Intelligent Fish feeding through Integration of ENabling technologies and Circular principle

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1 Executive Summary

Aquaculture farming systems are very diverse in the EU and worldwide. Aquaculture now accounts for over half of the world's fish for direct human consumption and is expected to approach two-thirds by 2030 (Anderson et al., 2019). With aquaculture's growth, a number of high-profile concerns have arisen, including pollution, feeding practices, disease management and antibiotic use, habitat use, non-native species, food safety, fraud, animal welfare, impacts on traditional wild fisheries, access to water and space, market competition, and genetics. **Managing these concerns requires thoughtful and well-designed policies and regulations** (Anderson et al. 2019).

The European Green Deal and the Farm to Fork Strategy underline the potential of farmed seafood as a source of protein for food and feed with a low-carbon footprint, which has an important role to play in helping to build a sustainable food system (COM(2019) 640). At the same time, Knowledge and innovation (including the use of digital technology) are key to achieve a modern, resource-efficient and competitive economy for the EU aquaculture sector. Digital technologies are especially important for building the resilience and competitiveness of aquaculture and ensuring its green transition by successfully implementing digital transformation for people and businesses (COM(2021) 205).

In that context, the iFishIENCi Research & Innovation project aims to provide the European aquaculture sector with a competitive advantage and growth stimulation through breakthrough innovations supporting sustainable aquaculture based on enabling technologies and circular principles for representative fish species and farming systems.

The objective of the current iFishIENCi public report D4.13 (September 2021) is to analyse Gap and Opportunities for the regulatory framework of European aquaculture and to evaluate the role of informal institutions in the regulatory process. The current review is specifically accessing the regulatory framework, which affects circularity within EU aquaculture, supporting the iFishIENCi task on Zero waste and Valorisation of by-products and sludge (iFishIENCi Task1.5).

This report takes into account the recently published Strategic guidelines for a more sustainable and competitive EU aquaculture (COM (2021) 236 final), extensive literature research on regulatory framework as well as views expressed by aquaculture experts on policies, practices, and regulations along the entire value chain of aquaculture production in the frame of the Horizon4Aquaculture event[1].

[1] http://ifishienci.eu/horizon4aquaculture/

2 Introduction

The top ten aquaculture-producing countries in the world are China, Indonesia, India, Vietnam, Philippines, Bangladesh, Republic of Korea, Norway, Egypt and Thailand. The vast majority of aquaculture by production (net value) comes from Asia. In 2018, Asia was the world major producer responsible for 88.7% of the global aquaculture production and Europe 3.75%.

Europe has increased its production by 500.000 Tons from 2012 to 2018 (FAO 2020). In 2009, European aquaculture produced more than 1,800,000 tons of fish and 665,000 tons of shellfish, worth some 6.2 billion Euros. The production sector supported some 100,000 jobs and supplied the European processing sector, which employs some 130,000 people in the EU alone (EATIP, n.d.). As of 2019, the total European production of fish by aquaculture was estimated to 2,570,242 tons. Marine cold-water species represent 70% of total production, freshwater species 16% and marine Mediterranean 14%. Norway is the dominant producer in Europe with 56% of the total supply, mainly salmon but also large trout (>1.2 kg) production. The other countries that produce more than 100,000 tons annually are Turkey, United Kingdom and Greece. The main species produced are salmon, trout, seabream, seabass and carp, which represented 95% of the total European production in 2019 (FEAP, 2020).

Aquaculture farming systems are very diverse in the EU and worldwide and include for example the systems described in Figure 1 (Funge-Smith et al., 2001)).

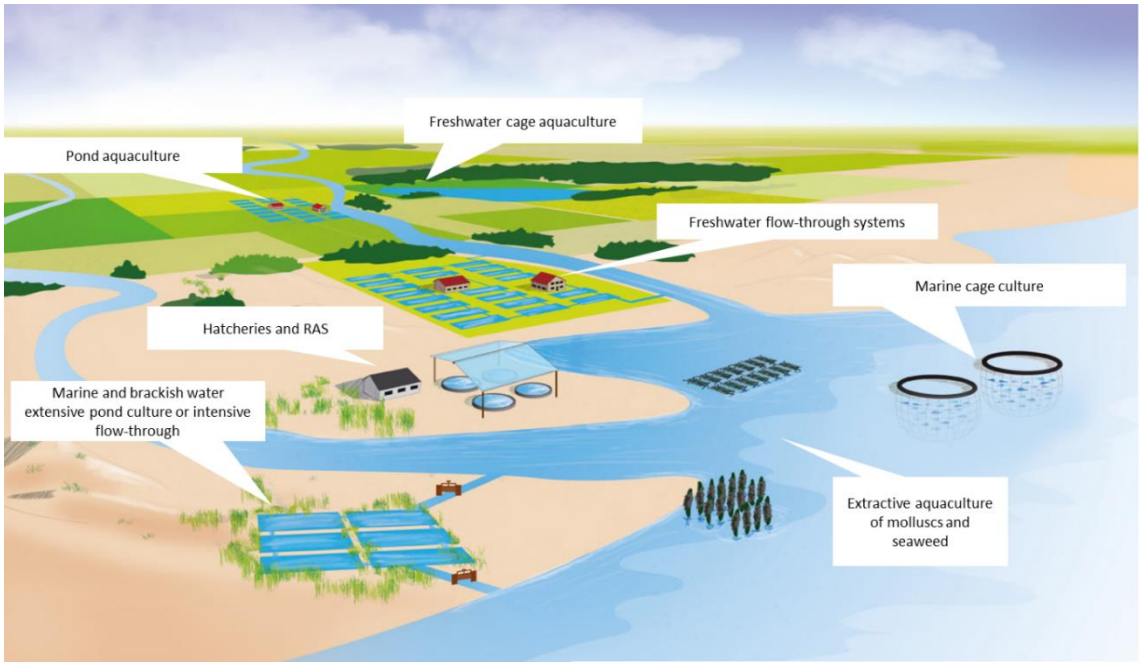

Figure 1 Aquaculture in Europe - Main technologies (iFishIENCi)

Since the Blue Revolution began in the late 1960s, global aquaculture production has grown rapidly. Aquaculture now accounts for over half of the world's fish for direct human consumption and is expected to approach two-thirds by 2030 (Anderson et al., 2019). With aquaculture's growth, a number of high-profile concerns have arisen, including pollution, feeding practices, disease management and antibiotic use, habitat use, non-native species, food safety, fraud, animal welfare, impacts on traditional wild fisheries, access to water and space, market competition, and genetics. **Managing these concerns requires thoughtful and well-designed policies and regulations** (Anderson et al. 2019).

In 2007, of the few countries worldwide that included aquaculture as an economic sector, 87% reported having some form of legal framework in place to regulate the development of responsible

aquaculture. By 2012, 98% percent of countries worldwide reported that aquaculture occurred in their countries, but only about 40% of these had legislative and institutional frameworks in place. Thus, the growth of aquaculture activities appears to have outpaced the development of legislation and legal frameworks to govern aquaculture. In 2018, the figure had risen to just over half, still indicating a need for some countries to adopt a legislative framework to better manage and benefit from aquaculture economic activity and at the same time set a major focus on social sustainability in fisheries and aquaculture value chains (FAO, 2020).

The European Green Deal and the Farm to Fork Strategy underline the potential of farmed seafood as a source of protein for food and feed with a low-carbon footprint, which has an important role to play in helping to build a sustainable food system (COM(2019) 640). At the same time, Knowledge and innovation (including the use of digital technology) are key to achieve a modern, resource-efficient and competitive economy for the EU aquaculture sector. Digital technologies are especially important for building the resilience and competitiveness of aquaculture and ensuring its green transition by successfully implementing digital transformation for people and businesses (COM(2021) 205).

