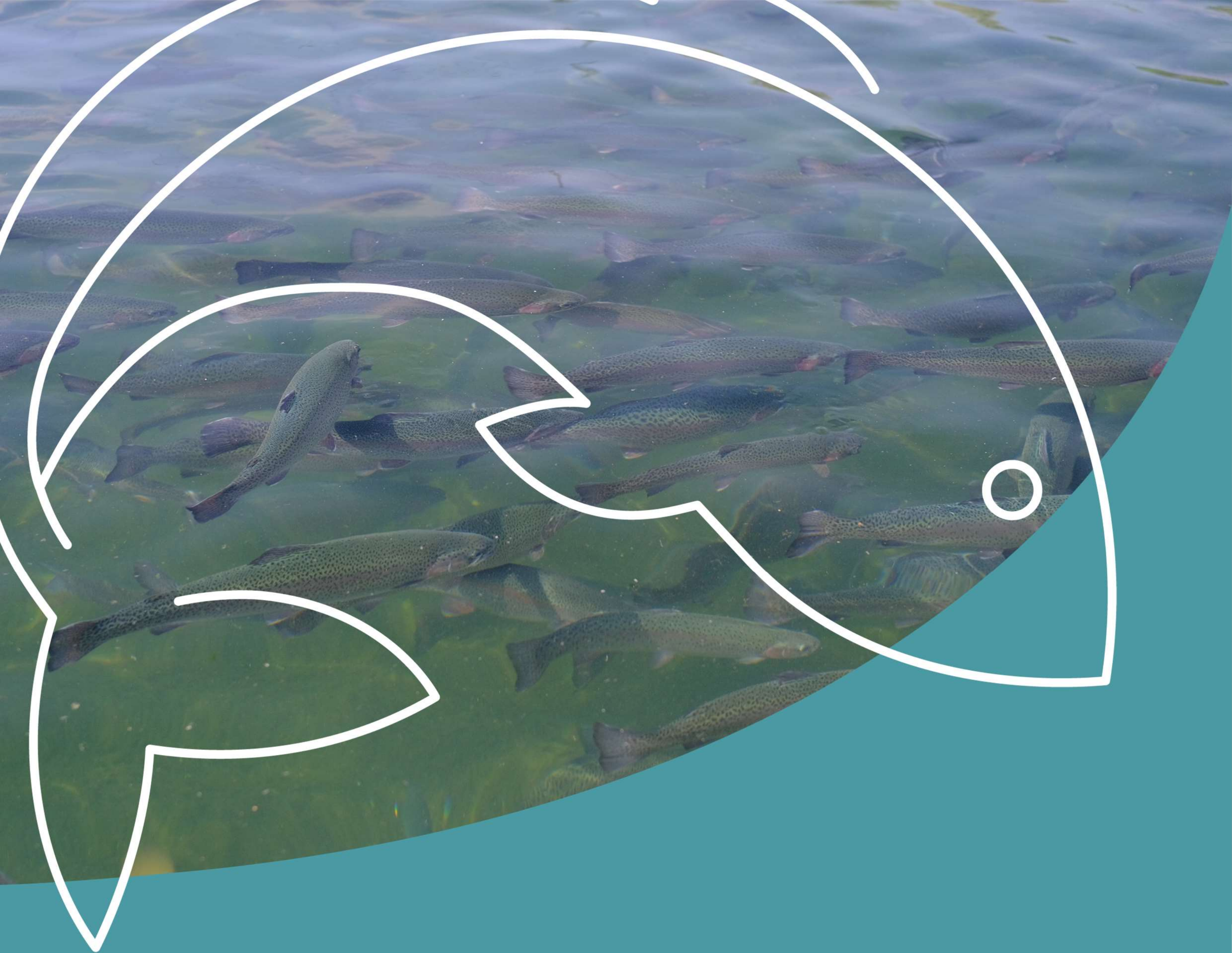

Guidance document on Fish Health Management

AAC 2024

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Guidance document on Fish Health Management to the attention of fish farmers in the light of climate change

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EXECUTIVE SUMMARY

Climate change poses a significant threat to European aquaculture, affecting its productivity and sustainability. Rising temperatures, altered precipitation patterns, and extreme weather events affect fish growth, health, and economic viability, leading to reduced yields and increased mortality rates. Socio-economic impacts extend beyond direct economic losses, affecting communities dependent on aquaculture. Water availability and quality are also affected, necessitating innovative management practices. To mitigate these challenges, European aquaculture must develop resilient systems, foster community engagement, and implement equitable adaptation measures. The European Union (EU) has developed legislation to address animal health in aquaculture, focusing on disease prevention and control. The EU's Blue Economy emphasizes low-impact aquaculture practices, carbon sequestration, and ecosystem preservation.

The adaptation to climate change strategies include developing climate-resilient fish strains, improving water management practices, and adopting innovative technologies. Aquaculture practices, including biosecurity, vaccination, and functional feed ingredients, are essential for maintaining aquatic animal populations and preventing disease outbreaks. Diversifying fish species, integrating new production systems, and implementing advanced technologies can help create a more resilient aquaculture sector in the EU. Integrated Multi-Trophic Aquaculture (IMTA) systems can enhance sustainability, water quality, and reduce environmental impacts, but requires evolving regulatory frameworks and policies. Broodstock selective breeding is a key strategy for improving animal health and addressing climate change challenges in European aquaculture. Genetic improvement involves selecting fish with increased disease resistance, superior growth performance, and adaptability to fluctuating environmental conditions. Benefits include disease resistance, improved immune system, fast growth and feed efficiency, adaptation to climate change, selective breeding, and reduced antibiotic dependence. The integration of genomic technologies and AI in breeding programs has revolutionized the field, enabling more precise breeding strategies and reducing antibiotic dependence.

The Progressive Management Pathway (PMP/AB) by the Food and Agriculture Organization of the United Nations (FAO) aims to reduce disease burden, improve aquatic health and welfare, minimize global spread, attract aquaculture investment opportunities, and meet the goals of the 'One Health' approach.

New diseases in fish farms pose a significant challenge, necessitating effective management strategies. Accurate identification, assessment, management, and prevention are essential. Biosecurity measures, vaccination programs, treatment protocols, preventive measures, continuous research into fish diseases, and education about best practices in disease management and biosecurity can enhance resilience against disease outbreaks and contribute to aquaculture sustainability.

Two different cases of fish disease outbreaks are exposed. Sea bream larvae affected by VNN and European sea bass affected by *Lactococcus garvieae*. The different characteristics of both cases require the implementation of different control measures.

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LIST OF ABBREVIATIONS

AAC	Aquaculture Advisory Council
aCAPs	Development of Aquaculture Climate Adaptation Plans
AMR	Antimicrobial Resistance
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
EC	European Commission
EFSA	European Food Safety Authority
EMFAF	European Maritime and Fisheries Fund
EU	European Union
F2F	Farm to Fork strategy
FAO	Food and Agriculture Organization of the United Nations
GWAS	Genome-Wide Association Studies
ICT	Information and Communication Technologies
IMTA	Integrated Multi-trophic Aquaculture
ISA	Infectious Salmon Anaemia
MANPs	Multi-Annual National Plans
MAPAMA	Ministry of Agriculture, Fisheries, Food and Environment from the Spanish *Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente*
NRL	National Reference Laboratory
PCR	Polymerase Chain Reaction
PMP/AB	Progressive Management Pathway for Improving Aquaculture Biosecurity
QTL	Quantitative Trait Locus
RAS	Recirculating Aquaculture System
SMEs	Small and Medium-sized Enterprises
SOPs	Standard Operating Procedures
SRS	Salmon Rickettsial Septicaemia
UK	United Kingdom

VER	Viral Encephalopathy and Retinopathy
VNN	Viral Nervous Necrosis
WHO	World Health Organisation
WOAH	World Organization for Animal Health

1. INTRODUCTION

Climate change poses a multifaceted threat to European aquaculture, impacting both its productivity and sustainability. The sector is increasingly vulnerable to a range of climatic stressors, including rising temperatures, altered precipitation patterns, and extreme weather events. These changes not only affect the biological aspects of aquaculture but also have significant socio-economic implications for communities reliant on this industry. The cumulative effects of these stressors necessitate a comprehensive understanding of their impacts and the development of adaptive strategies to mitigate them.

One of the primary concerns regarding climate change in aquaculture is the alteration of water temperatures, which can significantly affect fish growth and health. As temperatures rise, the metabolic rates of aquatic species increase, potentially leading to higher oxygen consumption and stress on fish populations. This phenomenon is particularly pronounced in species that are already at the upper limits of their thermal tolerance. For instance, studies have shown that higher temperatures can exacerbate the prevalence of diseases and parasites, further threatening fish health and aquaculture productivity. The implications of these biological changes are profound, as they can lead to reduced yields and increased mortality rates in aquaculture systems, particularly in regions where species are not well-adapted to warmer conditions (Awotunde, 2024; Contreras et al., 2020; Leung & Bates, 2012; Muthoka, 2024; Oyinlola et al., 2020; Quiazon, 2015; Reid et al., 2019).

Moreover, the economic ramifications of climate change on aquaculture are significant. A decline in fish stocks due to climate-induced stressors can lead to increased prices for aquaculture products, affecting both producers and consumers. The economic viability of aquaculture operations is closely tied to environmental conditions; thus, any adverse changes can disrupt market dynamics and threaten livelihoods. For instance, in the UK and Ireland, the aquaculture sector is already experiencing challenges related to climate change, with shifts in species distribution and changes in market demand complicating production strategies (Callaway et al., 2012; Froehlich et al., 2018; Khalid, 2022; Muthoka, 2024).

Furthermore, the socio-economic impacts of climate change extend beyond direct economic losses. Communities that depend on aquaculture for their livelihoods face increased vulnerability as climate change exacerbates existing inequalities and food insecurity. For example, smallholder fish farmers in various regions are particularly susceptible to the adverse effects of climate change, as they often lack the resources to adapt effectively. The socio-economic fabric of these communities can be severely strained as they grapple with fluctuating fish prices, reduced access to resources, and the potential for increased conflict over water and land use (Handisyde et al., 2016; Khalid, 2022; Muthoka, 2024).

In addition to direct impacts on fish health and economic viability, climate change also poses challenges related to water availability and quality. Changes in precipitation patterns can lead to water shortages or flooding, both of which can disrupt aquaculture operations. For instance, increased flooding can result in the loss of infrastructure and contamination of water sources, while prolonged droughts can limit water supply for aquaculture systems. These challenges necessitate innovative management practices that prioritize water conservation and quality control to ensure the sustainability of aquaculture operations in a changing climate (Akinrotimi & Edun, 2015; Bennett et al., 2023; Khalid, 2022; Reid et al., 2019; Zannat, 2023).

Adaptation strategies for European aquaculture must be multifaceted, addressing both the biological and socio-economic dimensions of climate change. This includes the development of resilient aquaculture systems that can withstand climatic stressors, such as the implementation of selective breeding programs to enhance disease resistance and thermal tolerance in fish species. Additionally, fostering community engagement and providing support for smallholder farmers can enhance adaptive capacity and promote sustainable practices within the sector. Policymakers must also consider the broader implications of climate change on food security and economic stability, ensuring that adaptation measures are equitable and inclusive (Bennett et al., 2023; Froehlich et al., 2018; Galappaththi et al., 2020; Handisyde et al., 2016; Pernet & Browman, 2021; Sae-Lim et al., 2017).

The future of European aquaculture in the face of climate change hinges on a proactive approach that integrates scientific research, community engagement, and policy support. By prioritizing resilience and sustainability, the aquaculture sector can navigate the challenges posed by climate change and continue to contribute to food security and economic development in Europe. This requires ongoing collaboration among stakeholders, including researchers, policymakers, and industry representatives, to develop and implement effective adaptation strategies that address the complex interplay of environmental, economic, and social factors (Oyinlola et al., 2020; Reid et al., 2019; Subasinghe et al., 2019).

