquaculture operators, public authorities and other stakeholders to exchange knowledge and improve their understanding of sustainable aquaculture practices. In this way, scientific institutions contribute not only to technological innovation but also to strengthening the institutional and technical capacities required for the implementation of circular aquaculture strategies.

Aquaculture Sector and Associations

Aquaculture operators represent the actors directly responsible for managing production activities within the lagoon system. In the Lefkada lagoon, aquaculture practices are closely linked to traditional lagoon fisheries that rely on extensive management systems based on fish migration and trapping techniques. These systems require detailed knowledge of lagoon hydrodynamics, seasonal ecological cycles and species behaviour, knowledge that has been accumulated over generations of local fishers. Operators manage the day-to-day functioning of aquaculture installations, maintain fishing structures and coordinate harvesting activities. Their role is therefore central in translating scientific recommendations and regulatory requirements into practical management actions. The success of circular aquaculture initiatives ultimately depends on the willingness and capacity of operators to experiment with new production approaches, adopt monitoring practices and participate in collaborative governance processes.

At the national level, aquaculture producers are represented by sectoral organisations such as the Hellenic Aquaculture Producers Organisation (HAPO) and the Federation of Greek Maricultures, which contribute to representing the interests of producers, promoting sustainable aquaculture development and facilitating communication between the sector and public authorities. In the specific context of lagoon fisheries, cooperative structures and professional associations also play an important role in coordinating management practices and representing the interests of lagoon fishers at regional and national levels. Through these organisational structures, the aquaculture sector can actively contribute to policy dialogue, participate in research and innovation initiatives and support the dissemination of best practices related to sustainable and circular aquaculture production.

Civil Society and Local Communities

Local communities and civil society organisations play an important role in shaping the social context within which aquaculture activities develop. In coastal areas such as Lefkada, economic activities including tourism, fisheries and environmental conservation coexist within a shared coastal landscape. The perceptions and expectations of local communities therefore strongly influence the level of social acceptance associated with aquaculture development. Community involvement contributes to ensuring that aquaculture initiatives are aligned with local cultural traditions and environmental values. In the case of the Lefkada lagoon, traditional lagoon fisheries represent an important element of the area's cultural heritage, reinforcing the connection between local communities and the lagoon ecosystem. Maintaining this connection is essential for ensuring that future aquaculture development strategies remain socially supported and culturally meaningful.

Civil society organisations, environmental groups and local associations can also play an active role in raising awareness about sustainable aquaculture practices

and promoting responsible management of coastal ecosystems. Through participation in consultation processes and collaborative governance platforms, these actors contribute to broadening the range of perspectives considered in decision-making processes.

Within the AZA4ICE project, the LiRRIEs participatory framework provided a structured platform for stakeholder dialogue, enabling representatives from public institutions, the aquaculture sector, research organisations and local communities to exchange views and identify common priorities. Such participatory mechanisms are essential for building trust among stakeholders and creating the social conditions necessary for the successful implementation of circular aquaculture initiatives in the Lefkada lagoon system.

It is essential to include targeted educational programs for students and young people in Lefkada as a core part of the Action Plan. If meaningful and long-term change is to be achieved, efforts must focus on the younger generation, fostering awareness, active participation and a sense of responsibility from an early age. By empowering youth through education and engagement, the initiative can create lasting social and environmental impact within the local community.

4. Regional Needs, Challenges and Opportunities

The stakeholder consultation process carried out within the AZA4ICE project provided valuable insights into the current conditions, expectations and concerns of actors involved in aquaculture management in the Lefkada lagoon system. The analysis highlighted a number of priority needs, potential challenges and emerging opportunities that are relevant for the development of circular aquaculture practices in the area. The Lefkada lagoon represents a complex socio-ecological system where aquaculture activities coexist with tourism, fisheries and environmental conservation priorities. Understanding the needs and constraints of the regional context is therefore essential for identifying realistic pathways for the implementation of Allocated Zones for Circular Aquaculture (C-AZA).

Regional needs

One of the most important needs identified by stakeholders concerns the strengthening of environmental monitoring systems. Lagoon ecosystems are inherently dynamic and sensitive to environmental changes, and reliable data on water quality parameters, nutrient dynamics and ecosystem conditions are essential for ensuring the sustainable management of aquaculture activities. Improved monitoring systems would support more informed decision-making processes and help detect potential environmental pressures at an early stage. The availability of long-term datasets on water quality, nutrient loads and ecological

indicators would also significantly improve the accuracy of modelling tools used for aquaculture planning and environmental suitability assessments.

Another key need relates to the development of technical knowledge and operational capacity associated with circular aquaculture approaches. While local operators possess extensive experience in traditional lagoon aquaculture practices, the implementation of integrated production systems such as IMTA requires additional technical expertise and specialised training. Capacity-building initiatives, demonstration activities and knowledge exchange programmes could therefore play an important role in facilitating the gradual adoption of circular production models adapted to lagoon environments.

Stakeholders also highlighted the importance of improving infrastructure and technical services supporting aquaculture operations. Although the current extensive aquaculture system requires relatively limited infrastructure, the diversification of production systems and the potential introduction of new species or integrated farming approaches may require additional logistical support, equipment and operational facilities. Investments in monitoring technologies, environmental sensors and improved maintenance of lagoon structures could enhance both the environmental sustainability and the operational efficiency of aquaculture activities.

Governance coordination emerged as another important area requiring further strengthening. Effective collaboration among public authorities, research institutions and aquaculture operators is essential for ensuring coherent planning processes and transparent management of aquaculture activities. Stakeholders emphasised the value of participatory governance platforms capable of facilitating communication among actors and supporting collective decision-making processes. In this context, the LiRRIEs participatory framework developed within the AZA4ICE project represents a useful platform for strengthening dialogue among stakeholders.

Finally, the need for stronger integration between aquaculture activities and broader socio-economic development strategies was also highlighted. Strengthening links between aquaculture production, local markets, tourism and regional identity could contribute to enhancing the economic resilience of lagoon-based production systems while reinforcing the cultural value associated with traditional aquaculture practices.

Environmentally Compatible Aquaculture Models

The development of aquaculture systems that remain fully compatible with the ecological characteristics of the Lefkada lagoon represents a key regional need. The lagoon forms part of a sensitive coastal wetland ecosystem, recognised for its ecological value and protected under European environmental legislation.