The so-called “4th industrial revolution” -Aquaculture 4.0 - is projected to enable a 15-20% increase in the aquaculture sector by the year 2030. In this context, European aquaculture has been recently applying innovative and disruptive technologies to transform fishery management strategies, with major impact on the implementation of new Circular Bioeconomy approaches. In addition to the expected impact on growth, the benefits of Aquaculture 4.0 include improved productivity, efficiency, and reduced costs.

Precision aquaculture and monitoring technologies in aquaculture, sensors increasingly collect optical (e.g. by video camera) and physical data to monitor, for example, fish growth, health and feed loss reduction are one answer of the aquaculture sector to digitalisation need. While past innovations focused on hardware and data collection, the challenge is now the pressure on farmers to consistently interpret the large amount of data. Here, AI and data processing can help by identifying patterns in feeding activities and presenting strategies to farmers, ranging from cost-efficient use of feed to maintaining fish welfare. The knowledge needed for developing aquaculture systems under a blue growth paradigm requires innovations in monitoring. This is achievable through intensive data integration across various scales. IoT provides interconnectedness among systems and across sensors, and enables managers to analyse data generated by satellite observations jointly with those provided from electronic fish tags. The key challenge with all these innovations is to combine data across data providers and countries and analyse them in a consistent way. Cloud computing and AI therefore would benefit if data were consistent and follow standards for their collection and processing. FAO through standard-setting bodies such as the Coordinating Working Party on Fishery Statistics (CWP), United Nations Centre for Trade Facilitation and Electronic Business, and the Research Data Alliance, already play a leading role by contributing to the development of standards, guidelines and best practices (FAO, 2020).

Further the application of both established and newly emerging recycling methods to aquaculture has great potential to make the industry more sustainable and to greatly increase production output.

- Retrieved solids, dissolved nutrients and seafood by-products can all be reused to benefit aquaculture itself, and also other industries including agriculture and nutraceuticals. As just one example, recycling of omega-3 fatty acids from seafood by-products and the use of bioremediating microalgae and filter-feeders (e.g. polychaetes, bivalves) can enable a large increase in the supply of omega-3 oils, with significant economic and human health benefits.
- Energy generated from sludge digestion, clean water retrieved from bioremediation, and upcycled nutrients through integrated aquaculture systems, could each help sustain intensive arable farming. These recycling methodologies have the potential to play primary roles in establishing sustainable circular economies in aquaculture (Campanati et al., 2021).

2.1 Objective of the iFishIENCi Research & Innovation project

In that context, the iFishIENCi Research & Innovation project aims to provide the European aquaculture sector with a competitive advantage and growth stimulation through breakthrough innovations supporting sustainable aquaculture based on enabling technologies and circular principles for representative fish species and farming systems. In order to address the needs of a large amount of stakeholders of the aquaculture sector in Europe, the iFishIENCi project is focusing on five representative fish species: (1) **Seabass**, a Mediterranean pure-marine species, (2) **Atlantic salmon**, an anadromous species of northern regions, (3) **Rainbow trout**, a freshwater species widely farmed in Europe, America and Japan, (4) **African catfish** and (5) **Tilapia**, worldwide freshwater species.

The iFishIENCi project is testing the innovative elements in controlled environments in different types of aquaculture systems:

- **Recirculating Aquaculture System** –RAS - (marine and freshwater) in Germany and Malta
- **Open cage** in Greece and Norway
- **Semi-closed** cage system in Norway
- **Flow-through** in Hungary and
- **Ponds** in Laos

The iFishIENCi Research & Innovation project aims to set a standard on digital aquaculture:

(1) by setting "the Fish" at the heart of the decision-making in fish production, through joining forces between experts in fish and fish-farming and experts in digitization, IoT and AI;
(2) by selecting the most promising emerging technologies on smart monitoring and control system, and pushing them forward through targeted development and integration;
(3) by demonstrating the value of new and sustainable feed sources, contributing to the consolidation of a circular and blue bioeconomy; and
(4) by proposing optimal value-chain for valorisation of waste from fish farming (water, sludge) and from the production of ingredients (exhausted medium from yeast, waste generated from the production of the antioxidant supplement).

The aim of the iFishIENCi series of three reports on Regulatory Framework and Requirements is therefore to identify and assess the Legal framework and its requirements, the responsible farming standards and certification schemes as well as the Ethical, Environmental, and H&S Requirements linked with the Fish farming industry and the Nutrition and breeding especially in the European aquaculture.

2.2 Objective of past iFishIENCi report on regulatory framework and requirements

As the European aquaculture companies operate in complex markets with multifaceted interface at local and global level, previous iFishIENCi report D4.12 prepared in July 2019 and revised in October 2020, focused on outlining:

- EU regulation, both sector specific and cross-sector regulation, for nutrition and breeding in European aquaculture
- national regulations seen from a Maltese, Norwegian, Danish, Spanish, Greek, Hungarian, German and French (the countries of the consortium members) perspective because although the European national regulations for a large part are implementation of EU regulation, there are differences, which influence the competitiveness of national industry
- responsible legislation of other countries such as Ireland, Scotland and Turkey in order to identify lessons to learn from those countries

- existing framework of Standardisation and Certification

2.3 Objective of current iFishIENCi report on regulatory framework and requirements

The objective of the current iFishIENCi public report D4.13 (September 2021) is to analyse Gap and Opportunities for the regulatory framework of European aquaculture and to evaluate the role of informal institutions in the regulatory process. The current review is specifically accessing the regulatory framework, which affects circularity within EU aquaculture, supporting the iFishIENCi task on Zero waste and Valorisation of by-products and sludge (iFishIENCi Task1.5).

The iFishIENCi project is looking into which types of aquaculture wastes are the most promising for valorisation considering following aspects for the selection: practical collection, volumes, characteristics, legislation, and if this waste is currently valorised or if there is a need for further valorisation. Regulations exist on the waste and wastewater treatment systems from Recirculating Aquaculture Systems (RAS), as they exist on municipal and industrial wastewater treatment, but regulations on sludge further treatment as studied by the iFishIENCi project focused on Algae cultivation are still inexistent. The iFishIENCi project is trialling an innovative form of waste valorisation by using the wastewater for algae and yeast production and the dewatered sludge for extraction and recovery of nutrients for algae cultivation (nitrogen and phosphorus). Therefore, a thorough analysis of existing barriers on EU and local regulations from iFishIENCi target countries (Hungary, Malta, Germany, Spain and Norway), which hinder the new use for this waste stream, and identify the diversity of legislations, possible bottle necks and ongoing developments which affect directly or indirectly this valorisation route of interest is needed. Apart from RAS systems, regulations on ponds and Open cages will also be investigated, as similar barriers in the different methods of production might help with the identification of possible bottlenecks, and proposal of solutions and current ongoing developments.

This report takes into account the recently published Strategic guidelines for a more sustainable and competitive EU aquaculture (COM (2021) 236 final), extensive literature research on regulatory framework as well as views expressed by aquaculture experts on policies, practices, and regulations along the entire value chain of aquaculture production in the frame of the Horizon4Aquaculture event[2].

2.4 Objective of upcoming iFishIENCi report on regulatory framework and requirements

At the end of the iFishIENCi project (July 2022), the iFishIENCi public report D4.14 will

(1) Assess current use of certification (mandatory vs. voluntary)
(2) Compare use of certification with consumer attitude
(3) Develop Guidance aligned with current legislation: iFishIENCi 's recommendations in Policy briefs relying under others on the outcome of the "Aquaculture Going Circular" event (7.2.2).