2. REGULATORY FRAMEWORK

In the scope of this work, we can differentiate between animal health and climate change legislation.

2.1. *Animal health regulatory framework*

European Union (EU) legislation related to animal health in aquaculture has been developed to address the challenges faced by the sector, especially with regard to the prevention and control of diseases, both infectious and parasitic. This legislation is essential to ensure sustainability and food safety, as well as to protect public health and the environment. The legislation is based on principles of biosecurity, epidemiological surveillance and disease management, and is implemented through various directives and regulations affecting EU Member States.

One of the main directives governing fish health is Regulation (EU) 2016/429, known as Animal Health Law, which establishes a framework for the prevention and control of diseases, including aquaculture. This directive requires Member States to implement surveillance programmes to detect notifiable diseases and to put in place control measures to prevent their spread. In addition, the Regulation promotes cooperation between Member States and the European Commission to ensure a coordinated approach to fish health management.

The implementation of this legislation varies between Member States, depending on their capacities and resources. For example, in countries such as Spain and Italy, where aquaculture is a significant part of the fishing economy, robust surveillance systems and biosecurity protocols have been developed to minimise the risk of disease outbreaks. In contrast, other Member States with less experience in aquaculture may face challenges in implementing these regulations, which may result in increased vulnerability to disease. In any case, such differences observed between Member States can be found between different regions within the same state. The heterogeneous development of aquaculture in the regions of the European Union leads to such differences in the application of animal health regulations.

Some of the reasons for these differences include:

- Different species.
- Different environments.
- Different production systems.
- Different size of farms and national or regional sector.
- Different technological development at the farm level.

These differences imply differences at the species' biological level, as well as different requirements (environment, nutrition, welfare, etc.). It also determines differences in the profitability of the enterprises, influencing the measures that can be put in place.

International cooperation also plays a crucial role in fish health management. The EU collaborates with organisations such as the World Organisation for Animal Health (WOAH) to set international standards and share information on aquatic diseases. This collaboration is vital to tackle the spread of diseases across borders and to ensure that aquatic products are safe for consumption.

European legislation on veterinary medicinal products has been developed on two main bases: the fight against antimicrobial resistance and the preservation of animal health and welfare. The two basic rules regulating the use of veterinary medicinal products are the Regulation (EU) 2019/4, regulating the medicated feed, and the Regulation (EU) 2019/6, regulating the Veterinary Medicines. This is aligned with the Farm to Fork strategy (F2F) of the European Union.

These two Regulations came into force at early 2022, so the evaluation of its effects cannot be assessed by obtaining robust results due to the short time of its application.

Anyway, differences of application of the Regulation about Veterinary Medicines and Medicated Feed in the different Member States has been observed.

Regulation in the EU also promotes research and development of alternatives to antibiotics in aquaculture, as overuse of antibiotics can lead to bacterial resistance and public health problems (Mulazzani & Malorgio, 2015). Legislation also encourages the use of probiotics and other biological approaches for disease control, which can contribute to a more sustainable aquaculture that is less dependent on chemical treatments (Radosavljević et al., 2019).

2.2. *Environmental and sustainability regulatory framework*

The Aquaculture Advisory Council (AAC) report on "European Aquaculture: Climate Change Adaptation and Mitigation" (Huntington, 2022) highlights the need to integrate environmental considerations into fish health management. This report highlights that climate change may exacerbate the incidence of diseases in aquaculture, which in turn may affect the production and sustainability of the sector. It is therefore essential that aquaculture health policies are aligned with climate change adaptation strategies to ensure the resilience of the sector.

The key EU policies that relate to fish farming and climate change include:

- **EU Biodiversity Strategy for 2030**: This strategy aims to address the main drivers of biodiversity loss and includes measures to protect and restore nature, enabling transformative change to support biodiversity globally.

- **EU's Blue Economy**: This policy emphasizes the importance of high standards in product quality and animal health in European aquaculture. It advocates for the development of low-impact aquaculture practices, such as low-trophic and organic aquaculture, which contribute to sustainability goals.

- **Strategic Guidelines for a More Sustainable and Competitive EU Aquaculture (2021-2031)**: This document outlines the necessity to minimize the negative effects of aquaculture on climate change and highlights the potential for carbon sequestration through low-trophic aquaculture practices. It also emphasizes the need for research on the impact of climate change on fish health.

The European Council adopted the European Climate Law in June 2021, aiming for a climate-neutral EU by 2050 and a 55% reduction in net greenhouse gas emissions by 2030. This is part of the European Green Deal, which focuses on a clean, circular economy, biodiversity restoration, and pollution reduction. The Farm to Fork Strategy aims to transition to a sustainable food system with a positive environmental impact, biodiversity restoration, food security, nutrition, and public health. Other key EU policies include the Organic Action Plan, EU Biodiversity Strategy for 2030, and the EU's Blue Economy. The EU Integrated Maritime Policy also addresses climate change, with the Marine Strategy Framework Directive requiring Member States to specify climate change impacts in their national marine strategies (Huntington, 2022).

The Organic Action Plan (2021) reinforces organic aquaculture by supporting breeding and animal welfare, promoting polyculture and multi-trophic aquaculture (IMTA), and hatcheries and nurseries activities for juveniles. The EU Biodiversity Strategy for 2030 addresses the main drivers of biodiversity loss by implementing an enhanced governance framework, filling policy gaps, consolidating existing efforts, and ensuring full implementation of existing legislation.

The European Climate Law (2021) aims to achieve a climate-neutral EU by 2050 and a reduction of net greenhouse gas emissions by at least 55% by 2030. The European Green Deal (2019) provides an action plan to boost resource efficiency, transition to a clean, circular economy, restore and preserve ecosystem biodiversity, and reduce pollution. The Farm to Fork strategy (2020) is part of the Green Deal, focusing on food safety, animal and plant health, and effective internal markets.

The EU's Blue Economy (2021) highlights the high standards in product quality and animal health of European aquaculture but also emphasizes the need for diversification. Low-impact aquaculture, such as low-trophic, multi-trophic, and organic aquaculture, could contribute to the European Green Deal and the farm-to-fork strategy, leading to a sustainable blue economy. The new strategic guidelines encourage circular practices in aquaculture, including the production of bio products and biofuels.

Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2031 focus on climate change adaptation and mitigation, minimizing potential negative effects of aquaculture on climate change through carbon-sequestration through low-trophic types of aquaculture and preserving ecosystems through pond and wetlands aquaculture. Additionally, research gaps on the potential impact of climate change on fish health are highlighted.

3. IMPACT OF CLIMATE CHANGE ON FISH HEALTH

The impact of climate change on fish health is a multifaceted issue that encompasses a range of direct and indirect effects. These effects are primarily driven by alterations in environmental conditions, including temperature fluctuations, changes in water quality, and the frequency of extreme weather events. The physiological responses of fish to these changes can significantly influence their growth, reproduction, and overall health, thereby affecting aquaculture productivity and sustainability.

One of the most critical direct impacts of climate change on aquaculture is the alteration of water temperature, which plays a vital role in the metabolic processes of fish. Elevated temperatures can enhance the metabolic rates of fish, leading to increased growth rates up to a certain threshold, beyond which stress responses may occur, resulting in reduced growth and increased mortality rates. For instance, studies have shown that tilapia farming in regions experiencing extreme cold weather has resulted in reduced feeding and growth due to metabolic stress. Moreover, the physiological stress induced by high temperatures can exacerbate the susceptibility of fish to diseases and parasites, further complicating aquaculture management (Cascarano et al., 2021; Islam, 2024; Pimolrat et al., 2013; Reid et al., 2019).

In addition to temperature, changes in water quality due to climate change can severely impact fish health. Increased nutrient excess from extreme weather events can lead to harmful algal blooms, which produce toxins detrimental to fish health and can result in mass die-offs. Furthermore, fluctuations in salinity and dissolved oxygen levels, often exacerbated by climate change, can create hostile environments for aquaculture species, leading to decreased survival rates and lower productivity (Callaway et al., 2012; Maulu et al., 2021; Reid et al., 2019).

Indirectly, climate change can affect fish aquaculture through its impact on feed availability and costs. As climate change alters the distribution and abundance of wild fish stocks, the availability of fishmeal and other feed ingredients may become less predictable, leading to increased costs for aquaculture operations. This economic strain can further limit the ability of fish farmers to implement necessary adaptations to their practices, thereby exacerbating the vulnerability of aquaculture systems to climate change impacts (Asiedu et al., 2018; Mehrim & Refaey, 2023).

The socio-economic implications of climate change on aquaculture are particularly pronounced in developing regions, where small-scale fish farmers often lack the resources and knowledge to adapt effectively. In Ghana, for example, small-scale aquaculture operations face significant challenges due to climate-induced flooding, droughts, and increased operating costs, which threaten their livelihoods and food security. Similarly, in Southeast Asia, aquaculture systems are ranked among the most vulnerable to climate change impacts, with many farmers struggling to cope with the changing environmental conditions. This highlights the urgent need for targeted support and capacity-building initiatives to enhance the adaptive capacity of vulnerable communities engaged in aquaculture (Asiedu et al., 2018; Lebel et al., 2018; Nadarajah & Eide, 2020; Rahman et al., 2021).

Adaptation strategies are essential for mitigating the impacts of climate change on fish aquaculture. These strategies may include the development of climate-resilient fish strains, the implementation of improved water management practices, and the adoption of innovative technologies such as remote sensing and GIS for site selection. Furthermore, fostering collaboration among stakeholders, including government agencies, researchers, and fish farmers, can facilitate the sharing of knowledge and resources necessary for effective adaptation (Galappaththi et al., 2020; Hossain et al., 2021; Rahman et al., 2021).

4. CURRENT PREVENTIVE MEASURES

Individual preventive measures in aquaculture include practices such as biosecurity, vaccination or use of functional feed ingredients.

4.1. Biosecurity measures

Biosecurity is defined as a set of management and physical measures designed to mitigate the risk of introduction of pathogenic agents into, or spread within, or release from, aquatic animal populations (WOAH, 2024a).

Biosecurity at the farm level contributes to national health standards in several significant ways (WOAH, 2024):

Figure 1. Main risk pathways for pests and diseases to spread on to, within and from a farm (Subasinghe & Shinn, 2023).

1. **Prevention of disease introduction**: By implementing robust biosecurity measures, aquaculture establishments can prevent the introduction of pathogenic agents into their facilities. This is crucial for maintaining the health of aquatic animal populations and preventing outbreaks that could affect broader ecosystems and human health.

2. **Control of disease spread**: Effective biosecurity practices help control the spread of diseases within aquaculture systems. By isolating sick animals, managing movements, and ensuring proper health monitoring, establishments can contain potential outbreaks, thereby reducing the risk of transmission to other farms and wild populations.

3. **Compliance with Regulations**: Establishments that adhere to biosecurity protocols are more likely to comply with national and international health regulations. This compliance is essential for trade, as many countries require proof of biosecurity measures to prevent the importation of diseases.

4. **Data collection and surveillance**: Biosecurity plans often include health monitoring and documentation of disease occurrences. This data is valuable for national health authorities to assess the health status of aquatic populations, identify emerging threats, and develop appropriate responses.

5. **Public confidence and market access**: Strong biosecurity measures enhance public confidence in the safety of aquaculture products. This can lead to better market access and trade opportunities, as consumers and regulators are more likely to trust products from establishments with proven biosecurity practices.

6. **Environmental health**: By preventing the spread of diseases from aquaculture to wild populations, biosecurity contributes to the overall health of aquatic ecosystems. Healthy ecosystems are vital for biodiversity and the sustainability of fisheries, which are important for national food security and economic stability.

7. **Emergency preparedness**: Establishments with well-defined biosecurity plans are better prepared to respond to disease outbreaks. This preparedness can mitigate the impact of such events on national health and economic stability, as rapid response can prevent widespread losses.