Ensuring that aquaculture activities maintain low environmental impact and support ecosystem functioning is therefore essential. Circular aquaculture approaches, including IMTA systems, offer the potential to enhance nutrient recycling and improve ecological efficiency by integrating fed and extractive species. Further research and pilot initiatives are required to identify production models that are technically feasible and environmentally compatible with the lagoon ecosystem.

Governance and Decision-Making Coordination

Effective governance coordination is necessary to ensure that aquaculture development remains consistent with environmental protection objectives and regional planning frameworks. Aquaculture management in Greece involves multiple administrative levels, including national ministries, regional authorities and local management bodies responsible for protected areas. Improved coordination mechanisms could help streamline licensing procedures, facilitate data sharing and ensure that planning decisions are supported by scientific evidence. Strengthening multi-stakeholder dialogue platforms would also contribute to improving transparency and trust among actors involved in aquaculture management.

Strengthened Local Capacity

Developing local capacity for the management of circular aquaculture systems represents another important priority. This includes strengthening the technical skills of aquaculture operators, improving the ability of local authorities to monitor environmental conditions and supporting research institutions in conducting applied studies relevant to lagoon aquaculture systems. Training initiatives and collaborative research activities could facilitate knowledge transfer between scientific institutions and local operators, supporting the gradual transition towards more sustainable production practices.

Technological and Knowledge Needs

The implementation of circular aquaculture systems requires access to appropriate technologies and technical knowledge. Monitoring tools capable of measuring environmental parameters, modelling platforms that support species suitability assessments and operational technologies for integrated aquaculture systems are essential components for the successful implementation of circular production models. Increasing the availability of such tools and improving access to technical guidance would support both operators and public authorities in making informed management decisions.

Regulatory Alignment and Policy Support

Ensuring that regulatory frameworks support the development of circular aquaculture practices represents another important regional need. Although Greece has established national policies regulating aquaculture development, additional efforts may be required to align existing regulations with innovative production approaches such as IMTA systems. Clarifying licensing procedures, simplifying administrative processes and ensuring coherence between aquaculture regulations and environmental protection policies would contribute to creating a more predictable institutional environment for operators.

Socio-Economic Integration and Stakeholder Engagement

Strengthening the integration of aquaculture within the broader socio-economic activities of the Lefkada region is also essential. Aquaculture activities coexist with tourism, small-scale fisheries and nature conservation initiatives, and maintaining positive interactions among these sectors is fundamental for long-term sustainability. Stakeholder engagement processes that involve local communities, tourism operators and environmental organisations can help ensure that aquaculture development remains socially acceptable and contributes to the economic vitality of coastal communities.

Regional Challenges

Despite the favourable conditions for aquaculture development in the Lefkada lagoon, several challenges may influence the implementation of circular aquaculture approaches. One of the main challenges concerns the limited availability of detailed environmental and biological data required to support advanced modelling of species suitability and ecosystem interactions. Although basic environmental information is available, more comprehensive datasets would be beneficial for improving the accuracy of planning tools and supporting long-term management strategies. The technical complexity associated with circular aquaculture systems also represents a potential challenge. Integrated production models require a deeper understanding of ecological interactions between different trophic levels, as well as careful management of species combinations and environmental conditions. For many operators, the transition from traditional extensive systems to more integrated production models may therefore require additional technical guidance and practical demonstration activities. An additional challenge is linked to the hybrid nature of lagoon aquaculture systems, which are functionally closer to fisheries than to conventional aquaculture. In the Lefkada lagoon, production is largely based on extensive practices that rely on natural ecosystem productivity and fish migration dynamics, rather than controlled farming conditions. This dual character may create regulatory and management complexities, as existing aquaculture frameworks are not always fully adapted to

systems that operate at the interface between fisheries and aquaculture. As a result, planning, licensing and management approaches may require further adaptation to adequately reflect the specific characteristics of lagoon-based production systems.

Infrastructure limitations may also influence the feasibility of diversifying aquaculture activities. The lagoon currently operates under a relatively low-intensity management regime, and the introduction of new production systems may require investments in equipment, monitoring technologies and logistical support. Market uncertainty related to the commercialisation of non-traditional aquaculture species represents another challenge. Although integrated aquaculture systems may generate environmental benefits and production diversification, the economic viability of such systems ultimately depends on the existence of stable markets and value chains for the products generated.

Finally, the regulatory framework governing aquaculture activities in protected wetland areas may introduce additional administrative complexity. The coexistence of environmental protection regulations and economic development objectives requires careful coordination between competent authorities to ensure that licensing procedures remain transparent and predictable for operators.

Environmental Challenges

Environmental variability represents an inherent challenge in lagoon ecosystems. Fluctuations in salinity, temperature and nutrient concentrations may influence the productivity of aquaculture systems and the ecological balance of the lagoon. Climate change may further intensify these dynamics, potentially affecting water circulation patterns, ecological interactions and the resilience of lagoon habitats.

Economic Viability Challenges

Ensuring the economic sustainability of circular aquaculture systems remains a key challenge. Although integrated production models may improve ecological performance, their financial viability depends on production efficiency, operational costs and market demand for the species produced. Developing effective marketing strategies and strengthening value chains will therefore be important elements for ensuring long-term economic viability.

Technological and Knowledge Challenges

The implementation of innovative aquaculture systems requires access to technical expertise and operational technologies that may not yet be widely available at the local level. Bridging this knowledge gap requires collaboration

between research institutions, technical experts and aquaculture operators, as well as targeted training programmes capable of supporting the adoption of new practices.

Regulatory Challenges

The presence of environmental protection frameworks associated with Natura 2000 and wetland conservation policies may introduce additional regulatory requirements for aquaculture activities. While these regulations play a crucial role in safeguarding biodiversity, they may also complicate licensing procedures and require careful environmental assessments before new production systems can be implemented.

Regional Opportunities

Alongside these challenges, the Lefkada lagoon system also presents several favourable conditions that could support the development of circular aquaculture practices. The existing extensive aquaculture system is already characterised by low environmental impact and strong integration with natural ecosystem processes. This provides a solid foundation for exploring circular production approaches without fundamentally altering the traditional management structure of the lagoon. The environmental suitability analysis carried out within the AZA4ICE project indicated that the lagoon possesses environmental conditions compatible with aquaculture activities. The Site Suitability Index calculated for the pilot site suggests a moderate level of environmental suitability, indicating that production activities can be sustained provided that appropriate environmental management practices are maintained. The modelling of IMTA systems conducted during the project also identified promising species combinations capable of enhancing nutrient recycling within the lagoon ecosystem. The potential integration of extractive species such as bivalves or halophytic plants alongside traditional fish production could contribute to improving ecological efficiency while diversifying production outputs. The fisheries-like nature of lagoon aquaculture systems also represents an opportunity to develop low-impact, ecosystem-based production models that are inherently aligned with circular aquaculture principles.