[2] http://ifishienci.eu/horizon4aquaculture/

3 Regulatory Framework for EU aquaculture

EU defines 'aquaculture' as the rearing or cultivation of aquatic organisms using techniques designed to increase the production of the organisms in question beyond the natural capacity of the environment. The organisms remain the property of a natural or legal person throughout the rearing or culture stage, up to and including harvesting (Regulation (EU) No 1380/2013). 'Aquaculture products', are understood to mean 'aquatic organisms at any stage of their life cycle resulting from any aquaculture activity or product derived therefrom'. This broad inclusive approach is also evident in the law of several Member States, where the term aquaculture is used as a blanket description to describe all forms of fish farming and shellfish production. This may cover the many processes involved in rearing fish species through the provision of food and protection from predators and disease (Long, 2016).

3.1 Policy framework for Aquaculture

The EU policy framework for aquaculture relies mainly on following regulatory pillars:

- The **Common fisheries policy** aiming to enhance the competitiveness of the aquaculture sector and to promote a level playing field for EU operators by exploiting their competitive advantages through implementation of multiannual national strategic plan for the development of aquaculture activities in Member States (REGULATION (EU) No 1380/2013).
- The **Water Framework directive** aiming to achieve good quantitative and qualitative status for all ground and surface waters, covering inland waters and marine waters in the EU (DIRECTIVE 2000/60/EC).
- The **Marine Strategy Framework directive** aiming to protect the marine environment in Europe by reaching "Good environmental status" relating to Biological diversity, non-indigenious species, Commercial exploitation of fish and shellfish, Foodweb integrity, Human-induced eutrophication, Seafloor integrity, Concentration of contaminants and marine litter (DIRECTIVE 2008/56/EC).
- The Commission priorities for 2019-2024 (von der Leyen, 2019) especially the **European Green Deal** (COM(2019) 640) calling for a transformation of EU economy to become a modern, resource-efficient and competitive economy where net emissions of greenhouse gases are phased out and the EU's natural capital is protected.
- The **Sustainable Blue Economy** (COM(2021) 240) as a sustainable transition from the blue growth strategy (DG Mare, 2012) aiming to support sustainable growth in the marine and maritime sectors as a whole
- The **Farm To Fork Strategy** aiming to make food systems fair, healthy and environmentally-friendly (COM(2020) 381).
- The **Circular Economy Action Plan** aiming to reduce pressure on natural resources and create sustainable growth and jobs, as prerequisite to achieve the EU's 2050 climate neutrality target and to halt biodiversity loss (COM(2020) 98).
- The New **EU Strategy On Adaptation To Climate Change** aiming to adapt to the unavoidable impacts of climate change and become climate resilient by 2050 (COM(2021) 82).
- The **EU Biodiversity Strategy** for 2030 aiming to protect nature and reverse the degradation of ecosystems (COM(2020) 380).
- The **Strategic guidelines for a more sustainable and competitive EU aquaculture** for the period 2021 to 2030 (COM/2021/236 final)

3.2 Strategic guidelines for a more sustainable and competitive EU aquaculture

The European Green Deal is the EU's new growth strategy and aims at stimulating the economy and creating jobs while accelerating the green transition in a cost-efficient way. The strategic guidelines laid down by the EU in May 2021 aim to offer a common vision for EU Member States and all relevant stakeholders for the further development of aquaculture in the EU in a way that contributes to that growth strategy (COM(2021) 236 final):

(1) Competitive and resilient aquaculture sector
(2) Ensure the supply of nutritious and healthy food
(3) Reduce EU's dependency on seafood imports
(4) Create economic opportunities and jobs
(5) Become a global reference for sustainability

Achieving this vision will require addressing different challenges and opportunities of the EU aquaculture sector in order to reach the following inter-related objectives: (1) building resilience and competitiveness; (2) participating in the green transition; (3) ensuring social acceptance and consumer information; and (4) increasing knowledge and innovation. One key enabling condition for the EU aquaculture sector to grow as a resilient and competitive sector is a regulatory and administrative framework that is transparent and efficient.

As a follow-up to the Farm to Fork Strategy, the Commission is also working on a separate and specific initiative to support the production, safe consumption and innovative use of algae. This initiative will address the challenges and opportunities of algae farming and propose concrete actions for algae to become an important source of alternative protein for a sustainable food system and global food security (European Commission, 2020).

3.3 Regulations regarding Circularity in Aquaculture

Circular Economy is not only an approach to more appropriate waste management as often misinterpreted (Ghisellini et al., 2016), but is a solid concept to optimise process and product to reduce waste generation. This concept is mainly related to "closing the loop" of product lifecycles throughout the 3R concept: Reduce, Recycle, and Reuse. More recently a 9R concept was developed trying to minimize inputs from raw materials (mainly non-renewable ones) and to maximize outputs from waste or by-products; maintaining the resource value of a product as long as possible during its life cycle; rethinking the process and reintegrating the discard materials (when they reach their end-of-life) for other applications in the same or new systems.

The European Commission has taken the lead role in the EU regarding CE strategy since 2014, although each country is trying to promote its own strategy, depending on its particular interests. Therefore, the EU and MS policies respect to CE should be implemented in a coordinated way, considering the global context (Soula et al., 2019).

In December 2015, the EC launched the Circular Economy Action Plan (COM(2015) 614 final), and its complete execution was reported in March 2019 (COM(2019) 190 final). No specific actions on aquaculture have been included in these plans, likely because of its low environmental impact compared to priority sectors such as electronics, plastics, textiles or mobility. Still, some of the envisaged measures in the Circular Economy Action Plan are clearly relevant to aquaculture, particularly those related to water reuse or secondary raw materials.

Although specific and comprehensive legislation focused directly on factors which affect circularity in Aquaculture is either non-existing or limiting such practices such as waste valorisation, there is already an existing awareness that this must be improved, to support the EU to participate in the green transition set by the European Green Deal. This sector has a particular role to play in contributing to the transition to sustainable food systems, but also to the development of the bioeconomy and the

circular economy (through the use of renewable aquatic resources), and to reversing biodiversity loss, amongst others by reducing pollution. COM/2021/236 is including the implementation of waste management systems that minimize the environmental footprint of aquaculture activities and applying a circular-economy approach, including the use of waste.

Circular Economy in the aquaculture sector can be tackled under different angles in terms of waste management. Therefore, a common definition or approach may be a key step before progressing further models, strategies, or plans. This definition should serve as the basis for future recommendations toward circular economy business models in the aquaculture sector.

The iFishIENCi project, in collaboration with other European projects (AQUAIMPACT, ASTRAL and IMPAQT) participated in 2020 in the European consultation regarding the update of strategic guidelines for sustainable development of EU aquaculture (see 7.2.1). As part of the coordinated actions among these projects, a circularity definition was given:

"We consider circularity from the aquaculture point of view - in a food production system. We need to address the strengths of circularity considering, but not limited to, the importance of biological flows within aquaculture production systems.

The circular economy is defined as the action plan in which the value of the products, materials, and resources last within the economy for as long as possible, which aims to minimize waste generation. From our perspective, the circular economy as it may be applied to aquaculture, aims to produce renewable biological resources, facilitating a conversion of these resources and waste streams into value added products, such as food, feed, biobased products, and bioenergy.

Giving this specific dimension to circular economy, when addressing the nutrient flow mass and assessing the impacts of recirculating them from one biological species to another, or capturing them to be recirculated as new feed, the circular economy in aquaculture can also be defined and described as a circular bioeconomy."