The key biosecurity measures recommended for aquaculture establishments include (WOAH, 2024b):

1. **Health status of aquatic animals**: Only introduce aquatic animals with a known health status that is equal to or higher than the existing animals in the establishment. If the health status is unknown, these animals should be placed in quarantine.

2. **Quarantine procedures**: Quarantined aquatic animals should be managed to mitigate disease risks, which may include treatment for external parasites.

3. **Biosecure transport**: Ensure that the transport of aquatic animals is biosecure, avoiding exposure to and release of pathogenic agents.

4. **Movement of aquatic animals**: Movement between different populations within the establishment should be carefully considered maintaining the highest possible health status.

5. **Isolation of sick populations**: Isolate aquatic animal populations that show clinical signs of disease until the cause is identified and resolved.

6. **Removal of moribund or dead animals**: Moribund or dead aquatic animals should be removed from production units promptly and disposed of in a biosecure manner.

7. **Development of a biosecurity plan**: A comprehensive biosecurity plan should be developed, documenting transmission pathways, risk analysis, mitigation measures, and emergency procedures.

8. **Standard Operating Procedures (SOPs)**: Establish SOPs for routine management processes to support the effectiveness of the biosecurity plan.

9. **Training of personnel**: Ensure that all personnel are trained in the application of SOPs and understand their roles in implementing biosecurity measures.

10. **Health monitoring**: Implement health monitoring to track the health status of aquatic animals, including disease surveillance and recording of clinical signs, morbidity, and mortality.

11. **Routine review and auditing**: Regularly review and audit the biosecurity plan to ensure compliance and effectiveness, making adjustments as necessary based on operational changes or new disease risks.

The main biosecurity measures recommended for fish farms include (Tavornpanich et al., 2020):

1. **External biosecurity (Bio-exclusion)**: This involves measures to prevent the introduction of infectious agents into the farm. Key actions include:
   - Controlling access to the farm to limit contact with external environments.
   - Implementing strict hygiene protocols for equipment and personnel entering the farm.
   - Monitoring and managing wildlife interactions to reduce pathogen exposure.
2. **Internal biosecurity (Bio-management)**: This focuses on preventing the spread of infectious agents within the farm. Important strategies include:
   - Segregating different production groups to minimize cross-contamination.
   - Regular health monitoring and diagnostics to detect and manage disease outbreaks early.
   - Implementing effective waste management practices to prevent pathogen spread.
3. **Health management practices**: Regular health assessments and vaccinations where applicable, along with maintaining optimal environmental conditions to reduce stress and susceptibility to diseases.
4. **Training and awareness**: Educating farm staff about biosecurity protocols and the importance of disease prevention to ensure compliance and effective implementation of measures.

4.2. Vaccination

The use of vaccines is one of the most important tools to prevent diseases to appear. Vaccines have proven their value in controlling diseases in aquaculture, both for viral and bacterial diseases.

The development of efficient vaccines against the new and emerging pathogens is crucial to reduce the impact of climate change to aquaculture farms.

As climate change will alter disease patterns in European aquaculture farms, the biggest challenge will be to obtain effective vaccines against these new pathogens within a reasonable timeframe.

In this scenario, autologous vaccines have a crucial role to play, at least in the early stages after the emergence of a new disease, until commercial vaccines can be developed.

4.3. Training

Training of the personnel is crucial to control the appearance and spread of fish diseases. Early detection is essential, and this is not possible without proper knowledge of the person in charge of the animals.

A lifelong learning plan must be provided to the workers and stakeholders in order to improve the control of fish diseases.

This training must be applied to all the personnel, including managers, veterinarians, technicians and all the staff involved in the fish farm. The integration of digital platforms for the education and training of fish farmers can also be beneficial, as it allows them to access up-to-date information on management practices and disease prevention.

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5. POTENTIAL NEW PREVENTIVE MEASURES

The European Aquaculture: Climate Change Adaptation and Mitigation of the AAC (Huntington, 2022), states some potential solutions to create a more resilient aquaculture sector in the EU.

5.1. New species

In recent years, the European Union has diversified fish species production in aquaculture to meet market demand, adapt to changing environmental conditions, and promote more sustainable aquaculture. In addition to traditionally farmed species such as salmon, trout, gilthead seabream and turbot, new species have been introduced.

The diversification into less-used, lower-trophic species is also interesting to face the effects of climate change on European aquaculture. Some of these species are mollusk or macroalgae(Huntington, 2022).

In the case of fish, some of those potential species farmed in EU aquaculture include:

- Sole (*Solea solea*)
- Meagre (*Argyrosomus regius*)
- Greater amberjack (*Seriola dumerili*)
- Atlantic cod (*Gadus morhua*)
- European perch (*Perca fluviatilis*)
- Pike-perch (*Sander lucioperca*)

The diversification of species in European aquaculture, better adapted to climatic conditions or with greater adaptability, is a good strategy to face the challenges that climate change will bring.

5.2. New or improved production systems

Open water production

Offshore aquaculture in the EU is increasingly recognized as a critical sector for addressing the challenges posed by climate change to fish health. The integration of advanced technologies and sustainable practices in aquaculture is essential for enhancing fish health and ensuring the resilience of marine ecosystems. As climate change continues to impact marine environments, the EU's aquaculture sector must adapt to maintain productivity and sustainability.

Figure 2. Ocean Farm 1. Offshore salmon farm operated by Salmar Aker Ocean AS (Subasinghe & Shinn, 2023).

Aquaculture has emerged as a vital complement to traditional fisheries, particularly in the context of the EU's commitment to sustainable seafood production. The sector is experiencing rapid growth, with projections indicating that aquaculture will soon surpass wild fisheries as the primary source of seafood globally. This shift is driven by the need to meet increasing seafood demand while alleviating pressure on wild fish stocks. The EU has implemented stringent regulations to ensure that aquaculture practices adhere to high standards of environmental sustainability and fish health, as outlined in various directives. These regulations emphasize the importance of the "One Health" concept, which recognizes the interconnectedness of human, animal, and environmental health (Raposo de Magalhães et al., 2018; Şonea et al., 2021)

The health of farmed fish is significantly influenced by their rearing conditions and the management practices employed. Research indicates that understanding the biological responses of fish to various stressors, including environmental changes, is crucial for improving fish welfare and productivity (Lazado et al., 2024).

RAS

The integration of Recirculating Aquaculture Systems (RAS) technology presents a promising avenue for mitigating the effects of climate change on European aquaculture. RAS technology is designed to minimize water usage and reduce waste, which is critical in the context of increasing freshwater scarcity and environmental degradation driven by climate change (Buric et al., 2015; Martins et al., 2010). By recycling water and nutrients, RAS can significantly lower the ecological footprint of aquaculture operations, making them more sustainable and resilient to climate-induced stressors such as temperature fluctuations and water quality degradation (Ellis et al., 2017; Maulu et al., 2021).

Figure 3. Filtration overview of a Recirculating Aquaculture System farm.

One of the primary advantages of RAS is its ability to maintain optimal environmental conditions for aquatic species, which is particularly important given the unpredictable nature of climate change (Ellis et al., 2017; Martins et al., 2010). For instance, RAS can help manage water temperature and quality, thereby reducing the vulnerability of fish stocks to extreme weather events and other climate-related impacts (Reid et al., 2019). Furthermore, the closed-loop nature of RAS systems allows for better control over disease management and feed efficiency, which are crucial for maintaining productivity in a changing climate (Lal et al., 2024; Nazar et al., 2024).

Overall, the use of RAS technology in European aquaculture not only addresses immediate challenges posed by climate change but also aligns with broader sustainability goals. By reducing water consumption, minimizing waste, and enhancing species resilience, RAS can play a pivotal role in transforming aquaculture into a more sustainable and climate-resilient industry. Therefore, continued investment in RAS and related technologies is essential for the future of aquaculture in Europe amidst the ongoing challenges of climate change (Bohnes et al., 2019; Martins et al., 2010; Maulu et al., 2021).

Although RAS systems are already widely used in aquaculture, in many cases they are used during a short phase of the production cycle. Extending the duration of use of these systems would result in improved batch health management. The less time animals are exposed to adverse environmental conditions, such as those found in offshore farms, the greater the ability to control their health and welfare. Therefore, extending the period spent in a RAS would improve aquaculture health management.

This aligns with Huntington (2022) to cultivate fish in a more controlled environment.

Integrated Multi-Trophic Aquaculture (IMTA)

Integrated Multi-Trophic Aquaculture (IMTA) has emerged as a promising solution to address the challenges posed by climate change and ensure fish health in European aquaculture. This innovative approach involves the simultaneous cultivation of multiple species from different trophic levels, allowing for the recycling of nutrients and organic waste produced by fed species, such as finfish, into food for extractive species, such as shellfish and seaweeds. The IMTA system not only enhances the sustainability of aquaculture practices but also contributes to improved water quality and reduced environmental impacts, which are critical in the context of climate change.

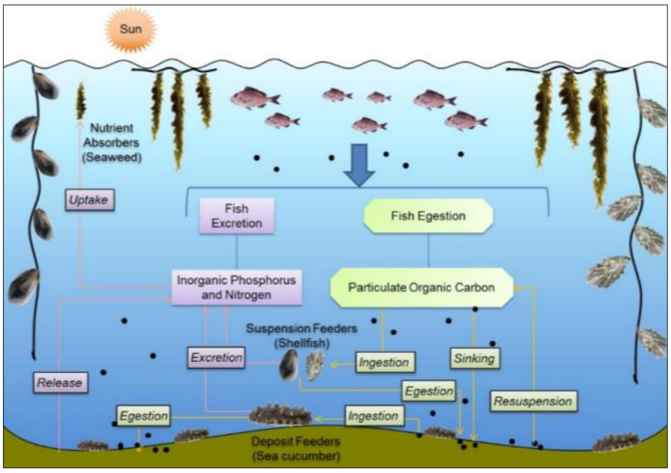

Figure 4. Integrated multi-trophic aquaculture (IMTA) system concept (Azhar & Memiş, 2023).

The IMTA model operates on the principle of nutrient cycling, where the waste products from one species serve as inputs for another. For instance, uneaten feed and metabolic waste from fish can be utilized by filter-feeding organisms like mussels and sea cucumbers, which in turn contribute to the overall health of the ecosystem by improving water clarity and quality (Heriansah et al., 2022; Molloy et al., 2011). This symbiotic relationship is particularly beneficial in coastal aquaculture settings, where nutrient loading can lead to detrimental effects on water quality and marine life. Studies have shown that IMTA systems can significantly reduce the accumulation of solid waste and enhance the overall productivity of aquaculture operations (Heriansah et al., 2022; Nurfadillah et al., 2021).

In Europe, where aquaculture plays a vital role in the economy, particularly in countries with extensive coastlines like Portugal and Spain, the implementation of IMTA can provide both economic and environmental benefits (Alexander et al., 2015; Resende et al., 2022). The integration of IMTA systems can help mitigate the adverse effects of traditional aquaculture practices, which often lead to nutrient pollution and habitat degradation. By adopting IMTA, aquaculture operations can align with the European Union's sustainability goals, promoting practices that are less harmful to the environment while still meeting the growing demand for seafood (Granada et al., 2016; van Osch et al., 2017).

Moreover, the resilience of IMTA systems to climate change is noteworthy. As ocean temperatures rise and water quality fluctuates, the diversity of species cultivated in IMTA systems can provide a buffer against these changes. Different species may respond variably to environmental stressors, thus ensuring that at least some components of the system remain productive even under adverse conditions (Azhar & Memiş, 2023; Buck et al., 2018). This resilience is further enhanced by the ability of IMTA systems to adapt to local environmental conditions, making them suitable for various coastal ecosystems across Europe (Azhar & Memiş, 2023).