Another important opportunity lies in the strong cultural and environmental identity associated with the lagoon landscape. Traditional aquaculture practices represent an integral part of the local heritage and could be further valorised through sustainable branding initiatives, eco-tourism activities and the promotion of high-quality lagoon products linked to environmentally responsible production methods. Finally, the stakeholder engagement activities carried out within the AZA4ICE project revealed a generally positive attitude among local actors towards

the exploration of circular aquaculture approaches. This level of interest and openness provides a favourable social and institutional context for future initiatives aimed at strengthening the sustainability and resilience of aquaculture in the Lefkada lagoon system.

Strong Stakeholder Motivation

The participatory activities carried out within the AZA4ICE project demonstrated a strong level of stakeholder engagement and willingness to explore innovative aquaculture solutions. Local operators, public authorities, and research institutions expressed interest in collaborative initiatives that could support the development of environmentally sustainable aquaculture practices while maintaining the cultural identity associated with traditional lagoon fisheries.

Lefkada Positioning Potential

The Lefkada lagoon system also holds potential to position itself as a regional example of environmentally responsible lagoon aquaculture. By combining traditional knowledge with scientific innovation and participatory governance approaches, the area could serve as a pilot case for the development of circular aquaculture models in Mediterranean coastal lagoons. Such positioning could attract research initiatives, funding opportunities and sustainable tourism activities linked to the promotion of environmentally friendly aquaculture practices.

5. Current Legal, Regulatory and Licensing Framework

Aquaculture activities in Greece are regulated through a combination of national legislation (Law 4282/2014 on Aquaculture Development), sectoral planning instruments, notably the Special Framework for Spatial Planning and Sustainable Development for Aquaculture (2011), and European Union directives. These measures, including the EU Strategic Guidelines for Aquaculture, are aimed at ensuring environmental protection, sustainable resource management, and the sustainable development of the sector. In addition to the aforementioned legal instruments, aquaculture activities in Greece are also subject to the provisions of Legislative Decree No. 420/1970 (Fisheries Code), particularly Article 35. This legislation remains highly relevant for activities carried out in waters rich in fish resources, including transitional environments such as lagoons. Its application is especially important in lagoon systems like Lefkada, where aquaculture practices are functionally and historically linked to fisheries activities, production systems must also comply with conservation regulations associated with protected areas and wetland ecosystems.

The regulatory framework seeks to balance economic development with the protection of sensitive coastal and marine ecosystems, particularly in areas characterised by high ecological value such as coastal lagoons and wetlands, in alignment with the Marine Strategy Framework Directive (2008/56/EC). The licensing process for aquaculture installations in Greece typically involves several administrative stages and the participation of multiple competent authorities, as mandated by the Hellenic Ministry of Rural Development and Food. Aquaculture operators are required to comply with spatial planning regulations, environmental protection legislation (Law 4014/2011 on environmental licensing), and water management policies derived from the EU Water Framework Directive (2000/60/EC). In most cases, licensing procedures include mandatory Environmental Impact Assessments (EIA), technical project evaluations, and consultations with competent environmental authorities before the authorisation of production activities, ensuring adherence to the Directive 2011/92/EU.

In lagoon environments such as the Lefkada lagoon system, aquaculture activities must also comply with conservation regulations associated with protected areas and wetland ecosystems. The lagoon is part of the wider network of coastal wetlands protected under European environmental legislation, including Natura 2000 provisions (Birds Directive 2009/147/EC and Habitats Directive 92/43/EEC), which impose specific requirements aimed at safeguarding biodiversity, habitat integrity, and ecological processes. As a result, aquaculture development in such areas must demonstrate compatibility with conservation objectives through appropriate assessments and ensure that production activities do not compromise the Good Ecological Status (GES) of the ecosystem as defined by EU environmental standards. The introduction of circular aquaculture systems, including IMTA, may require additional consideration within existing regulatory frameworks. Innovative production models that integrate multiple species or introduce new farming components may not always be explicitly addressed by current licensing procedures defined in older national statutes. Ensuring that regulatory systems are capable of accommodating such innovations, a priority highlighted in the European Green Deal and in the Farm to Fork Strategy, while maintaining strict environmental safeguards represents an important aspect of future aquaculture governance. Compliance with these evolving standards is essential for the transition toward a circular blue economy.

National and Regional Legislation

The regulatory framework for aquaculture in Greece is primarily defined at the national level through sectoral policies and spatial planning instruments that guide the development and organisation of aquaculture activities. One of the key policy instruments is the Special Framework for Spatial Planning and Sustainable Development for Aquaculture, which establishes strategic guidelines for the spatial organisation of aquaculture activities and promotes the creation of organised aquaculture development areas. Within this framework, specific zones known as

Areas for Organised Aquaculture Development (POAY) are designated to concentrate aquaculture activities and ensure coordinated environmental management. These zones aim to reduce spatial conflicts, improve monitoring and facilitate the implementation of integrated management approaches for aquaculture development.

At the regional level, administrative responsibilities related to aquaculture management are exercised by the Region of the Ionian Islands, which oversees the implementation of national policies, participates in licensing procedures and coordinates regional development strategies. Regional authorities also collaborate with national ministries responsible for fisheries, aquaculture and environmental protection to ensure compliance with regulatory requirements. Additional responsibilities related to environmental monitoring and wetland management may involve specialised environmental authorities responsible for the protection of Natura 2000 sites and coastal ecosystems. These institutions play an important role in evaluating the ecological compatibility of aquaculture activities and ensuring that environmental regulations are effectively implemented.

Regulatory Framework for Innovative Systems

While the existing regulatory framework provides general guidance for aquaculture development, innovative production systems such as IMTA may present new regulatory considerations. Integrated aquaculture models combine multiple species performing different ecological functions, which may not always fit easily within licensing categories designed for single-species production systems. For example, the integration of fed species with extractive organisms such as bivalves or halophytic plants may require the simultaneous authorisation of different types of aquaculture activities within the same production area. Similarly, environmental monitoring requirements may need to be adapted to account for the ecological interactions between species and the overall nutrient dynamics of integrated systems. Addressing these regulatory challenges requires close collaboration between competent authorities, research institutions and aquaculture operators in order to ensure that licensing procedures remain clear, transparent and compatible with innovative aquaculture approaches.