As a result of the consultation process, the Strategic guidelines for a more sustainable and competitive EU aquaculture (COM(2021) 236 final):

- Recognize aquaculture as a relevant sector to be part of a more circular management of resources.
- Highlight the aquaculture role in the development of the circular economy.
- Recommend the improvement of the environmental profile through:
    - the application of circular-economy approach, including the use of waste
    - the development of Implemented Multi-trophic Aquaculture (IMTA) systems

3.4 Regulations regarding Waste and Water management in Aquaculture

Aquaculture activities generate a diversity of waste that depends on the cultured species, the productive system used, the degree of intensity of the activity and the production capacity. The aquaculture wastes can be Solid waste (faeces and uneaten feed), Wastewater (both particulate and dissolved organic/inorganic matter, nitrogen and phosphorous) and Residues of animal origin (dead animals, residues from the processing of fish). Recently, various types of discharge reuse have been investigated:

- Use other industries effluents in aquaculture for example geothermal water re-use (for both heat and water) or treated community wastewater (for both nutrients and water) (VicInAqua)
- Use of aquaculture effluents in other industries for irrigation or biogas production
- Reuse of water and dissolved nutrients within aquaculture

The Waste Framework Directive (WFD) is the key legislative document on waste at EU level (Directive 2008/98/EC). The WFD is transposed into national legislation of the Member States by means of

separate legal acts. The scope of the directive is determined by the definition of 'waste' in Article 3 as: 'any substance or object which the holder discards or intends or is required to discard'.

The European List of Waste (LoW) is the key document for classification of waste (Commission Decision 2000/532/EC). The consolidated version of the LoW has existed since 2000 and has been revised by Commission Decision 2014/955/EU, in order to adapt it to scientific progress and align it with developments in chemicals legislation. Aquaculture waste is classified as

- Wastes from agriculture, horticulture, forestry, hunting and fishing, food preparation and processing (code 02)
    - Waste from aquaculture (type 02.01) or
    - Waste from preparation and processing (type 02.02)

Aquaculture waste are identified as sludges from washing and cleaning and from on-site effluent treatment, animal-tissue waste, waste plastics (except packaging), animal faeces, urine and manure (including spoiled straw), or effluents. All these types of wastes are mainly absolute non-hazardous entries (ANH), which means that they cannot be allocated to hazardous entries and are non-hazardous without any further assessment.

It is important to highlight that (1) Waste waters and (2) Animal by-products, except those which are destined for incineration, landfilling or use in a biogas or composting plant, shall be excluded from the scope of the WFD. These residues are regulated (1) by the Water Framework Directive (Directive 2000/60/EC) and (2) by the Animal by-products Regulation (Regulation (EC) No. 1069/2009).

Building on a tradition of water protection legislation, the EU has now in force four main pillars addressing discharges to aquatic ecosystems:

- The first two are the directives from 1991 on urban wastewater treatment (Council Directive 91/271/EC) and on nitrates pollution from agricultural sources (Council Directive 91/767/EEC, or the Nitrates Directive).
- Furthermore, the Water Framework Directive (Directive 2000/60/EC) is the 'flagship' of EU water policy and legislation, which has expanded the scope of EU water policies to all inland and coastal water bodies and addresses all sources of impacts, not only related to waste water from municipal and industrial sources.
- Finally, the Environmental Quality Standards Directive (Directive 2008/105/EC, EQSD) is the legislative framework regulating the release of chemicals into the aquatic environment across the EU. The EQSD applies to surface waters, i.e. inland waters, transitional waters (estuaries and inlets) and coastal waters out to 12 nautical miles.

Besides, the objective of the EU is to achieve and maintain the good ecological/environmental status (GES) and the good chemical status of inland, coastal and marine waters. This is supported by further EU legislation:

- the Industrial Emissions Directive (Directive 2010/75/EU),
- the REACH legislation (Regulation (EC) No 1907/2006 and Directive 2006/121/EC),
- the Biocidal Products Regulation (Regulation (EU) No 528/2012),
- the Veterinary Medicines Directive (Directive 2001/82/EC),
- the Plant Protection Products Regulation (Regulation (EC) No 1107/2009) and the Sustainable Use of Pesticides Directive (Directive 2009/128/EC)
- the regulation on persistent organic pollutants (Regulation (EU) 2019/1021)

3.5 Regulations regarding Recirculating Aquaculture Systems (RAS)

Recirculating aquaculture systems (RAS) are operated as outdoor or indoor systems. Due to the intensive mode of fish production in many of these systems, waste treatment within the recirculating loop as well as in the effluents of these systems is of primary concern.

- In outdoor RAS, such treatment is often achieved within the recirculating loop. In these systems, extractive organisms, such as phototrophic organisms and detritivores, are cultured in relatively large treatment compartments whereby a considerable part of the waste produced by the primary organisms is converted in biomass.
- In indoor systems, capture of solid waste and conversion of ammonia to nitrate by nitrification are usually the main treatment steps within the recirculating loop. Waste reduction (as opposed to capture and conversion) is accomplished in some freshwater and marine indoor RAS by incorporation of denitrification and sludge digestion.

In many RAS, whether operated as indoor or outdoor systems, effluent is treated before final discharge. Such effluent treatment may comprise devices for sludge thickening, sludge digestion as well as those for inorganic phosphate and nitrogen removal.

The higher the rate of recirculation the less new water will be used, and the less discharge water will need to be treated. In some cases, no water at all will return to the surrounding environment. However, this kind of “zero discharge” fish farming is costly to build and the running costs for the waste treatment are significant. Also, daily operation of the waste treatment will require significant attention to make it work efficiently. For zero-discharge fish farming one should also be aware that a certain amount of water exchange is always needed to prevent the accumulation of metals and phosphorous compounds in the system. The bottom line is that authorities and the fish farmer must agree on a discharge permission that allows protecting the environment whilst having an economical viable fish farming business (Bregnballe, 2015).

It is important to mention the different types of wastewater and waste from RAS systems, such as wastewater discharge, wastewater treatment (sludge formation), waste reduction (as opposed to capture and conversion), sludge treatment, sludge disposal and sludge further treatment and reuse.

3.5.1 Treatment of Sludge from RAS

Regulations exist on waste disposed from freshwater RAS, which may be treated in regional waste treatment facilities or biogas plants, as normally the amount of sludge is not enough for own RAS farms to have their own methane biodigestor. Such sludge may be also used for agricultural purposes in the form of fertilizer or compost, and treatment options for waste disposed from marine RAS are more limited.

If the RAS system were to be qualified as a potential wastewater treatment plant, which sometimes happens as in the case of aquaponics, the sludge (which can be avoided, if an additional cycle for remineralization of this sludge is integrated or if the sludge is degraded on-site in the filter sludge) no registration under the fertilizer law is required. If used outside the premises, regulations related to organic waste or sewage sludge disposal (more restrictive) apply. Filter sludge would be considered sewage sludge if the system as a whole is considered a wastewater treatment plant (sometimes the case for aquaponics systems). Whether this applies in practice remains to be determined.

3.5.2 Treatment of Wastewater from RAS

The Water Framework Directive (WFD), covering inland and coastal waters, mentions RAS wastewater legislation and regulation in Europe and reuse of wastewater from RAS.

The Commission Staff Working Document on the application of the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) in relation to aquaculture mentions RAS as

industry good practice and suggestion to minimise pathogen exchange with wild fish and shellfish and the release of chemical treatments into the environment (SWD(2016) 178 final).