The economic viability of IMTA is another critical aspect, as it offers opportunities for diversification and increased profitability. By cultivating multiple species, aquaculture operations can tap into different markets and reduce their reliance on single species, which can be vulnerable to market fluctuations and disease outbreaks (Granada et al., 2016; van Osch et al., 2017). Furthermore, the co-cultivation of species with independent commercial value can enhance the overall economic sustainability of aquaculture enterprises (Anggorowati & Munandar, 2022; Granada et al., 2016). For example, the integration of high-value species such as sea cucumbers or seaweeds can provide additional revenue streams while simultaneously improving the ecological footprint of the operation (Anggorowati & Munandar, 2022; Azhar & Memiş, 2023).

However, the successful implementation of IMTA in European aquaculture is not without challenges. Regulatory frameworks and policies must evolve to support the adoption of these systems, as current regulations may not adequately address the complexities of multi-species cultivation (Alexander et al., 2015; Hughes & Black, 2016).

5.3. Broodstock selective breeding

Broodstock selective breeding in European aquaculture is a critical strategy for enhancing animal health and addressing the challenges posed by climate change. While it is true that there are already initiatives for selective breeding of broodstock, there is still a large field of development in this direction with a very large potential for breeding animals that are more resistant to diseases, fluctuating environmental conditions such as rising water temperatures or acidification of the oceans.

The selective breeding of fish is a crucial instrument for strengthening aquaculture health and tackling the difficulties related to fish health, particularly in the framework of modern aquaculture and climate change. Genetic improvement emphasises the selection and breeding of fish that exhibit increased disease resistance, superior growth performance, and adaptability to fluctuating environmental conditions.

We can classify the main strategies and benefits of genetic improvement for aquaculture health as follow:

- Disease resistance
- Improved immune system
- Fast growth and feed efficiency
- Adaptation to climate change
- Selective breeding
- Reduction of antibiotic dependence

Disease Resistance

Through genetic selection, breeders can identify and reproduce individuals that are naturally more resistant to certain bacterial, viral, or parasitic diseases. For example, breeding programs for Atlantic salmon have improved resistance to sea lice (*Lepeophtheirus salmonis*) and diseases such as salmon rickettsial septicaemia (SRS).

The selective breeding of turbot (*Scophthalmus maximus*) has been explored to enhance disease resistance and growth rates, which are critical for maintaining production levels in the face of environmental stressors (Saura et al., 2019).

The breeding of hybrid species can result in individuals with greater disease resistance. This has been demonstrated in species such as tilapia, where certain hybrids show a higher ability to combat common pathogens in aquaculture environments.

Improved immune system

By selecting fish with a greater immune capacity, fish farmers can reduce the need for pharmaceutical treatments and antibiotics. This not only improves fish health but also reduces the emergence of antimicrobial resistance, which is a growing problem in aquaculture.

Identifying and crossing individuals with stronger immune systems helps create more robust populations that are less likely to suffer disease outbreaks under stressful conditions, such as abrupt changes in temperature or salinity.

Fast growth and feed efficiency

By selecting for faster growth, fish spend less time in aquaculture conditions, reducing their exposure to diseases. This has been successfully implemented in species like salmon and tilapia, where improved genetic lines reach commercial sizes more quickly.

Selecting fish with a greater capacity to convert feed into body mass reduces feeding costs and, in some cases, improves gut health, which translates into greater resistance to intestinal infections.

Adaptation to climate change

One of the significant advantages of selective breeding is its ability to enhance the physiological and immunological responses of aquaculture species to climate-induced stressors. Fish bred through genetic improvement may show greater resistance to stress factors such as rising temperatures, variability in oxygen levels, and changes in salinity. This type of resilience helps mitigate the effects of climate change on fish health. For example, studies have shown that selectively bred oysters can alter their biomineralization pathways, which promotes resilience to environmental acidification, a direct consequence of climate change (Fitzer et al., 2019).

Breeding programs can also select fish that better tolerate extreme conditions, such as high ammonia concentrations or poor water quality, reducing mortality and improving overall health in cultivation.

Selective breeding

In selective breeding programs, individuals are identified and bred not only for desirable commercial traits like growth but also for low disease incidence. This creates stronger and healthier generations, reducing the need for medical interventions.

Moreover, the integration of genomic technologies into breeding programs has revolutionized the field. Techniques such as genome-wide association studies (GWAS) and genomic selection enable the identification of specific genetic markers associated with desirable traits, including disease resistance (Yáñez et al., 2023). Houston et al. (2020) emphasise that the application of genomics allows for more precise breeding strategies, which can significantly enhance the efficiency of genetic improvement programs. The potential of genome editing technologies, such as CRISPR/Cas9, further accelerates these efforts by allowing for targeted modifications that can improve traits related to health and resilience against diseases (Yang et al., 2022).

Reduction of antibiotic dependence

With genetic improvement, diseases that typically require treatment with antibiotics or chemicals can be reduced, promoting more sustainable aquaculture. This also addresses growing concerns about the emergence of antibiotic-resistant pathogens. In addition to genetic improvement, some improved fish lines are bred to have a better response to probiotics and prebiotics, which strengthen the natural microbiota of fish and make them less susceptible to infections.

5.4. Use of new technologies

In recent years, the development of AI has been exponential. The ways in which IA and other new technologies, such as imaging processing or machine learning, can help in the early detection of fish disease are still a study field, but they will be helpful in the future.

Some of these new technologies can be classified as follows:

- Artificial Intelligence and Machine Learning

  AI models can predict outbreaks based on environmental data and historical disease trends. AI-driven systems can automate feeding and water management to optimize fish health and reduce waste, minimising the disease risk.

- Biosensors and monitoring systems

  Sensors can track water quality or fish behaviour, helping to detect early harmful environmental changes or signs of disease.

- Blockchain and data management

  Blockchain and cloud computing can help to analyse the evolution of the fish and predict the future evolution.

- Remote sensing and drones

  The use of drones or satellite imaging can help monitoring the aquatic environment, detecting threats. Drones can also be used to inspect fish farms without the presence of humans, reducing the stress of the animals.

New technologies can also aid to improve farm management and husbandry and to produce in a more controlled environmet, that is also stated by Huntington (2022).

6. RESPONSE TO NEW CHALLENGES AND COMMISSION POLICIES

There are some critical points for responding to new challenges in aquaculture, particularly in the context of climate change and public health issues. Key points include:

6.1. Improving aquaculture biosecurity

There is a need to improve aquaculture biosecurity procedures.

The Food and Agriculture Organization of the United Nations (FAO) has developed the "Progressive Management Pathway for Improving Aquaculture Biosecurity (PMP/AB) (Figure 5)".

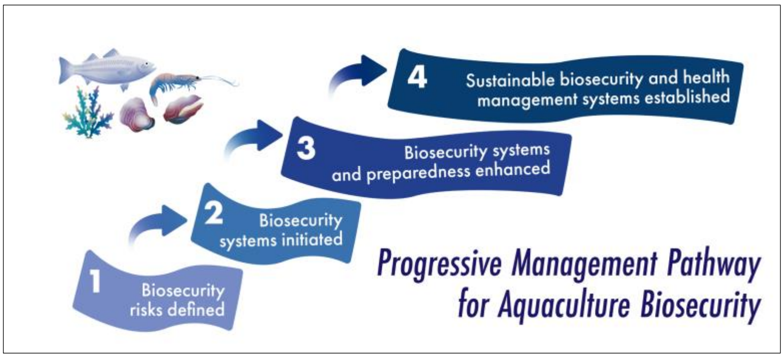

Figure 5. Proposed FAO implementation of aquaculture biosecurity, using the Progressive Management Pathway (PMP-AB)(FAO, 2023).

"The vision of the PMP/AB is to reduce the burden of diseases by improving aquaculture biosecurity practices worldwide in order to support food security and nutrition, social and economic development and resilience, rural livelihoods, food safety and public health, and the environmental sustainability of the aquaculture sector" (FAO, 2023).

This pathway stablishes four steps (FAO, 2023):

- Stage 1: Define the risk for biosecurity.

Table 1. Stage 1 of PMP/AB (FAO, 2023).

	Stage 1: Biosecurity risks defined **Objective:** Define biosecurity strategies to support aquatic health and production	
KEY OUTCOMES	1	Key stakeholders are identified and production systems, marketing network and associated socioeconomic drivers are well described and understood for aquaculture sectors (value-chain analysis)
	2	Key threats to aquaculture and biosecurity vulnerabilities are identified and described
	3	Risk hotspots, critical control points and risk mitigation measures are identified through risk analysis
	4	The enabling environment for aquaculture biosecurity is reviewed and developed
	5	Aquatic organism health or aquaculture biosecurity strategies that aim at reducing the impact of listed endemic diseases are developed and endorsed at enterprise, local-sector and national levels (Gateway Pass)

- Stage 2: Biosecurity systems initiated.

Table 2. Stage 2 of PMP/AB (FAO, 2023).

		Stage 2: Biosecurity systems initiated **Objective:** Take action to improve biosecurity in aquaculture sectors
KEY OUTCOMES	1	Aquatic organism health or aquaculture biosecurity strategies developed in Stage 1 are implemented by public and private stakeholders
	2	The management of biosecurity vulnerabilities and occurrence of listed endemic diseases are monitored
	3	There is evidence that the biosecurity system strengthens aquatic health resilience and reduces the impact of diseases within the aquaculture sector
	4	The enabling environment is further developed, with the necessary standards and plans, and enhanced by co-operation between public and private sectors
	5	Aquatic organism health or aquaculture biosecurity strategies are enhanced and revised, based on evidence gained from programme implementation (Gateway Pass)

- Stage 3: Biosecurity systems and preparedness enhanced.

Table 3. Stage 3 of PMP/AB (FAO, 2023).

		Stage 3: Biosecurity systems and preparedness enhanced **Objective:** Enhance biosecurity and preparedness in aquaculture sectors
KEY OUTCOMES	1	Revised aquatic organism health or aquaculture biosecurity strategies are implemented
	2	Continuous surveillance is conducted for detection and monitoring of emerging and listed diseases
	3	Disease incidences and impacts are reduced
	4	Enabling environment is strengthened and relevant legislation, standards and plans are established or revised to support aquatic organism health or aquaculture biosecurity strategies
	5	Commitment is demonstrated, including investment, from public and private stakeholders to safeguard progress (Gateway Pass)

- Stage 4: Sustainable biosecurity and health management systems established.

Table 4. Stage 4 of PMP/AB (FAO, 2023).

		STAGE 4: Sustainable biosecurity and health management systems established Objective: Sustainable health management to support the national aquaculture system
KEY OUTCOMES	1	Risk management activities are sustained and improved based on evidence
	2	Systems for preparedness and response to emergencies, and associated capabilities, are fully developed
	3	The enabling environment is maintained and continuously improved as necessary
	4	Reduction of disease burden is achieved for all (including small-scale producers) and food security for consumers
	5	National and international stakeholders have confidence in national aquatic health services and ecosystem health

The implementation of PMP/AB at national level is considered as a critical point for the European or national aquaculture strategies.

The expected goals of the PMP/AB are (FAO, 2023):

- A sustainable reduction in disease burden.
- Improved aquatic health and welfare at farm, national and regional levels.
- Minimisation of the global spread of disease.
- Attraction of aquaculture investment opportunities.
- Meeting the goals of the 'One Health' approach.

6.2. Minimising antimicrobial resistance (AMR)

Addressing AMR is crucial for maintaining fish health and ensuring the sustainability of aquaculture practices.

The use of antimicrobials in European aquaculture has been reduced in the last years, mainly due to:

- Higher concern about the importance of fish health.
- Development and use of vaccines against the main bacteria affecting aquaculture animals.
- Improvement of biosecurity measures at farm level.

Climate change can lead to an increasing number of AMR. This is due to:

- New pathogens might need more antimicrobial use until preventive measures are effective against it.
- Higher temperatures can cause the development of AMR.

The development of antimicrobial resistance is a threat to the aquaculture sector, both because of the disastrous consequences for production due to the impossibility of treating certain bacterial pathologies, and because of the consequences for public health.