Proposed Regulatory Solutions

In order to facilitate the implementation of circular aquaculture systems in the Lefkada lagoon, several regulatory improvements should be considered. One potential approach involves strengthening the integration between aquaculture licensing procedures and spatial planning instruments that identify suitable areas for aquaculture development. The results of the AZA4ICE analyses could support this process by providing scientific information on site suitability, species compatibility and circularity assessment. Another important step could involve the development of specific guidelines for the evaluation of integrated aquaculture

systems within environmental assessment procedures. Such guidelines would help competent authorities assess the environmental performance of circular production models and ensure that licensing decisions are based on consistent evaluation criteria. Finally, improving coordination between national ministries, regional authorities and environmental management bodies could contribute to streamlining administrative procedures and reducing uncertainty for operators interested in exploring innovative aquaculture approaches.

6. Current Status of Aquaculture Enterprises

Aquaculture activities in the Lefkada lagoon are primarily based on traditional extensive practices that have historically developed within Mediterranean lagoon ecosystems. These production systems rely largely on natural ecological processes and have been adapted over time to the environmental characteristics of shallow coastal lagoons. Traditional lagoon fisheries typically exploit natural fish migration patterns between the marine environment and the lagoon system. Fish enter the lagoon during specific periods of their life cycle and are subsequently harvested using traditional trapping systems positioned at lagoon inlets. This production model relies primarily on the natural productivity of the lagoon ecosystem. The existing production system is characterised by relatively low environmental impact and minimal infrastructure requirements. Because production relies on natural ecological processes rather than intensive farming methods, these systems are generally considered compatible with the ecological characteristics of coastal wetlands. However, production volumes remain relatively modest, and economic returns may be limited compared to more intensive aquaculture systems. For this reason, opportunities exist to enhance the productivity and resilience of the lagoon aquaculture sector through the diversification of species and the gradual introduction of complementary production components. The integration of extractive species such as bivalves or halophytic plants could contribute to improving the ecological efficiency of the system while generating additional production outputs. Such diversification could increase economic resilience while maintaining the ecological balance of the lagoon environment.

Circularity Readiness Profile

The analysis carried out within the AZA4ICE project suggests that the Lefkada lagoon possesses several characteristics that could support the gradual adoption of circular aquaculture practices. The existing extensive production model already operates in close interaction with natural ecosystem processes, providing a favourable foundation for the implementation of integrated aquaculture approaches. In particular, the relatively low environmental pressure associated with current practices reduces the risk of ecological imbalances and creates favourable conditions for the introduction of additional trophic components aimed at

enhancing nutrient recycling. However, the transition towards circular production systems would require targeted technical support, pilot demonstrations and stakeholder engagement processes capable of supporting the gradual adoption of new practices.

7. Vision for Circular Aquaculture in Lefkada

The long-term vision for aquaculture development in the Lefkada lagoon is based on the gradual transition towards circular and ecosystem-based production systems that combine economic viability with environmental sustainability. This vision builds upon the ecological characteristics of the lagoon and the traditional knowledge associated with lagoon fisheries while introducing innovative approaches capable of enhancing resource efficiency. In this context, it is essential to recognise that aquaculture in the Lefkada lagoon operates as a fisheries-based system, relying on natural productivity, hydrodynamic processes and fish migration patterns rather than controlled farming conditions. The transition towards circular aquaculture must therefore be adapted to this specific context, avoiding the direct transfer of intensive marine aquaculture models and instead promoting solutions that are compatible with extensive, ecosystem-driven production systems. Circular aquaculture approaches aim to maximise resource efficiency by promoting nutrient recycling and integrating multiple trophic levels within aquaculture production systems. By combining species that occupy different ecological niches, circular systems can transform organic and inorganic waste into additional biomass, thereby improving overall system productivity while reducing environmental pressures. The introduction of IMTA systems could allow the combination of fed species with extractive organisms capable of utilising organic and inorganic waste. In lagoon environments, such systems may involve the integration of fish production with filter-feeding bivalves and halophytic plants capable of absorbing dissolved nutrients. At the same time, the vision for circular aquaculture in Lefkada emphasises the importance of preserving the cultural and ecological heritage associated with traditional lagoon fisheries. Rather than replacing existing production systems, circular approaches are intended to complement and strengthen traditional practices while improving their environmental and economic sustainability. while improving their environmental and economic sustainability and maintaining the strong ecological integration that characterises lagoon-based production systems.

8. Potential of C-AZA Results

The application of the AZA4ICE methodology to the Lefkada pilot site provided valuable insights into the environmental suitability of the lagoon for circular aquaculture development. The site suitability analysis integrated environmental

parameters, water use compatibility and infrastructure availability to evaluate the overall potential for aquaculture activities. The results indicated an acceptable level of suitability, suggesting that the lagoon can support sustainable aquaculture development when appropriate environmental management practices are maintained. In addition to the spatial suitability assessment, the species suitability analysis identified several candidate species that could potentially be integrated into circular aquaculture systems based on their environmental requirements and ecological functions. The modelling of IMTA configurations highlighted a promising combination involving European seabass (*Dicentrarchus labrax*), Pacific oyster (*Magallana gigas*) and halophytic plants such as *Salicornia* spp. This configuration demonstrated favourable characteristics in terms of nutrient recycling, ecological compatibility and potential economic value. In such a system, seabass would represent the fed component generating organic and inorganic nutrients, oysters would function as filter feeders capable of removing particulate organic matter from the water column, and halophytic plants would absorb dissolved nutrients, contributing to improving overall nutrient balance within the system. These results provide a strong scientific basis for exploring pilot implementation of circular aquaculture systems within the lagoon environment. Demonstration projects based on these configurations could generate valuable information on environmental performance, operational feasibility and economic viability, supporting future decisions on the potential expansion of circular aquaculture approaches in the Lefkada lagoon system.