As with traditional aquaculture, production permits are necessary to establish a RAS facility. In addition, licenses are required for the intake and discharge of water. With decreasing availability of suitable, regulated coastal areas, licenses for cage-based aquaculture are difficult and expensive to obtain, which is a substantial driver for moving the production on land.

3.5.3 Organic products from RAS

EU regulations explicitly excludes recirculation aquaculture systems (RAS) for aquaculture grow-out from organic certification because they are not close enough to nature, according to Commission Regulation (EC) No 710/2009. Meanwhile, according to Council Regulation (EC) No 834/2007, one criterion for organic food production is its contribution to sustainable development. Against this background, one might argue that in spite of their distance to nature RAS are innovative solutions to sustainability issues in food production (Meisch, 2019) and (Science for Environment Policy, 2015).

3.6 Regulations regarding Open cage Aquaculture

The Marine Strategy Framework Directive (MSFD) is relevant to marine aquaculture including open cages. Regarding water protection, marine aquaculture may pose impacts related to nutrient and organic matter discharge and use of pesticides and drugs. The magnitude of aquaculture impact in marine waters, in contrast with impacts from other sources, has not been fully assessed, as it is difficult to gauge in relation to the overall impacts of anthropogenic activities. However, the effects are dependent on factors such as the hydrological conditions at each aquaculture facility, the type of species being cultured, the production method and the management practices.

The MSFD aims to achieve Good Environmental Status (GES) in marine waters. GES is based in eleven descriptors, among which eutrophication, hydrographical conditions and contaminants are related to water quality and discharges. Whereas GES assessment is expected for large sea areas, impacts of aquaculture facilities are likely to happen at a local scale, thus contributing only to a small part of anthropogenic impacts. However, the existence of multiple facilities could mean a threat to achieve GES, particularly in contained environments such as land-based facilities discharging at a specific point, shallow waters or closed areas such estuaries. Hence, despite the current scale of aquaculture operations and the local impacts, it is possible that aquaculture, alongside all other sectors, will need to reduce impacts in order to reach GES under MSFD (Soula et al. 2019).

Globally, aquaculture operations are treated under the main law of the sea provisions, as well as the FAO's Code of Conduct on Responsible Fisheries and its technical guidelines (FAO, 1995). However, a range of multilateral environmental agreements (MEAs) have implications for mariculture operations including the Convention on Biological Diversity -CBD- (Zedan, 2005) and the Ramsar Wetlands Convention (Convention, 1971). International trade law instruments as well as trade-related MEAs, specifically the Convention on International Trade in Endangered Species of Wild Fauna and Flora(CITES, 1973) and the Cartagena Protocol on Biosafety to the CBD (Cartagena protocol, 2000) have relevance for aquaculture. Global instruments dealing with intellectual property and access and benefit-sharing issues in the aquaculture sector, including the Nagoya Protocol (Nagoya protocol, 2010) also have relevance for aquaculture (Bankes et al. 2016).

3.7 Regulations regarding Pond and Flow-through Aquaculture

Ponds used in Aquaculture, just as RAS systems, fall under the Water Framework Directive (WFD). The Directive, which applies to inland water and coastal water up to 1 nautical mile from coastal State baselines, takes an integrated approach to water management, by bringing together existing water

conservation legislation and establishing a planning system based on river basins, watercourses and associated coastal areas organized into substantially-sized “River Basin Districts”, most important among them are the River Basin Management Plans (RBMPs), which focuses on achieving good ecological and chemical status of surface water.

A key point about the Directive is that it is not concerned, as previous water legislation has been (e.g. Bathing Water Directive, Urban Waste Water Treatment Directive) with a single aspect of the water environment but takes an integrated approach focussing on resulting water quality. This means that aquaculture cannot be considered isolated from other pressures on the freshwater and inshore marine environment (Hedley, 2009).

3.8 National/Local Regulations relevant for the iFishIENCi project

Although Member states for a large part directly translate EU regulation in their national regulation to implement it, there are differences, which influence the competitiveness of the national industry.

3.8.1 Aquaculture regulation in Germany

Building permits for technical aquaculture and obtaining discharge permits for wastewater can be problematic because handled differently from region to region and offers investors little planning reliability. Regarding wastewater, the main obstacle to the further development of the sector is economic viability and **regional licensing problems.** According to information from some federal states, building permits for technical aquaculture facilities in outdoor areas are not granted at all or only after long test procedures. In other states, however, e.g. Schleswig-Holstein permits can be obtained if construction is planned in industrial estates or special use areas. Obtaining discharge permits for wastewater can also be problematic, handled differently from region to region and offers investors little planning reliability.

The leaflet DWA-M 777 "Water / wastewater treatment in fish farming" (DWA, 2021) was recently released by the German Association for Water, Wastewater and Waste (DWA). For the first time, Fish production processes, including the process-related emission sources in the wastewater, the soil and the air as well as their reduction possibilities according to the state of the art, are described in detail in the DWA regulations. The processes for the treatment of circulating water and wastewater as well as sludge according to the state of the art or the best available techniques (BAT) are presented and recommendations for the planning and operation of the plants are given. Production-integrated measures to reduce wastewater pollution as well as other environmental media are listed.

Most of the current fish production in Germany takes place in plants that do not produce any wastewater in the sense of wastewater law. These include (partially closed) cold water flow-through systems, in which mainly trout are raised, pond systems (e.g. for carp) and the only small amount of net enclosures. Closed recirculation systems represent the most modern and intensive methods of fish production, which are characterized by a high water use intensity and extensive location independence. They have internal water treatment and at the same time require treatment of the discharged water. A high development potential is ascribed to these closed circuit systems. Closed circulation systems are usually subject to the provisions of the Water Management Act and the Wastewater Tax Act (AbwAG, 1976), since up to 20% of the system volume is replaced daily due to the nature of the process. However, there is no appendix to the Waste Water Ordinance (AbwV, 1997). In the past, this sometimes led to problems, particularly when it came to plant approval.

This leaflet is intended in particular to provide assistance in the approval process. To provide information, support and decision-making for the water authorities, system operators and system manufacturers, this leaflet provides guidelines and guide values for the relevant procedures and parameters for closed circuit systems. In the scope of this leaflet, aquaculture essentially takes place as fish production inland or on land and primarily in fresh water. Systems or parts of systems used in

marine aquaculture for fish and shrimp are dealt with at the appropriate points, although there are currently few commercially operating systems of this type within the scope of the leaflet (DWA, 2021).

3.8.2 Aquaculture regulation in Malta

Aquaculture in Malta began in the late 1980s but it was not until 1994 that the first policy on aquaculture was issued by the then Planning Authority entitled "Policy and design guidelines - fish farming" (PDG), updated in 2004.

The Fisheries Operational Programme for Malta 2007-2013 (FOPM, 2011) was prepared in accordance with Council (EC) Regulation No. 1198/2006 regarding the European Fisheries Fund (EFF) in July 2006. The purpose of the programme was to identify priorities for the development of Maltese fisheries, aquaculture and processing in accordance with the objectives of the Common Fisheries Policy (CFP).The FOPM is based onMalta's National Strategic Plan For Fisheries 2007-2013, which gives its objectives for the development of aquaculture as "To stabilise existing aquaculture production, increase product diversification and improve the value added of the sector". Specific actions were taken to close the production cycle of existing aquaculture production and to achieve the diversification of cultivated species and to reduce the negative impact of existing operations on the environment.