Therefore, strategies to minimise the development of antimicrobial resistance should be a basic pillar for the future development of EU aquaculture.

6.3. One Health approach

One Health approach integrates human, animal, and environmental health, recognizing the interconnectedness of these domains. It's an initiative born from Food and Agriculture Organization of the United Nations (FAO), World Organisation for Animal Health (WOAH) and World Health Organization (WHO).

While the application of a One Health approach to animal health is essential, in the case of aquaculture this is even more critical, as the animals are in many cases not isolated from the surrounding environment.

With the exception of RAS farms, which are more isolated from the environment, all other aquaculture farms have frequent interaction with wildlife. Furthermore, on these farms they are exposed to varying environmental conditions, which can predispose them to the development of diseases if these conditions are changing or extreme.

The One Health approach goes beyond simple zoonotic disease control. Through the One Health approach, management can also be improved at the aquaculture farm level, as it applies a collaborative and multifactorial system that can support the development of sustainable aquaculture.

The use of a One Health approach for the aquaculture sector, both at farm level and at the level of health policy development, is essential for the proper development of European aquaculture.

7. GUIDANCE DOCUMENT AND EMERGENCY PROCEDURES

7.1. Steps in front a new disease in fish farms

The emergence of new diseases in fish farms represents a significant challenge for aquaculture, necessitating a comprehensive understanding of the factors contributing to disease outbreaks and the implementation of effective management strategies. The steps involved in addressing the appearance of a new disease can be categorized into several phases: identification, assessment, management, and prevention. Each of these phases requires a multifaceted approach that integrates scientific research, practical applications, and stakeholder engagement.

Identification of new diseases

The first step in managing a new disease outbreak in fish farms is the accurate identification of the disease. This involves clinical observations and laboratory diagnostics to confirm the presence of pathogens. The identification process may include phenotypic and molecular detection methods, such as PCR assays, which have been effectively utilized to detect viruses like the Tilapia Lake Virus (TiLV) (Mugimba et al., 2018).

Moreover, understanding the clinical signs associated with specific diseases is crucial. Symptoms such as abnormal swimming behaviour, lesions, and increased mortality rates can serve as initial indicators of disease presence (Aftabuddin et al., 2016). The rapid identification of these signs allows for timely intervention, which is critical in preventing the spread of the disease within the farm and to surrounding aquatic environments (da Costa et al., 2023).

Early detection system

Early detection system, as described by WOAH (2024b) means a "system which ensures the rapid recognition of signs that are suspicious of a listed disease, or an emerging disease, or unexplained mortality, in aquatic animals in an aquaculture establishment or in the wild, and the rapid communication of the event to the Competent Authority, with the aim of activating an investigation by the Aquatic Animal Health Services with minimal delay".

The early detection and communication are crucial in order to minimise the impact of the disease and its spread to other farms or wild animals.

Assessment of disease impact

Once a disease is identified, the next step is to assess its potential impact on fish health and farm productivity. This assessment involves evaluating the severity of the outbreak, the species affected, and the potential economic losses associated with the disease (Halim et al., 2020; Tavares-Dias & Martins, 2017). For example, the emergence of bacterial diseases like furunculosis caused by *Aeromonas salmonicida* can lead to significant economic burdens due to high mortality rates and treatment costs (Gauthier et al., 2021).

In addition to economic considerations, the assessment phase should also encompass ecological impacts. The interaction between farmed fish and wild populations can exacerbate disease spread, as seen with sea lice infestations linked to salmon farming. Understanding these dynamics is essential for formulating effective management strategies that mitigate both economic and ecological risks (Kristoffersen et al., 2013).

Depending on the pathogen and its potential impact at the farm or at the regional level, the possibility of euthanizing the fish should be considered as an aim to avoid spread of the disease into the farm, neighbour farms and/or wild populations.

Responsabilties

The different parties involved in the procedure have different responsibilities in the event of a disease event (Figure 6).

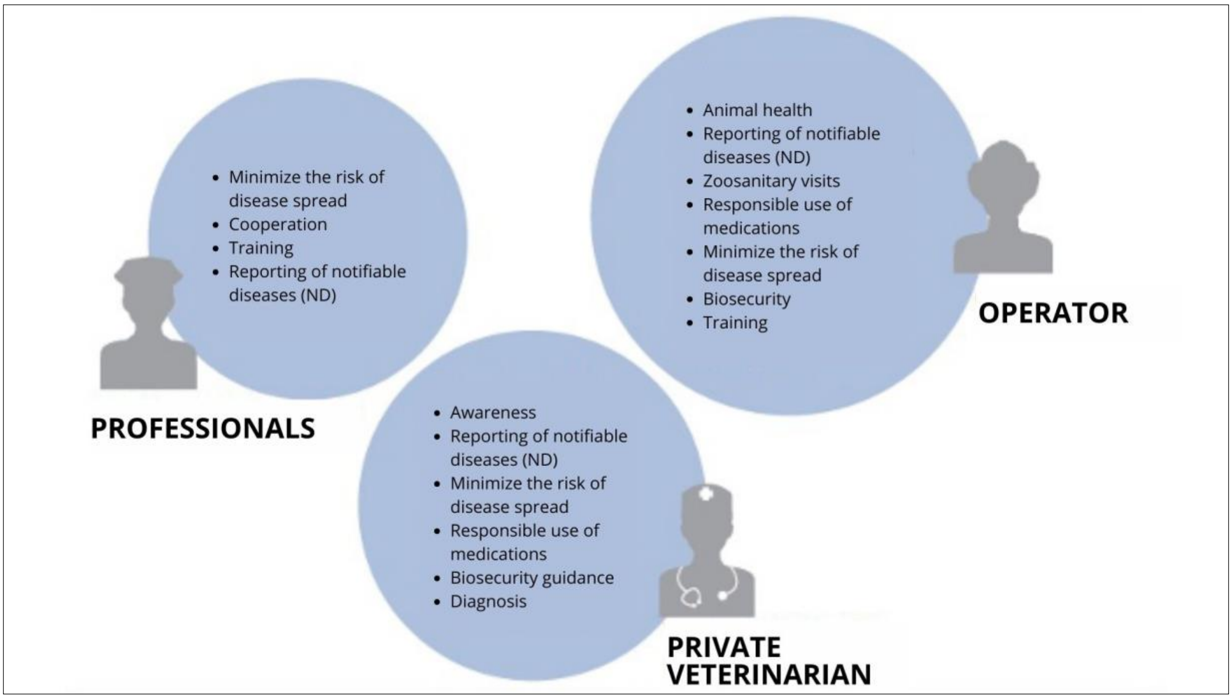

Figure 6. Distribution of responsabilities (Adapted from MAPAMA, 2017).

Management Strategies

Effective management strategies are crucial in controlling disease outbreaks once they are identified and assessed. These strategies may include biosecurity measures, vaccination programs, and treatment protocols. Biosecurity practices, such as controlling fish movement and maintaining water quality, are vital in preventing the introduction and spread of pathogens. For instance, the implementation of strict biosecurity measures has been shown to reduce the incidence of diseases in aquaculture settings significantly (Arechavala-Lopez et al., 2013; Georges et al., 2023).

Vaccination is another critical component of disease management in aquaculture. Advances in vaccine development have led to the creation of effective vaccines against various bacterial pathogens, which can enhance fish survival rates and reduce reliance on antibiotics. However, the success of vaccination programs depends on the timing of administration and the health status of the fish population prior to vaccination (Ben Hamed et al., 2021).

In addition to preventive measures, treatment protocols must be established to address outbreaks when they occur. This may involve the use of antibiotics or other therapeutic agents, although the emergence of antibiotic resistance poses a significant challenge. Therefore, it is essential to monitor the efficacy of treatments and adjust protocols as necessary to ensure effective disease control (Laith & Najiah, 2014).

Prevention of future outbreaks

Its important to perform an analysis of the case, in order to determine whether the system failed and where to strengthen the preventive measures. A risk analysis must be performed to detect the critical points of the production process.

The final step in managing new disease appearances in fish farms is the implementation of preventive measures to reduce the likelihood of future outbreaks. This involves a combination of improved farming practices, ongoing research, and stakeholder education. For instance, reducing stocking densities can help alleviate stress among fish, thereby decreasing their susceptibility to infections. Additionally, maintaining optimal water quality and nutrition is crucial for enhancing fish health and resilience against diseases (Tavares-Dias & Martins, 2017; Teodorowicz, 2013).

Continuous research into fish diseases and their management is essential for adapting to emerging threats. For example, studies on the epidemiology of diseases and the development of rapid diagnostic tools can provide valuable insights into disease dynamics and facilitate timely responses. Furthermore, educating fish farmers about best practices in disease management and biosecurity can empower them to take proactive measures in their operations (Mishra, 2017; Mugimba et al., 2018; Mulei et al., 2021).

The emergence of new diseases in fish farms requires a systematic approach encompassing identification, assessment, management, and prevention. By integrating scientific research with practical applications and stakeholder engagement, fish farmers can enhance their resilience against disease outbreaks and contribute to the sustainability of aquaculture.

7.2. Identifying a new disease in a fish farm

Identifying a new disease in a fish farm is a critical process that involves systematic observation, clinical assessment, and laboratory diagnostics. The emergence of diseases in aquaculture can significantly impact fish health and farm productivity, necessitating a structured approach to disease identification. This response outlines the key steps involved in identifying a new disease in a fish farm, supported by relevant literature.

1. Initial observations and clinical signs

The first step in identifying a new disease is through careful observation of the fish population. Farmers should monitor for any unusual behaviour or physical signs that may indicate illness. Common clinical signs include abnormal swimming patterns, lethargy, loss of appetite, and visible lesions or discolouration on the skin. For instance, atypical furunculosis in Atlantic salmon has been characterized by specific lesions that can be recognized during routine inspections. Early detection of these signs is crucial, as it allows for timely intervention and can prevent the spread of the disease to other fish within the farm (Godoy et al., 2010).

2. Gathering historical data

Collecting historical data on fish health and previous disease outbreaks in the farm is essential. This data can provide insights into patterns of disease occurrence and help identify potential risk factors associated with new outbreaks. For example, understanding the environmental conditions, stocking densities, and previous health management practices can aid in recognizing the context in which a new disease may arise. Historical data can also assist in differentiating between endemic diseases and newly emerging ones, which may require different management strategies (Fritsvold et al., 2021).

3. Laboratory diagnostics

Once clinical signs are observed, laboratory diagnostics play a vital role in confirming the presence of a new disease. Various diagnostic techniques can be employed, including histopathology, microbiological cultures, and molecular methods such as polymerase chain reaction (PCR). For example, multiplex PCR has been successfully utilized to detect multiple bacterial pathogens in fish, allowing for a comprehensive understanding of the disease dynamics within the farm. Accurate laboratory diagnostics are essential for identifying the causative agent of the disease, which can be a virus, bacterium, or parasite (Kim et al., 2015; Tapia-Cammas et al., 2011).

4. Pathogen characterization

Characterizing the pathogen involved in the disease is crucial for understanding its virulence and potential impact on fish populations. This may involve typing the pathogen to determine its strain and virulence factors, which can inform treatment and management strategies. For instance, the characterization of cardiomyopathy syndrome (CMS) in Atlantic salmon has revealed specific viral associations that are critical for developing targeted interventions. Understanding the pathogen's characteristics can also aid in monitoring vaccination programs and assessing the effectiveness of biosecurity measures (Fritsvold et al., 2021).

5. Environmental assessment

The environmental conditions of the fish farm can significantly influence disease emergence and progression. Factors such as water quality, temperature, and stocking density should be assessed to determine their potential impact on fish health. Poor water quality, for example, can lead to increased stress in fish, making them more susceptible to infections. Regular monitoring of environmental parameters is essential for maintaining optimal conditions that support fish health and reduce the risk of disease outbreaks (Korekawa et al., 2019).