9. Proposed Actions

Key Actions and Interventions

The proposed actions translate the results of the AZA4ICE environmental suitability assessment, species modelling analysis and stakeholder engagement process into a structured operational pathway for the development of circular aquaculture in the Lefkada lagoon system. The actions respond directly to the main needs identified during the pilot activities, including the need to strengthen technical knowledge related to circular aquaculture practices, improve environmental monitoring capacities, reinforce coordination between institutional actors and aquaculture operators, and test in practice the feasibility of circular aquaculture systems adapted to lagoon ecosystems. Particular attention is given to the ecological characteristics of the Lefkada lagoon, which represents a sensitive coastal wetland environment where aquaculture activities must remain compatible with environmental conservation objectives and with other socio-economic uses of the lagoon area. For this reason, the proposed interventions combine technical innovation, environmental safeguards and participatory governance mechanisms in order to ensure that aquaculture development remains environmentally sustainable while supporting the economic resilience of local production systems. Overall, the actions are designed to support a gradual

transition from traditional extensive aquaculture practices towards more circular and ecosystem-based production models. Rather than replacing existing lagoon management systems, the proposed approach seeks to build upon the ecological characteristics of the lagoon and the existing knowledge of local operators, introducing complementary practices that enhance nutrient recycling, production diversification and environmental monitoring. In this context, it is important to recognise that lagoon aquaculture systems in Lefkada operate at the interface between fisheries and aquaculture, relying largely on natural ecosystem productivity and traditional fish capture dynamics. The proposed actions therefore adopt a context-specific approach that does not aim to impose conventional aquaculture models, but rather to adapt circular aquaculture principles to a system that is structurally closer to fisheries. This implies the development of flexible management solutions, the adaptation of regulatory and monitoring approaches, and the integration of traditional ecological knowledge with innovative circular production practices.

The proposed interventions are structured around five complementary areas of action: strengthening local technical capacity, testing integrated aquaculture systems through demonstrative pilot facilities, promoting community awareness and participation, reinforcing environmental monitoring systems, and establishing coordination mechanisms capable of supporting long-term governance of circular aquaculture initiatives. These actions are conceived to be implemented in parallel over a period of approximately twenty-four months, allowing the gradual development of pilot initiatives while simultaneously establishing the institutional and technical foundations required for the future operationalisation of C-AZA in the Lefkada lagoon system.

Action 1: Capacity Building Program

Objective: *Strengthen local technical capacity and facilitate the adoption of circular aquaculture practices among lagoon operators and institutional stakeholders.*

The transition towards circular aquaculture practices in the Lefkada lagoon requires the strengthening of local technical capacity and institutional knowledge. During the stakeholder consultation carried out within the AZA4ICE pilot activities, several participants expressed strong interest in sustainable aquaculture approaches. However, discussions also revealed that many operators and local actors have limited technical knowledge regarding the practical implementation of IMTA systems and other circular production models. For this reason, a structured capacity-building programme is proposed in order to provide a comprehensive learning pathway combining scientific knowledge, practical guidance and peer exchange among stakeholders. The programme aims to facilitate the gradual adoption of circular aquaculture practices among lagoon operators while also improving the understanding of circular production principles among institutional stakeholders involved in aquaculture governance. Training activities will focus on

the ecological functioning of circular aquaculture systems and the design and management of IMTA configurations adapted to lagoon environments. Particular attention will be given to nutrient recycling processes within aquaculture systems, species compatibility in integrated production models, water quality monitoring practices and the operational management of multi-species aquaculture systems. The programme will also explore the economic opportunities associated with production diversification, including the potential market value of extractive species such as bivalves and halophytic plants. In addition, the capacity-building activities will provide guidance on the regulatory framework governing aquaculture development and on potential funding opportunities supporting sustainable aquaculture initiatives.

The programme will target aquaculture operators active in the lagoon, technical staff from public authorities, researchers, and other stakeholders involved in lagoon management. Training will be delivered through a combination of workshops, field demonstrations and online seminars in order to facilitate knowledge exchange between scientists, practitioners and institutions. Also, It is essential to include targeted educational programs for students and young people in Lefkada. If meaningful and long-term change is to be achieved, efforts must focus on the younger generation, fostering environmental awareness, encouraging active participation and cultivating ecological consciousness from an early age, while also attracting new talent and fresh perspectives to the sector. By empowering youth through education and engagement, the initiative can create lasting social and environmental impact within the local community.

The estimated budget for the implementation of this action ranges between €40,000 and €60,000.

Action 2: Demonstrative IMTA Facilities

Objective: *Validate the feasibility of circular aquaculture systems within the Lefkada lagoon environment.*

The establishment of a demonstrative IMTA system represents a central component of the Action Plan. The objective of this action is to validate the feasibility of circular aquaculture systems within the environmental conditions of the Lefkada lagoon while providing a practical demonstration of integrated production models. The pilot facility will integrate a fed species with extractive organisms capable of utilising organic and inorganic nutrients released during aquaculture production. Based on the modelling results generated within the AZA4ICE project, a promising configuration combines European seabass (*Dicentrarchus labrax*) with filter-feeding bivalves (*Magallana gigas*) and halophytic plants such as Salicornia. This trophic structure enhances nutrient recycling processes while promoting ecological integration within the lagoon ecosystem. The demonstrative system will operate at a limited experimental scale within the lagoon in order to allow careful observation of production performance,

ecological interactions and operational feasibility. The pilot facility will generate valuable data on species growth performance, nutrient dynamics and system efficiency under integrated production conditions. Environmental monitoring activities will accompany the operation of the pilot system in order to assess water quality parameters, nutrient dynamics and ecological interactions between species. These monitoring activities will provide scientific evidence on the environmental performance of circular aquaculture systems within lagoon environments. In addition to its experimental function, the pilot facility will also serve as a learning platform where aquaculture operators, policy makers and researchers can observe the functioning of integrated aquaculture systems and exchange practical knowledge on circular production practices. The design of the demonstrative system will take into account the extensive and fisheries-based nature of lagoon aquaculture in Lefkada, ensuring that the pilot remains compatible with existing management practices and hydrodynamic conditions rather than introducing fully intensive production models.

The estimated investment cost for this action ranges between €120,000 and €180,000.

Action 3: Community-Based Circularity Initiatives

Objective: *Enhance social acceptance of circular aquaculture and strengthen community participation in sustainable lagoon management.*

The long-term success of circular aquaculture initiatives depends not only on technical feasibility but also on the level of social acceptance and engagement among local communities. Lagoon ecosystems are closely connected to local cultural identity and economic activities, making community participation an important component of sustainable management strategies. Building on the positive engagement observed during the stakeholder consultation process, the LiRRIE events, a series of community-based initiatives will be developed to increase awareness of circular aquaculture concepts and promote local participation in lagoon conservation efforts. These initiatives will focus on communicating the environmental benefits associated with circular aquaculture systems, particularly their contribution to nutrient recycling, ecosystem restoration and sustainable food production. Activities may include educational workshops, public presentations, outreach initiatives involving schools and local organisations, and visits to the demonstration site. Participatory initiatives such as lagoon clean-up events or environmental awareness campaigns may also be organised in order to strengthen the relationship between aquaculture activities and environmental stewardship within the lagoon system.