Other initiatives taking their lead from national policy include the Water Catchment Management Plans (1st and 2nd WCMP), which provides a summary of how the EU Water Framework Directive (WFD) was implemented in Malta, and Integrated Coastal Zone Management (ICZM). With regard to the WCMP, the key measure relating to aquaculture is to "define and implement operational guidance for aquaculture activities (Environment and Resource Authority Malta,2021).

There is clearly a need to define more accurately what species can be farmed where, and to differentiate between different types of production systems e.g. nursery and on-growing facilities and their possible location. A further observation on policy is that whilst there is reference to consultation between relevant Government departments and agencies, there appears to have been little or no consultation with the aquaculture industry itself. This is contrary to EU policy, which emphasises the need for proper stakeholder consultation.

The current basis for aquaculture legislation in Malta is the Fisheries Conservation and Management Act of 2001 (FAO 2014) This act includes the requirement of a permit for the installation or operation of an aquaculture establishment, granted by the Director responsible for fisheries management subject to a list of conditions established with the consultation of the Chairman of the Malta Maritime Authority (MMA) and the Chairman of MEPA with regard to the allocation of 'an appropriate site for the aquaculture establishment'. This act, therefore, formally lays out a requirement for consultation between the Director of Fisheries, the Malta Maritime Authority and the Malta Environment and Planning Authority for the granting of an aquaculture permit. The fact that no specific conditions or requirements are listed for these issues suggests that individual aquaculture permits may vary with respect to the list of conditions required for operation, and may vary over time according to government policy and approved development plans and planning policies (Scott et al. 2012).

3.8.3 Aquaculture regulation in Hungary

The EU produces around 70.000 tonnes of common carp annually via ponds. The majority of production is concentrated in Central and Eastern Europe. Hungary, along with Czech and Poland are the top three EU producers (71% of EU production in 2018). Catfish is also part of the production. Hungary's production increased by 90% from 2009 to 2018. The rise in Hungarian production can be explained by investment in geothermal water heated intensive systems. Hungary now has a strong freshwater Aquaculture share in the EU Market (7th largest producer) (EUMOFA, 2021).

Hungary is a leading country in the pond farm diversification. According to this system, pond farming is associated with other activities, such as ecosystem and tourist services. There is also a purposefully developed system of facilities available for visitors including, inter alia, pensions, restaurants, wellness centers, summer camps and museums. The development of multifunctional pond fish farming is an important issue in Central and Eastern Europe, where pond fish farming plays an important role in food supply and rural development. Diversification permits to traditional pond farms to develop and employ more people while preserving its environmental benefits. The advantages of multifunctional pond farming are:

- Improvement of economic stability due to the diversification which generates extra-income from the new activities (tourism, angling, etc.);
- Improvement of the public perception of the farm.

Fish ponds generally have closed recycle system, which ensures the protection of farmed fish from their wild counterparts.

3.8.4 Aquaculture regulation in Norway

Norway has been pioneering in aquaculture legislation and provided her first law with the temporary Aquaculture Act of 1973, then her first permanent Act in 1985 and the latest Act in 2005. The Act has been amended several times, adapting the situation to the new technologies and environmental requirements and consumer's demands. However, this legislation is mainly set up for salmon and trout

Aquaculture legislation in Norway is in general quite comprehensive. The Aquaculture Act of 2005 sets the premises for all aquaculture activities. In addition, there are a number of more detailed formal regulations pertaining to specific areas of production, such as licencing, technical standards for salmon farms, running operations, or increasing production volume. The Aquaculture Act defines aquaculture as production of aquatic ("water-living") animals and plants, while the regulations may operate with a narrower definition of which kinds of aquaculture they regulate.

When it comes to licencing, the Norwegian management of aquaculture is based on both production licences and site licences. In general, the production licences are granted by the Norwegian fisheries authorities, while the site licencing involves several state sector agencies as well as both regional county and local municipal authorities. The County Authorities, who have the authority to grant site licences pursuant to the Aquaculture Act, coordinate the application process and functions as a onestop-shop. However, granting a site licence requires that several sector authorities, such as the Norwegian Food Safety Authority, the Coastal Administration, and the environmental authorities with the regional County Governors' offices, have approved permits pursuant to sector legislation (Act on Food production and Food Safety (LOV-2003-12-94-124), the Animal Welfare Act (LOV-2018-06-19-97), the Pollution Control Act (LOV-1981-03-13-6) and the Harbour and Fairways Act (LOV-2019-06-21- 70)). In practice, this gives the sector authorities a de facto veto right. Recently (October 2020), there was a public hearing regarding suggested changes to the licencing regulations regarding pollution control. The suggested change involves replacing the requirement of a separate permit pursuant to the Act on Pollution Control with a list of requirements that need to be fulfilled before a licence can be granted. The Norwegian Aquaculture regulations were also pioneering in the establishment of tools and good practices to streamline the licensing procedures through the one-stop-shop. The law guarantees the obligation for the fisheries authorities to ensure good coordination of the application process among all authorities involved in such procedures.

3.8.5 Aquaculture regulation in Spain

Spain`s Autonomous Regional Governments independently apply their own regulations, sharing its competences between the Central Government. In the case of aquaculture, there are several pieces of legislation applying to aquaculture (sanitary, environmental, sectoral, health, market, etc.) both from central government and regionals. The Autonomous regions have exclusive competence in

aquaculture and the conflicts caused for the lack of coordination in some cases, or the over-regulated scenario in others, usually result in the stagnation of aquaculture. Just like the other Member States in the EU, environmental and health regulations in Spain are imposed by European Union Directives, but it is in the sectoral regulation managing the aquaculture where the lack of common criteria may arise from one region to other.

The ownership of the domain public in coastal areas and sea waters belongs to Spain and central government, therefore, any occupation in those areas for aquaculture needs and additional license or concession by Central or Spanish authorities according to the Spanish Law of Coasts 22/1988, and the Decree 1471/89, developing the Law of Coasts, (Law of Costs 1988). The combination of both regional and national competences, results in complications and red tape when granting aquaculture licences.

For example, the enforcement of aquaculture specific regulations in Galicia by regional authorities alongside the application of national rules, especially those allowing to occupy the public domain issued by Central authorities, namely, the Ministry of Ecologic Transition, and other general legislation, environmental, animal health, etc., leads the promoters to complex and cumbersome procedures to get a license or the extension or renewal. Around 10 public administrations or authorities may be involved in this process giving their report or feedback to authorizing the activity. Because of this distribution of competences, the procedure for issuing aquaculture permits became the key problem causing the stagnation of many industry initiatives for aquaculture.

The first Aquaculture law in Spain was the Marine aquaculture Act in 1984 (FAO SPAIN) Then, the regions started exercising their competencies and Galicia was the first to regulate aquaculture in a different way than fisheries with the Law for marine aquaculture 15/1985. Now the aquaculture in Galicia is regulated by Law 11/2008 (3 December) on fishing in Galicia (Gobierno de Espana, 2008) , which has undergone subsequent changes and with a complete chapter for aquaculture and its permits. Galician Aquaculture Strategy (ESGA) is constituted as the articulation and organization document that governs the planning and management of aquaculture activity in Galicia towards the 2030 horizon. Nowadays, the Galician region as well as the rest of the Spanish regions follow the guidelines from the European Strategic Aquaculture Plan to streamline all aquaculture license procedures.