6. Collaboration with veterinarians and experts

Engaging with veterinarians and aquatic health specialists is crucial for effective disease identification and management. These professionals can provide expertise in diagnosing fish diseases and developing appropriate treatment protocols. Collaboration can also facilitate access to advanced diagnostic tools and technologies that may not be available on-site. For instance, expert systems for fish disease diagnosis can enhance the accuracy and speed of disease identification, allowing for timely interventions (Hatzilygeroudis et al., 2023; Iatridou et al., 2018).

7. Reporting and documentation

Accurate documentation of all observations, diagnostic results, and management actions taken is essential for tracking disease trends and outcomes. This documentation can serve as a valuable resource for future disease management efforts and can help in identifying patterns that may indicate the emergence of new diseases. Reporting findings to relevant authorities or aquaculture organizations can also contribute to broader surveillance efforts and inform best practices within the industry (Gkikas et al., 2024).

8. Continuous monitoring and surveillance

Continuous monitoring and surveillance of fish health are vital for early detection of new diseases. Implementing routine health checks and environmental assessments can help identify potential outbreaks before they escalate. Surveillance programs that include regular sampling and testing can provide critical data on the health status of fish populations and the presence of pathogens, enabling proactive management strategies (Li et al., 2022).

In conclusion, identifying a new disease in a fish farm requires a systematic approach that encompasses initial observations, laboratory diagnostics, environmental assessments, and collaboration with experts. By integrating these steps, fish farmers can enhance their ability to detect and manage emerging diseases, ultimately contributing to the sustainability of aquaculture practices.

7.3. Contingency plan

A comprehensive contingency plan for a fish farm must consider several risks and problems that may impede operations, such as natural disasters, market volatility, and health emergencies. The preparation of such a plan necessitates a thorough analysis of potential risks and an awareness of the vulnerabilities encountered by aquaculture operations, alongside the carry out of effective risk management measures.

In health crises, such as the appearance of diseases, the development of a contingency plan is crucial.

This document presents a proposal for a fundamental contingency plan addressing mass mortality and the occurrence of a fallowing.

Response to the occurrence of mass mortalities

In the event of mass mortalities, the following procedures shall apply:

- Communication to the veterinary services. In each case, the need to notify the Competent Authority will be assessed.
- Immediate removal of mortalities. Increase the frequency of removal of mortalities. Removal of mortalities from affected batches with specific material and equipment or last removal to avoid the potential spread of an infectious pathogen.
- Notification to an approved by-product manager for final disposal.
- Investigation of possible causes of mortality and application of appropriate control measures in each case.
- In case of suspicion of an infectious origin, biosecurity and cleaning and disinfection measures shall be applied to avoid its dispersion to the rest of the animals on the farm and to other farms.
- If considered necessary, fallowing shall be applied.

Action to be taken when a fallowing is applied

When a fallowing of a farm is necessary due to the occurrence of a significant infectious pathogen, the following guidelines shall be followed:

- Communication to the veterinary services. Communication to the Competent Authority.
- Communication, where appropriate, to clients who have received live animals intended for breeding or fattening and which could potentially be infected.
- Slaughter, by means of humane procedures, of affected or suspect animals.
- Immediate removal of aquatic animal waste.
- Removal of the aquatic animal waste from the farm by an approved by-products manager for final disposal.
- Treatment, if necessary, of the water of the farm or the water used for the slaughter of the animals to eliminate infectious pathogens.
- Cleaning and disinfection of facilities, equipment and materials. Removal and replacement of those that cannot be adequately cleaned and disinfected.
- Investigation of the event to determine the route of entry of the pathogen into the facility.
- Establishment of corrective measures to prevent further entry of the pathogen.

8. CASE STUDIES AND SPECIFIC PROCEDURES

In the following section, two examples of how to manage the emergence of a new disease on a farm will be discussed. On one hand, the emergence of a viral disease at the hatchery level, and on the other hand, the appearance of a bacterial disease affecting a marine species in grow-out for the first time.

- VNN in gilthead sea bream affecting fish at hatcheries.
- *Lactococcus garvieae* in European sea bass affecting fish in marine fattening farms.

The measures that can be implemented in these two cases are different due to the distinct production systems in place.

8.1. VNN in Gilthead seabream

According to WOAH (2019) The causative agent of Viral Encephalopathy and Retinopathy (VER) or Viral Nervous Necrosis (VNN) was initially identified as a new member of the Nodaviridae family after brain tissues from affected striped jack larvae were purified, leading to the naming of the virus as striped jack nervous necrosis virus (SJNNV) (Mori et al., 1992). Later, similar agents causing VER/VNN were isolated from other diseased fish species (Chi et al., 2001; Comps et al., 1994).

The European sea bass (*Dicentrarchus labrax*) has been notably impacted by this virus, leading to outbreaks of viral nervous necrosis (VNN) and viral encephalopathy and retinopathy (VER).

The first documented cases of betanodavirus infections in *Dicentrarchus labrax* were reported in the late 1980s, where the disease was characterized by severe neurological symptoms and high mortality rates among juvenile fish (Breuil et al., 1991). After this, the same symptoms appeared in a farm based in the Mediterranean French coast (Breuil et al., 2001). Since then, the virus has been identified in various regions, including the Mediterranean, where it poses a significant threat to aquaculture. The disease is particularly virulent in larval and juvenile stages, with mortality rates reaching up to 100% under certain conditions. The pathogenesis of betanodavirus is associated with its ability to infect the central nervous system, provoking the characteristic clinical signs such as erratic swimming, loss of buoyancy, and darkening of the skin (Hodneland et al., 2011).

The most usual strain, and with a higher mortality rate, affecting European sea bass is RGNNV, but in 2007 a new reassortant strain RGNNV/SJNNV was isolated (Toffolo et al., 2007; Vendramin et al., 2014).

This disease was not a problem for gilthead sea bream (*Sparus aurata*) production until 2014, when a growing number of hatcheries in Europe experienced mass mortalities among sea bream larvae. The virus isolated from these outbreaks was characterized as being reassortant strains RGNNV/SJNNV (Toffan et al., 2017; Volpe et al., 2020).

The appearance of this reassortant strain in Mediterranean hatcheries was a challenge for those farms affected by a disease that they had never faced in gilthead sea bream. The way some of those farms managed the problem is a good example to study.

Detection of the problem

During the spawning season, an increased an abnormal mortality of Gilthead seabream was detected at the larval plant. The presence of nervous symptoms, added to the information of previous outbreaks of betanodavirus in other Mediterranean farms, raised suspicion of this pathogen causing the symptoms and the mortality.

Communication to veterinarians

After the detection of the abnormal mortality, the veterinarians working for the company were warned.

After the inspection and study of the farm records, samples were taken to determine analytically If betanodavirus was the responsible.

Analytical confirmation of VNN

Specimens were dispatched to various laboratories to verify the presence of betanodavirus in the infected animals.

The samples dispatched originated from various batches and units of the farms, aiming to ascertain the magnitude of the disease on the premises.

Numerous batches tested positive, however none over 1 gramme.

Crisis management team establishment

After confirming betanodavirus as the cause of the reported mortality, a crisis management team was established to implement measures for controlling and eradicating the disease from the farm.

The crisis management team evaluated the epidemic, examining the potential causes.

Farm records were examined to identify probable entry paths and evaluate the risks of pathogen escape, mostly through the departure of animals since the previous negative betanodavirus test conducted on the farm.

The crisis management team, after evaluating all options, resolved to euthanise all the animals on the farm.

Given that the VNN outbreaks in gilthead sea bream exclusively impacted larvae, with no symptoms observed in specimens exceeding approximately 1 g, there is significant apprehension regarding the potential mutation of the virus and its transmission to larger fish. This scenario parallels the RGVNN strain, which initially emerged in hatcheries and subsequently affected larger fish years later, resulting in severe outbreaks in offshore fattening farms.

The objective of the measures implemented was to prevent the disease from spreading from the affected farms and to confine it to those farms that were affected, prioritising the general interest over personal interests.

Communication to Authorities and neighbour and related aquaculture farms

The authorities were notified of the outbreak and the measures implemented to control it. The authorities supervised the process after the communication.

The neighbouring farms, along with those epidemiologically associated, were notified of the epidemic, facilitating the sharing of pertinent information regarding clinical signs and implemented control measures.

Stamping-out

The farmers decided to perform a stamping-out of the farm.

Many aspects were taken into account before taken this decision. The most important are:

- Cost-benefit of the measure.
- Possibility of eradicating the pathogen at the farm.
- Possibility of spreading the disease to other farms.
- Possibility of the pathogen to start affecting larger fish, over 1 g.

The euthanasia was performed with an anaesthetic overdose. The process was designed and controlled by veterinarians.

After the euthanasia, the aquatic animal wastes were managed as Category I by-products.

Fallowing of the farm

After euthanasia of the animals, all the material at the farm was properly destroyed. All the facilities were deeply cleaned and disinfected. After this, the farm was kept without animals until being sure that the pathogen was eliminated. PCR performed on surfaces and water was also useful for this purpose.

Biosafety conditions were improved, taking advantage of modifications to facilities and processes, with a focus on biosecurity.

Quarantine and testing of new broodstock

After the disease was unequivocally eradicated, new broodstock arrived to the farm.

The animals were kept in a quarantine facility adjacent to the hatchery. The animals were tested multiple times to ensure there was no risk of reintroducing the disease to the farm.

8.2. Lactococcus garvieae in European seabass

Lactococcus garvieae is a significant pathogen that affects a wide range of host species, particularly in the dairy and aquaculture farms. It was initially identified in bovine mastitis, but *L. garvieae* has been isolated from many different species and environments, both marine and terrestrial.

L. garvieae is recognized as a pathogen in various fish species, including rainbow trout (*Oncorhynchus mykiss*), yellowtail (*Seriola quinqueradiata*), and grey mullet (*Mugil cephalus*) (Evans et al., 2009; Wang et al., 2006; Salogni, 2024). The disease provoked by *L. garvieae* is known as lactococcosis, a disease characterized by severe haemorrhagic septicaemia in fish, which can lead to substantial economic losses in aquaculture (Ortega et al., 2020; Guglielmetti et al., 2009).

In the context of aquaculture, *L. garvieae* has emerged as a major pathogen, particularly in the farming of salmonids and other fish species. The lactococcosis outbreaks appear especially during warmer months when water temperatures rise, creating favourable conditions for the pathogen (Guglielmetti et al., 2009; Salogni, 2024).

The pathogenicity of *L. garvieae* in fish is attributed to its virulence factors, which include the ability to adhere to host tissues and avoid immune responses (Lin et al., 2023; Miyauchi et al., 2012). Genetic studies have shown that *L. garvieae* strains exhibit significant genetic diversity, which may contribute to their variable pathogenic potential across different host species (Ferrario et al., 2012; Kawanishi et al., 2006).

In late summer and early autumn 2023, the pathogen appeared affecting European sea bass (*Dicentrarchus labrax*) for the first time in fattening farms in different locations in Europe (Italy and Spain) within a very short period of time.

Detection of the problem

Abnormal mortality was detected by the professionals working at farms producing Eurpean sebass.

the signs were not compatible with any disease previously detected in the farms or described in European sea bass.

The disease was affecting animals exceeding 600 g.

Communication to veterinarians.

The company's veterinary services were informed to take appropriate diagnostic and control measures. In cases where the farm belongs to an Animal Health Defence Group, their veterinary services are also informed.

Samples are taken to investigate the causal agent of the disease. When it is confirmed that it is not one of the usual etiological agents affecting this species, the samples are sent to fish pathology laboratories.

Analytical confirmation of lactococcosis.

In the fish pathology laboratories, the pathogen was isolated, confirming that it was *Lactococcus garvieae*.

Subsequent studies confirmed that the strain affecting European sea bass is not similar to the strain affecting rainbow trout.

Communication to Authorities and neighbour aquaculture farms.