The estimated budget for this action ranges between €20,000 and €30,000.

Action 4: Environmental Monitoring and Safeguards

Objective: *Ensure the ecological compatibility of aquaculture activities through structured environmental monitoring and adaptive management.*

Given the ecological sensitivity of lagoon ecosystems, environmental monitoring represents a critical component of the Action Plan. The monitoring framework is designed to ensure that aquaculture activities remain compatible with ecosystem conservation objectives and that circular aquaculture systems contribute positively to the ecological functioning of the lagoon. Monitoring activities will focus on assessing water quality conditions, nutrient dynamics and potential ecological impacts associated with aquaculture operations. Key parameters include dissolved oxygen concentrations, nutrient levels, turbidity, chlorophyll-a concentrations and sediment quality indicators, all of which are particularly relevant for the ecological functioning of lagoon environments. The monitoring programme will support adaptive management practices by providing timely information that allows adjustments to aquaculture operations if environmental thresholds are exceeded. This adaptive approach ensures that production activities remain aligned with environmental protection objectives. Monitoring approaches will also consider the specific dynamics of lagoon ecosystems, including natural variability and fish migration patterns, which are characteristic of systems operating at the interface between fisheries and aquaculture.

In addition to supporting aquaculture management, the monitoring system will contribute to improving scientific knowledge on the ecological dynamics of the Lefkada lagoon and provide useful data for future spatial planning and ecosystem-based management initiatives.

The estimated cost for monitoring activities over the implementation period ranges between €50,000 and €80,000.

Action 5: Commercial Support and Funding Mobilization

Objective: *Strengthen cooperation among institutions, aquaculture operators and local stakeholders through a structured governance mechanism.*

The successful implementation of circular aquaculture initiatives requires effective coordination among public authorities, aquaculture operators, research institutions and local stakeholders. For this reason, a structured governance mechanism will be established in order to facilitate cooperation and information exchange among the different actors involved in lagoon management. A multi-stakeholder coordination platform will be created to support dialogue and joint decision-making regarding aquaculture development in the Lefkada lagoon system. The platform will follow principles similar to the LiRRIE participatory framework applied during the AZA4ICE project and will include representatives of public authorities, aquaculture operators, research institutions and civil society organisations. Through regular meetings, the platform will provide a forum for

discussing the progress of the Action Plan, sharing monitoring results, identifying emerging challenges and coordinating future initiatives supporting circular aquaculture development. The coordination platform will also contribute to identifying funding opportunities capable of supporting pilot initiatives and infrastructure investments required for circular aquaculture development. Potential funding sources include European programmes supporting sustainable aquaculture and blue economy innovation, as well as national and regional funding instruments dedicated to fisheries and coastal management.

Creating a favorable environment for investment and long-term sectoral growth requires the establishment of tailored financial support mechanisms, including targeted funding schemes under relevant national and European programs, alongside a more streamlined and adaptive regulatory framework for innovative aquaculture in Greece. Reducing administrative complexity and improving access to financing would strengthen stakeholder confidence, facilitate the adoption of sustainable practices and enhance the sector's overall development potential.

Also, the vertical integration of lagoon-related activities through the establishment of organized facilities for fish handling, processing, and value-added product development seems useful. Such infrastructure would enhance product quality, strengthen local value chains and create opportunities for the production of high-value traditional products. At the same time, these facilities could operate as visitor-friendly and educational spaces, contributing to public awareness, experiential tourism and knowledge dissemination.

The estimated budget for governance and coordination activities ranges between €30,000 and €50,000.

Responsible Actors

The successful implementation of the proposed actions relies on coordinated collaboration among multiple institutional and local actors. Public authorities responsible for fisheries and aquaculture management will play a central role in facilitating regulatory processes and ensuring alignment with national aquaculture policies and environmental regulations. Research institutions and universities will provide scientific and technical expertise, particularly in relation to environmental monitoring, IMTA system design and the evaluation of ecological interactions. Aquaculture operators will play a key role in implementing pilot activities and testing circular production systems within the lagoon environment. Local communities, civil society organisations and educational institutions will contribute to awareness-raising activities and community engagement initiatives supporting sustainable lagoon management.

Further, it would be important to establish a dedicated management body for the operation and governance of the lagoon, such as a Fisheries Cooperative or a Municipal Enterprise, supported by a clear and sustainable business plan. Such a

structure would provide the institutional and operational framework necessary for the long-term management, economic viability and environmental stewardship of the lagoon ecosystem.

Implementation Timeline

The implementation of the Action Plan is structured over a 24-month period organised into three main phases.

Phase 1: Preparation and Stakeholder Mobilisation (Months 1–6)

During the first phase the governance framework and coordination mechanisms will be formally established. Preparatory activities will include stakeholder meetings, the definition of cooperation agreements between participating actors and the technical planning of the demonstration pilot. Capacity-building activities will begin during this phase, while baseline environmental monitoring will be initiated in order to establish reference conditions for the lagoon ecosystem.

Phase 2: Pilot Implementation and Capacity Development (Months 7–18)

The second phase will focus on the operational implementation of the proposed actions. The IMTA demonstration pilot will be installed and progressively brought into operation. Environmental monitoring will be conducted throughout this phase to evaluate the ecological performance of the integrated system. Training activities will continue with additional technical modules and field-based learning sessions, while community engagement initiatives will promote public awareness and participation.

Phase 3: Evaluation and Knowledge Dissemination (Months 19–24)

The final phase will focus on evaluating the results of the pilot actions and identifying opportunities for further development. Monitoring results and operational experiences will be analysed to assess the feasibility and sustainability of circular aquaculture systems in the lagoon. The results will be disseminated through workshops, technical reports and stakeholder meetings in order to support the replication of successful approaches in other lagoon environments.

Financial Aspects and Funding Resources

The implementation of the proposed actions may be supported through a combination of European, national and regional funding instruments that promote

sustainable aquaculture development, innovation in the blue economy and the protection of coastal ecosystems. Given the strategic importance of sustainable aquaculture within European maritime and environmental policies, several financial mechanisms may contribute to supporting the implementation of the Action Plan. At the European level, funding opportunities are available through programmes dedicated to fisheries, aquaculture and maritime development, including instruments supporting sustainable aquaculture practices, environmental innovation and the circular economy. In particular, financial support may be mobilised through initiatives promoting ecosystem-based aquaculture, climate-resilient coastal economies and sustainable food production systems. Complementary financial resources may also be accessed through research and innovation programmes focusing on marine ecosystems, sustainable aquaculture technologies and circular production models. These programmes may support both pilot initiatives and research activities aimed at improving technical knowledge and environmental monitoring capacities. At the national and regional levels, additional funding opportunities may be available through programmes dedicated to fisheries management, coastal development and environmental protection. These instruments may support investments related to pilot infrastructure, monitoring systems, capacity-building activities and stakeholder engagement initiatives. By combining multiple funding sources, the Action Plan aims to ensure financial feasibility while facilitating the gradual development of circular aquaculture practices within the Lefkada lagoon system.