4 Regulatory Barriers to sustainable EU aquaculture

The importance of the sustainable development of the EU aquaculture was recognised by the European Commission in the early 2000s, when the communication COM/2002/0511 final, "Strategy for the Sustainable Development of European Aquaculture" was released. This document provided a vision to maintain the competitiveness, productivity and durability of the aquaculture sector, at the same time guaranteeing coherence with the strategies for environmental protection. Some of the issues identified as barriers by this analysis were:

- the demand of fishmeal and fish oil,
- animal health and welfare,
- competition for space,
- potential risk of eutrophication and
- the lack of specific EU legislation for aquaculture

Technology, rational use of natural resources, governance and socio-economics needed to be integrated to achieve that goal. Looking for a more active implementation of measures to boost the aquaculture sector, the Commission presented the common priorities and general objectives at EU level (COM 2013(0229) final), identifying four priority areas:

1. administrative burdens,
2. access to space and water,
3. competitiveness and
4. competitive advantages due to high quality, health and environmental standards.

The diagram below illustrates the complex situation of aquaculture development in the EU.

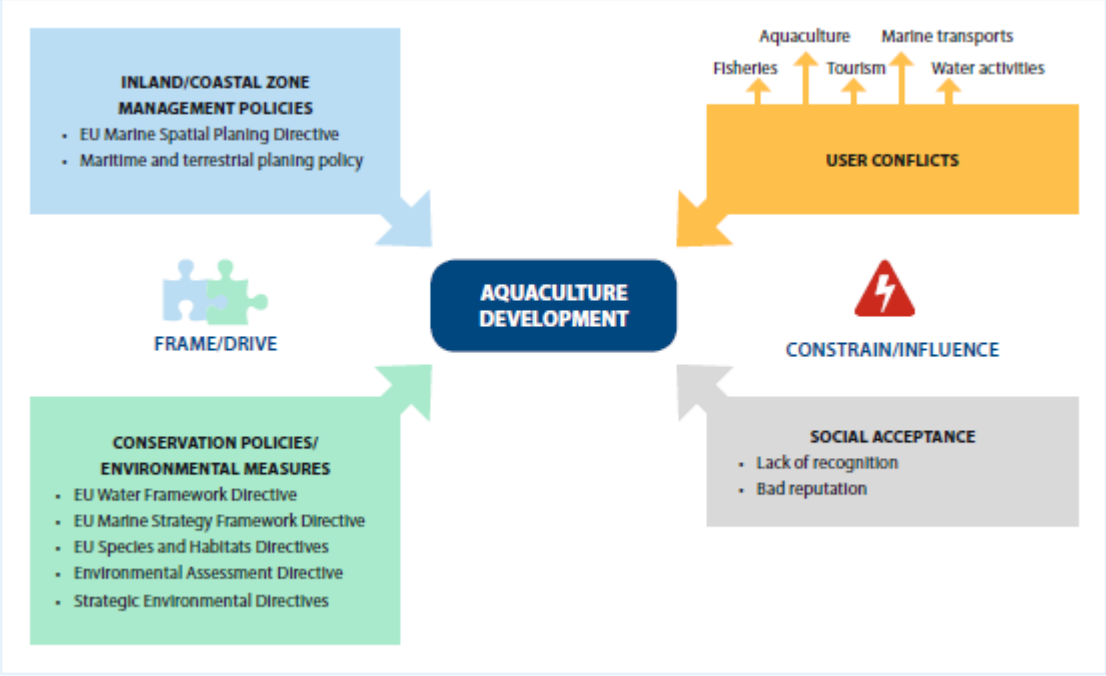

Figure 2 Multiple factors affecting aquaculture development in the EU (Budzich-Tabor et al., 2018)

As stated in the EUMOFA report on Freshwater Aquaculture in the EU (EUMOFA, 2021) the member States are encouraged to implement the measures needed to tackle challenges related to the simplification of administrative procedures, to allow further development of freshwater aquaculture and to establish incentives to adopting innovative sustainable solutions.

4.1 Barriers in term of multilevel Governance

Regarding regulatory permits and licenses, multilevel governance can result in barriers or risks. The barrier of Governance where EU regulations overpower federal regulations is handled by each Member State having their own legislation, following EU directives, and it is not possible to have a one-size-fits-all approach for aquaculture as competences in aquaculture fall within Member States (MS) jurisdictions with different operations across Europe, which leads to quite heterogeneous legislation. Legislation must be doable/achievable and vested with realistic objectives.

Having in mind these needs and interests to improve legislation and simplify licensing procedures, the European Commission (EC) has made considerable efforts to raise aquaculture development and its policy and administrative framework. The EC used the main Strategic Guidelines for Aquaculture, the aquaculture rules into the Common Fisheries Policy, the Directives on Maritime Spatial Planning, Marine Strategy Framework Directive and Water Framework Directive, among others. In terms of institutional support DG MARE and its Aquaculture department, the Aquaculture Advisory Council, etc. played an important role. Nevertheless, in Europe, it is not possible to have only one approach, which leads to quite heterogeneous legislation.

The complexity of national licensing systems and the lack of predictability of the timeline and outcome of licensing procedures are still flagged by the EU aquaculture sector as important barriers to growth. Licensing procedures can be particularly burdensome for SMEs. Challenges lie in both the sector's complex regulatory framework and the need to involve multiple authorities in the licensing process. Furthermore, concerns about the impact of aquaculture activities on the environment or on other economic activities often lead to appeal procedures, which further delay the process for obtaining or renewing a licence (COM(2021) 236 final).

It is necessary to put in place a comprehensive and concerted policy framework for the development of Circular Economy in the EU which facilitates, amplifies and complements primary action and control at national and sub-national levels.

4.2 Barriers in term of national/local Regulation

4.2.1 Inconsistency of licensing arrangements between aquaculture operators in Malta

Existing aquaculture producers in Malta are governed by a variety of operating licences with differing licence conditions, due to the evolution of the aquaculture regulatory requirements along with the development of the aquaculture industry over the past 20 years. Obviously, a uniform licensing procedure for all aquaculture operators would help to streamline overall governance of the aquaculture industry in Malta and mechanisms should be explored to find a way of achieving this goal. Lengthy process of licensing procedures for aquaculture developments: broad range of stakeholders that need to be consulted for the development of any new aquaculture development, this process may be extremely lengthy, with some development applications taking well over one year to process.

4.2.2 Financial and market barriers in Hungary

Difficulties in accessing financing opportunities as the sector is dominated by small-scale enterprises with low administrative capacity and lack of cooperation and market organization (freshwater fish producers are used to work individually). The sector's structure (dominated by small family-owned farms) could limit the innovation and the use of new technologies (Páczay, 2018).

The current European Maritime and Fisheries Fund (EMFF) provide 1,210,131,000 euros to the 28 EU member states for aquaculture for a period of 7 years (from 2014 to 2020). The 28 member countries opted a large share of the money for the aquaculture priority. For example, Spain as biggest aquaculture producer in the EU set 206 million euros, one fifths of its national financial envelope, for its fish farming sector. Hungary opted for around 25.75 million (66% of its total). This operational

programme should be financially and operationally and strengthened to boost investments, innovations and production in seawater and freshwater aquaculture in the next programming period (2021-2027) in the EU.

4.2.3 Constrains holding back development of aquaculture in Spain

Although Spain has a strong and comprehensive legal and juridical framework for aquaculture, it is noteworthy that there are several constraints that are presently holding back the further development of aquaculture. These include:

- Lack of predictability and legal certainty for new aquaculture initiatives.
- Comprehensive body of regulations from different authorities with a broad suite of measures with some difficulties in their practical application. Legislation that is applied by a multitude of dispersed authorities lacking interconnection.
- Licensing procedures are managed by separated bodies without communication or coordination in most cases and where the one-stop-shop does not work as it was expected in many cases.
- The lack of proper land-use planning as well as seawater-use planning with useful locations suited for aquaculture. In Spain, the expected planning for aquaculture sites is not finished yet which means not only constraints for aquaculture development but also creates a breeding ground for conflicts among other users of coastal and seawater at the expense of the aquaculture as the newest activity in these areas.