Animal Health Authorities were informed about the abnormal increase in mortality and the isolation of a new disease.

Open and truthful communication with nearby farms is also essential for better control of the possible spread of the disease and to minimize its effects on the sector.

Maximize the hygienic and biosafety measures at the farm.

In this case, the disease was affecting large fish, exceeding 600 g. Due to this and because the fact that isolation of the affected farms was not feasible, euthanasia of the affected batches was discarded.

- Reducing the biomass of the batches proved to be an effective measure for minimizing the effects of the disease. While it does not prevent the presence of the disease, it seems to significantly reduce the associated mortality.
- Strict biosecurity measures were put in place on the affected farms. For example:
- The frequency of removal of dead animals from the farm was increased in an attempt to minimise the spread of the disease to animals on the same farm.
- Visits to the farm were reduced to the absolute minimum.
- Stricter procedures for cleaning and disinfection of equipment and vessels were put in place.

Study the outbreak.

From the moment of detection, a crisis management team was established on the farm to assess the evolution of the disease over time, as well as the measures taken and their effects. This measure is essential for proper crisis management.

Developing of autologous vaccines

Vaccination has been an effective measure among those used for disease control in rainbow trout farms. For this reason, the development of vaccines for disease control in European sea bass is a priority.

While commercial vaccines are being developed, farms have opted to use autogenous vaccines in order to minimize the impact of the disease.

As the disease affects large fish, the effect of these autogenous vaccines will be seen and evaluated in the next years.

9. FREQUENTLY ASKED QUESTIONS (FAQS)

This section contains a compilation of frequently asked questions (FAQs) concerning the management of a fish farm in the case of a novel disease outbreak.

1. **What actions should I take if I detect an increased mortality at the farm?**

   The most important is to determine the reason of death as soon as possible. This may require consulting health assessments, sampling additional fish for analysis, and evaluating management protocols.

2. **What is the initial action to take upon the identification of a new disease?**

   The initial action, when possible, is to promptly segregate infected fish to prevent the spread of the disease. Perform a comprehensive evaluation to verify the disease and ascertain its possible aetiology.

3. **How can I verify the presence of a new disease?**

   Seek the counsel of a veterinarian specialised in fish health. Laboratory testing, such as cultures, PCR and histology, can assist in identifying infections and verifying the diagnosis.

4. **Which measures can be taken to control the disease spread?**

   The measures to be taken vary depending on the disease or aetiological agent. Most radical measures may include euthanasia of fish if it ensures confinement of the pathogen.

   Seek immediate counsel from a veterinarian.

5. **Which biosecurity measures must be instituted?**

   Check the section about Biosecurity in this report. The main measures are:

   - Quarantine: Isolate newly acquired fish stock and any infected specimens.
   - Access Control: Restrict entry to the farm and mandate decontamination of equipment and boots.
   - Equipment disinfection: Consistently clean and disinfect nets, tanks, and other equipment or facilities to prevent the expansion of the pathogen.

6. **Do I need to treat the animals?**

   Treatment must be evaluated and prescribed by a veterinarian. If the disease is transmissible and threatens the entire batch or farm, veterinary treatment may be imperative. Seek guidance from a veterinarian specialized in fish health for specific advice.

7. **What methods can I employ to track the dissemination of the disease?**

Routine health evaluations and observation of fish behaviour and mortality rates can facilitate the detection of alterations in the population's health state. Meticulously document all observations.

8. What measures can I take to avoid further outbreaks?

Carry out a detailed study of the origin of the pathogen and its spread, assessing the effectiveness of the measures taken. This will allow the identification of critical points and improve the preventive measures to be adopted.

Other measures as vaccination must be evaluated depending on the disease.

9. What is the significance of nutrition in the management of a disease outbreak?

Optimal feeding enhances the immune system of fish, increasing their resistance to illnesses. Maintain a balanced diet rich in important vitamins and minerals, particularly during and following a disease epidemic. Anyway, the decision about the fish feeding must be considered many factors as disease, species, type of facility, environmental factors… Ask for the opinion of specialised veterinarian.

10. Is it necessary to notify regulatory authorities regarding the outbreak?

It is imperative to notify regulatory authorities of new disease outbreaks, as they may have established protocols and can offer supplementary support or resources.

11. Am I permitted to sell fish during an outbreak?

Distributing fish during an outbreak may pose in risk other farms and ecosystems. Depending on the disease, there can be restrictions to the movement or destination of the animals.

Consult veterinarians and/or health authorities concerning limitations during disease outbreaks.

12. What documentation must I retain during an outbreak?

Maintain comprehensive documentation of:

- Evaluations and interventions for fish health.
- Mortality rates and impacted species - Implementation of biosecurity measures.
- Correspondence with veterinarians and regulatory bodies.

13. What is the method for communicating with personnel regarding the outbreak?

Conduct regular meetings to apprise staff of the situation, biosecurity protocols, and their responsibilities in handling the epidemic. Facilitate unambiguous and uniform communication while promoting enquiries.

14. What resources exist for the management of fish diseases?

Seek resources from fish health organisations, aquaculture extension services, and veterinary groups. They can offer counsel on disease identification, management strategies, and therapeutic alternatives.

15. Where can I send samples to confirm a new disease?

There are many laboratories available for fish disease diagnosis in every European country.

For notifiable diseases, samples must be sent to authorised laboratories, such as National Reference Laboratories for fish diseases. Consult the Halim, K. A., Ali, M. N., Rahman, T., & Faruk, M. A. R. (2021). Constraints of health management of commercially cultured high valued fishes. *Bangladesh Journal of Fisheries*, *32*(2), 333–32. https://doi.org/10.52168/bjf.2020.32.38

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GLOSSARY

Definitions used at this report according to the World Organization for Animal Health (WOAH) Aquatic Animal Health Code (WOAH, 2024a).

antimicrobial agent

A naturally occurring, semi-synthetic or synthetic substance that at in vivo concentrations exhibits antimicrobial activity (kill or inhibit the growth of microorganisms). Anthelmintics and substances classed as disinfectants or antiseptics are excluded from this definition.

Aquaculture

The farming of aquatic animals with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc.

Aquaculture establishment

An establishment in which amphibians, fish, molluscs or crustaceans for breeding, stocking or sale are raised or kept.

Aquatic animal products

Non-viable aquatic animals, parts of aquatic animals, or manufactured goods containing any material derived from aquatic animals that are intended for sale or trade.

Aquatic animal waste

Entire carcasses of aquatic animals, parts of aquatic animals, or associated liquids which are intended for disposal.

Aquatic animals

All viable life stages (including eggs and gametes) of fish, molluscs, crustaceans and amphibians originating from aquaculture establishments or from the wild.

Basic biosecurity conditions

A minimum set of conditions, as described in Article 1.4.6., required to ensure biosecurity for a specific disease, in a country, zone or compartment.

Biosecurity

A set of management and physical measures designed to mitigate the risk of introduction of pathogenic agents into, or spread within, or release from, aquatic animal populations.

Biosecurity plan

A document that identifies potential pathways for the introduction of pathogenic agents into, or spread within, or release from, a zone, compartment or aquaculture establishment and describes the measures applied to mitigate the identified risk, in accordance with the recommendations in the Aquatic Code.

Case

An individual aquatic animal infected by a pathogenic agent, with or without clinical signs.

Competent Authority

A Governmental Authority of a Member Country having the responsibility in the whole or part of the territory for the implementation of certain standards of the Aquatic Code.

Contingency plan

A documented work plan designed to ensure that all needed actions, requirements and resources are provided in order to eradicate or bring under control outbreaks of specified diseases of aquatic animals.

Diagnosis

Determination of the nature of a disease.

Disease

Clinical or non-clinical infection with one or more pathogenic agents.

Disinfectants

Chemical compounds or physical processes capable of destroying pathogenic agents or inhibiting their growth in the course of disinfection.

Disinfection

The process of cleaning and applying disinfectants to inactivate pathogenic agents on potentially contaminated items.

Early detection system

A system, as described in Article 1.4.7., which ensures the rapid recognition of signs that are suspicious of a listed disease, or anemerging disease, or unexplained mortality, in aquatic animals in an aquaculture establishment or in the wild, and the rapid communication of the event to the Competent Authority, with the aim of activating an investigation by the Aquatic Animal Health Services with minimal delay.

Emerging disease

A disease, other than listed diseases, which has a significant impact on aquatic animal or public health resulting from:

- a change of known pathogenic agent or its spread to a new geographic area or species; or
- a newly recognised or suspected pathogenic agent.

Epidemiological unit

A group of animals that share approximately the same risk of exposure to a pathogenic agent with a defined location. This may be because they share a common aquatic environment (e.g. fish in a pond, caged fish in a lake), or because management practices make it likely that a pathogenic agent in one group of animals would quickly spread to other animals (e.g. all the ponds on a farm, all the ponds in a village system).

Fallowing

For disease management purposes, an operation where an aquaculture establishment is emptied of aquatic animals susceptible to a disease of concern or known to be capable of transferring the pathogenic agent, and, where feasible, of the carrying water. For aquatic animals of unknown susceptibility and those agreed not to be capable of acting as vectors of a disease of concern, decisions on fallowing should be based on a risk assessment.

Feed

Any material (single or multiple), whether processed, semi-processed or raw, as well as live organisms, which is intended to be fed directly to aquatic animals.

Feed ingredient

A component, part or constituent of any combination or mixture making up a feed, including feed additives, whether or not it has a nutritional value in the animal's diet. Ingredients may be of terrestrial or aquatic, plant or animal origin and may be organic or inorganic substances.

Hazard

A biological, chemical or physical agent in, or a condition of, an aquatic animal or aquatic animal product with the potential to cause an adverse effect on aquatic animal health or public health.

Incidence

The number of new outbreaks of disease within a specified period of time in a defined aquatic animal population.

Infection

The presence of a multiplying or otherwise developing or latent pathogenic agent in a host. This term is understood to include infestation where the pathogenic agent is a parasite in or on a host.

Listed diseases

Diseases that are referred to in Chapter 1.3 of the Aquatic Animal Health Code (WOAH, 2024a).

Outbreak

An occurrence of one or more cases in an epidemiological unit.

Passive surveillance

Aquatic animal health surveillance typically based on observations of clinical or behavioural signs of disease, or an assessment of mortality or production data, which are generated by an early detection system or from other information which is available to the Competent Authority.

Pathogenic agent

An organism that causes or contributes to the development of a disease.

Prevalence

The total number of infected aquatic animals expressed as a percentage of the total number of aquatic animals in a given aquatic animal population at one specific time.

Quarantine

Maintaining a group of aquatic animals in isolation with no direct or indirect contact with other aquatic animals, in order to undergo observation for a specified length of time and, if appropriate, testing and treatment, including proper treatment of the effluent waters.

Risk

The likelihood of the occurrence and the likely magnitude of the biological and economic consequences of an adverse event or effect to animal or human health.

Risk analysis

The process composed of hazard identification, risk assessment, risk management and risk communication.

Risk assessment

The scientific evaluation of the likelihood and the biological and economic consequences of entry, establishment and spread of a hazard.

Sensitivity

The proportion of true positive tests given in a diagnostic test, i.e. the number of true positive results divided by the number of true positive and false negative results.

Specificity

The probability that absence of infection will be correctly identified by a diagnostic test, i.e. the number of true negative results divided by the number of true negative and false positive results.

Stamping-out policy

The carrying out under the authority of the Competent Authority, on confirmation of a disease, of preventive aquatic animal health measures, consisting of killing the aquatic animals that are affected, those suspected of being affected in the population and those in other populations that have been exposed to infection by direct or indirect contact of a kind likely to cause the transmission of the pathogenic agent. All these aquatic animals, vaccinated or unvaccinated, on an infected site should be killed and the carcasses destroyed by burning or burial, or by any other method that will eliminate the spread of infection through the carcasses or products of the aquatic animals destroyed.