10. Monitoring and Evaluation

An effective monitoring and evaluation framework is essential to ensure that the implementation of circular aquaculture practices in the Lefkada lagoon remains aligned with environmental sustainability objectives, economic viability and social acceptance. The monitoring system proposed in this Action Plan aims to track environmental conditions, operational performance, economic outcomes and stakeholder engagement throughout the implementation process. The collected information will support adaptive management by allowing decision-makers and stakeholders to identify emerging challenges, evaluate the effectiveness of implemented actions and adjust strategies when necessary. Monitoring activities are organised around four complementary groups of indicators: environmental performance indicators, technical and operational indicators, economic and circularity indicators, and social and governance indicators. Together, these indicators provide a comprehensive overview of the ecological, economic and institutional dimensions of circular aquaculture development within the lagoon system.

Progress indicators

Environmental performance indicators

Environmental monitoring focuses on maintaining the ecological integrity of the lagoon ecosystem while evaluating the potential contribution of circular aquaculture systems to nutrient recycling and water quality improvement. Lagoon environments are particularly sensitive ecological systems where hydrodynamic conditions, nutrient cycling and biological productivity interact closely. For this reason, particular attention is given to key parameters related to water quality, trophic dynamics and ecosystem health. Monitoring these parameters allows the early detection of potential environmental pressures and ensures that aquaculture activities remain compatible with conservation objectives and ecosystem functioning.

Indicator	KPI	Measurement method	Frequency	Responsible
Water quality	Dissolved oxygen (mg/L), turbidity (NTU), temperature	In situ sensors and field measurements	Monthly	Research partners / lagoon managers
Nutrient dynamics	Nitrogen and phosphorus concentrations	Water sampling and laboratory analysis	Quarterly	Research institutions
Phytoplankton dynamics	Chlorophyll-a concentration	Laboratory analysis	Quarterly	Research partners
Ecosystem health	Biodiversity index (fish and benthic organisms)	Field surveys	Annual	Research institutions
Sediment quality	Organic matter content and contaminant levels	Sediment sampling and laboratory analysis	Annual	Accredited laboratories

These indicators allow continuous assessment of whether aquaculture activities remain environmentally sustainable and whether circular aquaculture practices contribute positively to nutrient cycling and ecosystem stability within the lagoon.

The gradual semi-intensive development of selected aquaculture species may contribute to economic resilience, provided that such practices remain environmentally compatible and fully aligned with the traditional character and ecological functions of the lagoon ecosystem.

Also, tt is really important the environmental monitoring especially in the case of

Lefkada, where emphasis should be placed on addressing the growing environmental pressures currently affecting the lagoon ecosystem, especially those linked to ongoing infrastructure interventions, including the installation of the new water supply pipeline within the lagoon area. Establishing effective environmental oversight mechanisms is essential to safeguarding ecosystem resilience and ensuring that circular aquaculture and other sustainable blue economy activities can be developed within a stable and healthy ecological environment.

Technical and operational indicators

Technical and operational indicators are designed to assess the feasibility and effectiveness of circular aquaculture practices introduced within the Lefkada pilot site. These indicators focus on the performance of integrated aquaculture systems, the adoption of circular production practices and the operational efficiency of the proposed IMTA configurations. Monitoring these aspects helps determine whether circular aquaculture systems can be successfully implemented under the ecological and economic conditions of lagoon environments.

Indicator	KPI	Measurement method	Frequency	Responsible
Adoption of circular practices	Number of operators adopting circular aquaculture practices	Operator surveys	Annual	Project coordination
Pilot system performance	Production yield of fed and extractive species (kg/year)	Farm records	Annual	Operators
Feed efficiency	Feed Conversion Ratio (FCR)	Farm records	Annual	Operators
Integration of trophic levels	Biomass ratio between fed and extractive species	Production monitoring	Annual	Research partners
Environmental monitoring tools	Number of farms using environmental monitoring technologies	Surveys	Annual	Project team

These indicators allow the evaluation of operational performance and provide useful information for assessing the scalability and long-term viability of circular aquaculture systems in the lagoon context.

Economic and circularity indicators

Economic monitoring focuses on the ability of circular aquaculture systems to generate economic value while improving resource efficiency and production diversification. Circular aquaculture aims not only to reduce environmental impacts but also to strengthen the economic resilience of aquaculture enterprises by promoting the valorisation of secondary species, improving resource use efficiency and expanding market opportunities.

Indicator	KPI	Measurement method	Frequency	Responsible
Production diversification	Number of species cultivated in integrated systems	Farm records	Annual	Operators
Circular biomass use	Share of extractive species production (%)	Production records	Annual	Operators
Economic performance	Cost per kg of biomass produced	Financial records	Annual	Operators
Revenue diversification	Income generated from secondary species	Financial reports	Annual	Operators
Investment mobilisation	Funding secured for circular aquaculture initiatives (€)	Financial tracking	Annual	Project coordination

These indicators make it possible to evaluate the economic sustainability of circular aquaculture practices and their contribution to local economic development and diversification of lagoon-based production systems.

Social and governance indicators

The successful implementation of circular aquaculture depends not only on technical feasibility but also on effective governance and stakeholder participation. Social and governance indicators therefore focus on measuring the level of stakeholder engagement, knowledge transfer and institutional coordination achieved during the implementation of the Action Plan. Active involvement of aquaculture operators, local authorities, research institutions and civil society organisations is essential to ensure transparency, social acceptance and long-term sustainability of aquaculture development within the lagoon.

Indicator	KPI	Measurement method	Frequency	Responsible
Stakeholder participation	Number of participants in workshops and consultations	Attendance records	Annual	Project coordination
Capacity building	Number of trained stakeholders	Training reports	Annual	Project team
Knowledge dissemination	Number of outreach events and publications	Project reports	Annual	Project coordination
Social acceptance	Stakeholder satisfaction index	Surveys	Biennial	Project team
Institutional coordination	Number of coordination meetings between stakeholders	Meeting reports	Annual	Governance platform

These indicators help ensure that the development of circular aquaculture remains socially supported and institutionally coordinated across different governance levels.

Monitoring review and adaptive adjustments

Monitoring results will be periodically analysed in order to support adaptive management of aquaculture activities and ensure continuous alignment with environmental, economic and social objectives. A multi-stakeholder review process will be established to evaluate monitoring outcomes and discuss potential

adjustments to the implementation of the Action Plan. Regular review meetings involving public authorities, research institutions, aquaculture operators and other relevant stakeholders will provide opportunities to share monitoring results, identify potential risks and coordinate corrective actions where necessary. If environmental monitoring indicates signs of ecosystem stress, such as declining dissolved oxygen levels, excessive nutrient accumulation or changes in phytoplankton dynamics, adaptive management measures should be implemented. These can include adjustments to stocking densities, optimisation of IMTA system components or temporary modifications to production practices in order to maintain ecological balance within the lagoon system. Similarly, if monitoring results reveal limited participation in training programmes or stakeholder engagement activities, communication and outreach strategies should be revised in order to better address local needs and improve accessibility for aquaculture operators and community members.

Financial monitoring will also contribute to adaptive management. In the event of funding constraints or delays in accessing external financial resources, implementation priorities may be adjusted to focus on actions that generate the greatest environmental and social benefits with limited financial investment. At the end of the implementation period, a comprehensive evaluation should be conducted to assess the overall effectiveness of the Action Plan. This evaluation should consider the environmental performance of pilot aquaculture systems, the level of adoption of circular practices and the degree of stakeholder engagement achieved. The results will provide valuable guidance for the potential scaling-up of circular aquaculture approaches within the Lefkada lagoon system and in other Mediterranean lagoon environments with similar ecological characteristics.

11. Conclusion

This Action Plan provides a strategic framework to support the gradual development of circular aquaculture practices within the Lefkada lagoon system. Building upon the results generated through the AZA4ICE methodology, the plan identifies opportunities for enhancing the sustainability, resilience and diversification of lagoon-based aquaculture while maintaining the ecological integrity of this sensitive coastal ecosystem. Lefkada represents a distinctive aquaculture context where traditional extensive lagoon farming practices have developed over centuries in close interaction with natural ecological processes. These systems have historically maintained relatively low environmental impacts and represent an important component of the cultural and socio-economic heritage of the region. At the same time, evolving environmental challenges and economic pressures highlight the need to explore innovative approaches capable of strengthening the long-term viability of aquaculture activities. Circular aquaculture approaches offer a promising pathway for addressing these challenges by promoting more efficient use of resources, encouraging nutrient

recycling and integrating multiple trophic levels within aquaculture production systems. The potential introduction of IMTA configurations adapted to lagoon conditions may contribute to improving environmental performance while creating new economic opportunities through production diversification.

The Action Plan emphasises that the transition towards circular aquaculture should occur progressively and in close alignment with the ecological characteristics of the lagoon ecosystem. Environmental monitoring, scientific research and adaptive management therefore play a fundamental role in guiding decision-making processes and ensuring that aquaculture activities remain compatible with conservation objectives. Equally important is the role of governance and stakeholder participation. Effective collaboration among public authorities, research institutions, aquaculture operators and local communities is essential for creating the institutional conditions necessary to support innovation while maintaining social acceptance and transparency in decision-making processes. Through the combination of scientific knowledge, participatory governance and pilot experimentation, the Lefkada lagoon can serve as an important case study for exploring the application of circular aquaculture principles in Mediterranean lagoon environments. The experience gained through the implementation of this Action Plan may provide valuable lessons for other coastal regions seeking to balance aquaculture development with environmental protection and sustainable resource management. In this perspective, the Lefkada pilot site represents not only an opportunity to improve local aquaculture practices but also a contribution to the broader objective of promoting circular and ecosystem-based aquaculture systems across the Mediterranean region.

Summary and Next Steps

The implementation of this Action Plan will begin with a set of priority actions aimed at strengthening the governance framework and initiating the first technical and operational activities required to support the gradual transition towards circular aquaculture practices in the Lefkada lagoon system. In the short term, initial efforts will focus on reinforcing coordination among key stakeholders, including regional and local authorities, aquaculture operators, research institutions and environmental organisations. Strengthening this coordination is essential to ensure that future aquaculture development is guided by a shared understanding of environmental conditions, socio-economic priorities and regulatory requirements. In this context, the establishment or activation of the local LiRRIE platform will play a central role in facilitating dialogue among stakeholders and providing a structured forum for discussing the implementation of circular aquaculture practices within the lagoon environment. At the same time, priority will be given to improving the environmental monitoring of lagoon conditions. The collection of additional data on water quality, nutrient dynamics and ecosystem health will contribute to refining the assessment of aquaculture carrying capacity

and supporting evidence-based management decisions. Strengthened monitoring activities will also provide essential baseline information for evaluating the environmental performance of future circular aquaculture initiatives. In the following phase, capacity-building activities and technical workshops will be organised in order to support aquaculture operators in exploring the potential integration of extractive species within existing production systems. These initiatives will facilitate knowledge transfer between research institutions and aquaculture practitioners and will help identify practical solutions for implementing circular aquaculture practices adapted to lagoon conditions.

Pilot initiatives aimed at testing small-scale IMTA configurations may also be explored during this phase. Such pilot activities will focus on species combinations that are ecologically compatible with lagoon ecosystems and that present potential economic value, allowing stakeholders to evaluate the feasibility of circular production systems under real operational conditions. Over the medium term, the results generated through monitoring activities, stakeholder engagement and pilot experimentation will provide valuable evidence to guide the progressive development of circular aquaculture practices in the Lefkada lagoon. These experiences will contribute to strengthening technical knowledge, increasing stakeholder confidence and identifying potential opportunities for the gradual scaling-up of integrated aquaculture systems in suitable areas of the lagoon. In parallel, efforts will continue to facilitate access to European and national funding opportunities capable of supporting investments in sustainable aquaculture infrastructure, environmental monitoring technologies and innovation in production practices. Access to financial resources will be an important enabling factor for supporting the long-term implementation of circular aquaculture approaches.

Through these coordinated steps, the Action Plan aims to establish the conditions for a gradual and well-informed transition towards circular aquaculture in the Lefkada lagoon system. The proposed approach seeks to ensure that innovation in aquaculture development remains fully compatible with the ecological characteristics of the lagoon ecosystem while supporting the socio-economic sustainability of local aquaculture activities and coastal communities.

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