This policy should be accompanied by cleansing and disinfection procedures as defined in the Aquatic Code. Fallowing should be for an appropriate period determined by risk assessment.

Surveillance

A systematic series of investigations of a given population of aquatic animals to detect the occurrence of disease for control purposes, and which may involve testing samples of a population.

Targeted surveillance

Surveillance targeted at a specific disease or infection.

Unit

Individually identifiable elements. This is a generic concept used to describe, for example, the members of a population, or the elements selected when sampling. In these contexts, examples of units include individual animals, ponds, nets, cages, farms, villages, districts, etc.

Vehicle

Any method of transport by land, air or water.

Veterinarian

Person with appropriate education, registered or licensed by the relevant veterinary statutory body of a country to practise veterinary medicine/science in that country.

Veterinary Authority

Governmental Authority of a Member Country having the primary responsibility in the whole territory for coordinating the implementation of the standards of the Aquatic Code by Competent Authorities.

APPENDIX I. National Reference Laboratories for Fish Diseases for the list of NRL .

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GLOSSARY

Definitions used at this report according to the World Organization for Animal Health (WOAH) Aquatic Animal Health Code (WOAH, 2024a).

antimicrobial agent

A naturally occurring, semi-synthetic or synthetic substance that at in vivo concentrations exhibits antimicrobial activity (kill or inhibit the growth of microorganisms). Anthelmintics and substances classed as disinfectants or antiseptics are excluded from this definition.

Aquaculture

The farming of aquatic animals with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc.

Aquaculture establishment

An establishment in which amphibians, fish, molluscs or crustaceans for breeding, stocking or sale are raised or kept.

Aquatic animal products

Non-viable aquatic animals, parts of aquatic animals, or manufactured goods containing any material derived from aquatic animals that are intended for sale or trade.

Aquatic animal waste

Entire carcasses of aquatic animals, parts of aquatic animals, or associated liquids which are intended for disposal.

Aquatic animals

All viable life stages (including eggs and gametes) of fish, molluscs, crustaceans and amphibians originating from aquaculture establishments or from the wild.

Basic biosecurity conditions

A minimum set of conditions, as described in Article 1.4.6., required to ensure biosecurity for a specific disease, in a country, zone or compartment.

Biosecurity

A set of management and physical measures designed to mitigate the risk of introduction of pathogenic agents into, or spread within, or release from, aquatic animal populations.

Biosecurity plan

A document that identifies potential pathways for the introduction of pathogenic agents into, or spread within, or release from, a zone, compartment or aquaculture establishment and describes the measures applied to mitigate the identified risk, in accordance with the recommendations in the Aquatic Code.

Case

An individual aquatic animal infected by a pathogenic agent, with or without clinical signs.

Competent Authority

A Governmental Authority of a Member Country having the responsibility in the whole or part of the territory for the implementation of certain standards of the Aquatic Code.

Contingency plan

A documented work plan designed to ensure that all needed actions, requirements and resources are provided in order to eradicate or bring under control outbreaks of specified diseases of aquatic animals.

Diagnosis

Determination of the nature of a disease.

Disease

Clinical or non-clinical infection with one or more pathogenic agents.

Disinfectants

Chemical compounds or physical processes capable of destroying pathogenic agents or inhibiting their growth in the course of disinfection.

Disinfection

The process of cleaning and applying disinfectants to inactivate pathogenic agents on potentially contaminated items.

Early detection system

A system, as described in Article 1.4.7., which ensures the rapid recognition of signs that are suspicious of a listed disease, or anemerging disease, or unexplained mortality, in aquatic animals in an aquaculture establishment or in the wild, and the rapid communication of the event to the Competent Authority, with the aim of activating an investigation by the Aquatic Animal Health Services with minimal delay.

Emerging disease

A disease, other than listed diseases, which has a significant impact on aquatic animal or public health resulting from:

- a change of known pathogenic agent or its spread to a new geographic area or species; or
- a newly recognised or suspected pathogenic agent.

Epidemiological unit

A group of animals that share approximately the same risk of exposure to a pathogenic agent with a defined location. This may be because they share a common aquatic environment (e.g. fish in a pond, caged fish in a lake), or because management practices make it likely that a pathogenic agent in one group of animals would quickly spread to other animals (e.g. all the ponds on a farm, all the ponds in a village system).

Fallowing

For disease management purposes, an operation where an aquaculture establishment is emptied of aquatic animals susceptible to a disease of concern or known to be capable of transferring the pathogenic agent, and, where feasible, of the carrying water. For aquatic animals of unknown susceptibility and those agreed not to be capable of acting as vectors of a disease of concern, decisions on fallowing should be based on a risk assessment.

Feed

Any material (single or multiple), whether processed, semi-processed or raw, as well as live organisms, which is intended to be fed directly to aquatic animals.

Feed ingredient

A component, part or constituent of any combination or mixture making up a feed, including feed additives, whether or not it has a nutritional value in the animal's diet. Ingredients may be of terrestrial or aquatic, plant or animal origin and may be organic or inorganic substances.

Hazard

A biological, chemical or physical agent in, or a condition of, an aquatic animal or aquatic animal product with the potential to cause an adverse effect on aquatic animal health or public health.

Incidence

The number of new outbreaks of disease within a specified period of time in a defined aquatic animal population.

Infection

The presence of a multiplying or otherwise developing or latent pathogenic agent in a host. This term is understood to include infestation where the pathogenic agent is a parasite in or on a host.

Listed diseases

Diseases that are referred to in Chapter 1.3 of the Aquatic Animal Health Code (WOAH, 2024a).

Outbreak

An occurrence of one or more cases in an epidemiological unit.

Passive surveillance

Aquatic animal health surveillance typically based on observations of clinical or behavioural signs of disease, or an assessment of mortality or production data, which are generated by an early detection system or from other information which is available to the Competent Authority.

Pathogenic agent

An organism that causes or contributes to the development of a disease.

Prevalence

The total number of infected aquatic animals expressed as a percentage of the total number of aquatic animals in a given aquatic animal population at one specific time.

Quarantine

Maintaining a group of aquatic animals in isolation with no direct or indirect contact with other aquatic animals, in order to undergo observation for a specified length of time and, if appropriate, testing and treatment, including proper treatment of the effluent waters.

Risk

The likelihood of the occurrence and the likely magnitude of the biological and economic consequences of an adverse event or effect to animal or human health.

Risk analysis

The process composed of hazard identification, risk assessment, risk management and risk communication.

Risk assessment

The scientific evaluation of the likelihood and the biological and economic consequences of entry, establishment and spread of a hazard.

Sensitivity

The proportion of true positive tests given in a diagnostic test, i.e. the number of true positive results divided by the number of true positive and false negative results.

Specificity

The probability that absence of infection will be correctly identified by a diagnostic test, i.e. the number of true negative results divided by the number of true negative and false positive results.

Stamping-out policy

The carrying out under the authority of the Competent Authority, on confirmation of a disease, of preventive aquatic animal health measures, consisting of killing the aquatic animals that are affected, those suspected of being affected in the population and those in other populations that have been exposed to infection by direct or indirect contact of a kind likely to cause the transmission of the pathogenic agent. All these aquatic animals, vaccinated or unvaccinated, on an infected site should be killed and the carcasses destroyed by burning or burial, or by any other method that will eliminate the spread of infection through the carcasses or products of the aquatic animals destroyed.

This policy should be accompanied by cleansing and disinfection procedures as defined in the Aquatic Code. Fallowing should be for an appropriate period determined by risk assessment.

Surveillance

A systematic series of investigations of a given population of aquatic animals to detect the occurrence of disease for control purposes, and which may involve testing samples of a population.

Targeted surveillance

Surveillance targeted at a specific disease or infection.

Unit

Individually identifiable elements. This is a generic concept used to describe, for example, the members of a population, or the elements selected when sampling. In these contexts, examples of units include individual animals, ponds, nets, cages, farms, villages, districts, etc.

Vehicle

Any method of transport by land, air or water.

Veterinarian

Person with appropriate education, registered or licensed by the relevant veterinary statutory body of a country to practise veterinary medicine/science in that country.

Veterinary Authority

Governmental Authority of a Member Country having the primary responsibility in the whole territory for coordinating the implementation of the standards of the Aquatic Code by Competent Authorities.

APPENDIX I. National Reference Laboratories for Fish Diseases

Country	*Address*	*Contact person*
EUROPE 	**EUROPEAN UNION REFERENCE LABORATORY FOR FISH AND CRUSTACEAN DISEASES** DTU Aqua Section for Fish and Shellfish Diseases Henrik Dams Allé, Building 202 2800 Kongens Lyngby – Denmark	Niccolò Vendramin Phone: +45 2142 9148 E-mail: niven@aqua.dtu.dk
AUSTRIA 	University of Veterinary Medicine Division of Fish Health Clinic for Poultry and Fish Medicine Veterinärplatz 1 1210 Vienna - Austria	Tze Ho Justin Chan Phone: +43 1 25077-4730 E-mail: tze.chan@vetmeduni.ac.at
BELGIUM 	SCIENSANO Groeselenberg 99 1180 Ukkel-Brussels – Belgium	Mieke Steensels Phone: +32 479 87 13 34 E-mail: mieke.steensels@sciensano.be
BULGARIA 	National Diagnostic Research Veterinary Institute NRL of Fish, Mollusc and Crustacean Diseases 15 P. Slaveikov blvd 1606 Sofia - Bulgaria	Petya Stefanova Orozova Phone: +359 29 521 277 E-mail: Nrl-fmcd@bfsa.bg
CROATIA 	Croatian Veterinary Institute Department of Pathologival Morphology Laboratory for Fish Pathology Savska 143 10000 Zagreb - Croatia	Dražen Oraić Phone: +385 1 6123 614 E-mail: oraic@irb.hr
CYPRUS 	Veterinary Services State Veterinary Laboratories Laboratory for Animal Health Virology Section 1417 Nicosia - Cyprus	Christodoulos Pipis E-mail: director@vs.moa.gov.cy and hpipis@vs.moa.gov.cy Vasiliki Christodoulou Phone: +357 22 805 125 E-mail: vchristodoulou@vs.moa.gov.cy
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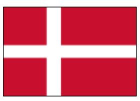
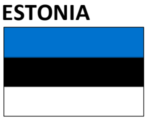
DENMARK 	DTU Aqua Section for Fish and Shellfish Diseases Henrik Dams Allé, Building 202 2800 Kongens Lyngby - Denmark	Niccolò Vendramin Phone: +45 2142 9148 E-mail: niven@aqua.dtu.dk
ESTONIA 	National Centre for Laboratory Research and Risk Assessment (LABRIS) Kreutzwaldi 30 51006 Tartu – Estonia	Katrin Mähar Phone: +372 738 6111 E-mail: nrl-fish-estonia@labris.agri.ee

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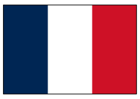
FRANCE 	Agence Nationale de Sécurité Sanitaire de l'alimentation, de l'environnement et du travail (ANSES) Ploufragan-Plouzané-Niort Laboratory/Unit Virology, Immunology and Ecotoxicology of Fish National Reference Laboratory (NRL) for notifiable fish diseases Technopôle Brest Iroise – CS10070 29280 Plouzané - France	Thierry Morin Unit Manager Phone: +332 9822 4462 E-mail: thierry.morin@anses.fr Lénaïg Louboutin Head of the NRL Phone: +332 9822 4720 E-mail: lenaig.loboutin@anses.fr
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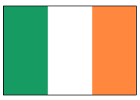
IRELAND 	Marine Institute Fish Health Unit Rinville Oranmore Co. Galway H91 R673- Ireland	Samantha White Phone: +353 (91) 387248 E-mail: samantha.white@marine.ie
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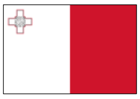
MALTA 	Veterinary Regulation Directorate Animal Health and Welfare Department Abattoir Street Albert Town, Marsa - Malta	Sara Barbiera E-mail: sara.barbiera@gov.mt
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