4.3 Barriers in term of Social and regulatory licensing

Regarding regulatory permits and licenses, multilevel governance can result in barriers or risks, both within a MS and between the MS and the EU, in relation to e.g. the Marine Strategy Framework Directive and the EU Water Framework Directive and River Basin Management principles for freshwater environments. The interactions between local, regional, national and EU legal requirements can often make the licensing process unpredictable and protracted. Even with regulatory permits and licenses in place, it is not always straightforward to get the support of local communities. At the same time, some consumers are not happy to have production at sea either.

Available information shows that charging policy for water abstraction, use and discharge for aquaculture varies considerably across Member States, ranging from no charging to charges that, according to the industry, can make an operation economically non-viable. The Commission will continue to ask Member States to justify the exclusion of certain activities from cost recovery when these represent a significant pressure on the aquatic environment, which needs to be addressed if the objective of good ecological/environmental status is to be achieved. The focus will be on whether Member States have provided in their River Basin Management Plans (RBMPs) a justification fulfilling all conditions of article 9.4 of the WFD.

Further, it should be taken into account that aquaculture does not consume significant quantities of water, as most of the water is returned to the rivers. The quality of the returned water varies widely and it depends on the type of aquaculture and local conditions. Water quality can often be equal to or sometimes even better than when abstracted. Timing can be a problem when legislations and regulations don’t keep up with adapting and updating with industry demands.

4.4 Barriers regarding the use of Sludge from Aquaculture

Faeces and uneaten feed may accumulate at the bottom of aquaculture tanks and on the seabed underneath off-shore facilities such as fish cages and mussel rafts or longlines, occasionally building up to tons over time in locations with a high density of cultures. These residues rich in organic matter constitute part of the natural diet of filter feeders –when particles are still suspended in the watercolumn- and deposit feeders. Nevertheless, Regulation (EC) No. 767/2009 on the placing on the market and use of feed, prohibits the use of animal waste to feed any other animal, both for food producing and non-food producing animals (Article 6, Annex III). This prohibition invalidates de facto Integrated Multitrophic Aquaculture (IMTA) schemes in which bivalves, sea anemones or detritivores such as sea cucumbers, sea urchins or polychaetes are co-cultivated with fish or fed on fish tank waste. Presently, only waste treatment options such as landfill, incineration or biogas production are allowed for this type of waste. This limits the potential of IMTA to contribute to the implementation of Circular Economy in aquaculture in the EU. Considering that in recent years a number of research projects on IMTA have been developed thanks to EU funding (IDREEM, OOMU,etc.), this is an example of how technology develops faster than regulations.

4.5 Barriers regarding the use of Wastewater from Aquaculture

4.5.1 Reuse of treated wastewater for agricultural irrigation

It must be taken into account that neither the Water Framework Directive nor the Marine Strategy Framework Directive contain explicit obligations for aquaculture wastewater.

In Annex II, section 1.4 the Water Framework Directive requires to Member States to collect and maintain the information on the type and magnitude of significant anthropogenic pressures on surface waters in each River Basin District to compile this information. Member States should identify significant point source and diffuse source pollution, in particular substances listed in Annex VIII, from urban, industrial, agricultural and other installations and activities for the purposes of each River Basin Management Plan, the key tool implementing Water Framework Directive. Discharges from aquaculture can be regarded as point-source inputs and thus monitoring information is likely to be required as a precursor to effective management (SWD (2016) 178 final).

The revision of the EU legislation that links aquaculture and water management and protection shows that the only matter of interest that is considered is the interaction between aquaculture facilities, as potential sources of pollution, and the water environment where effluents are discharged. These regulations do not deal with other aspects related to the use of water inside aquaculture facilities, such as the recycling of water into following aquaculture operations or the reutilisation of effluents. Nevertheless, the Water Framework Directive and some national regulations, foresee the reutilisation of treated wastewater for certain applications such as irrigation or street cleaning. For this purpose national regulations set different microbiological and physico-chemical quality criteria depending on the use. The reuse of aquaculture wastewater is thus more likely in the case of freshwater.

Following with the possibilities to use effluents from aquaculture or even for their reutilisation in aquaculture, the Circular Economy package presented by the EC at the end of 2015 reflects the commitment to develop actions to promote the reuse of water at the EU level:

- Reuse in integrated water planning and management to be considered systematically by Member States as an option when implementing water legislation at the community level.
- Minimum quality requirements for the reuse of water in irrigation and aquifer recharge.

The need to treat and reuse wastewater from different origins and for diverse applications is being increasingly recognized for reasons including prevention of ecosystem degradation from pollution and intentional reuse, particularly in regions with water scarcity. However, the implementation of

processes to reuse wastewater in aquaculture systems is still low, mainly due to the lack of incentives towards a circular economy model, the prioritization of short-term results, the lack of enforcement of the "polluter pays" principle, among other possible reasons. Water reuse is commonly and successfully practiced in several EU Member States, as well as in, for example, Israel, California, Australia, and Singapore. However, this practice is so far deployed below its potential in the EU. Limited awareness of potential benefits among stakeholders and the general public, and lack of a supportive and coherent framework for water reuse were identified as two major barriers preventing a wider spreading of this practice in the EU (European Commission, 2021). Another barrier to achieving greater water reuse is the lack of a coherent and harmonized legislative framework within the EU. MS develop their own standards, which often differ from one another, creating hurdles e.g. in the trade of agricultural products.

For these reasons, the European Commission endorsed a proposal to stimulate and facilitate the reuse of treated wastewater for agricultural irrigation (COM(2018) 337 final) to counteract the shortage in times of drought. This document proposes minimum quality requirements for the reuse of treated wastewater and also establishes obligations for production, distribution and storage, as well as risk management measures. The reclaimed water (i.e treated wastewater in specialized facilities) can be used for all types of agricultural irrigation (food and non-food crops). Again, this proposal is only valid for freshwater aquaculture. The proposal was turned into law in the new Regulation (EU) 2020/741 on minimum requirements for water reuse for agricultural irrigation. The new regulation is expected to boost the use of freshwater aquaculture effluents for food and non-food crops, at the same time establishing directions for the treatment and use of this wastewater and minimum quality requirements.

Aquaculture legislation in Europe in general is large and comprehensive, but it is not specific for the case of RAS wastewater Reuse. The legislation is essential for sustainable development of those activities to give legal certainty to promoters.

4.5.2 Use of wastewater from aquaculture for the culture of microalgae

A possible alternative to solve this situation in the current regulatory framework is the use of aquaculture wastewater for the culture of microalgae that in turn serve as food for filter-feeders. The valorisation of different types of waste water –urban, industrial, aquaculture- through the production of microalgal biomass has been thoroughly assessed in a wide number of scientific studies (Cai et al., 2013; Acién Fernández et al., 2018; Viegas et al., 2021) and projects which demonstrate a reliable recovery of nutrients, although some technical critical points have to be solved. Potential applications of the produced biomass range are diverse, but animal feeding seems to be one of the most interesting due to the content of proteins, polyunsaturated fatty acids and micronutrients.

Whereas valid concerns due to the potential presence of contaminants in wastewater may arise, currently there is a lack of legislation regulating the use of microalgae to treat wastewater and the applications of biomass. In this context, it seems that the use of microalgae grown in wastewater, and particularly aquaculture wastewater, as animal feed is governed by Regulations (EC) No 183/2005 laying down requirements for feed hygiene and (EC) No. 767/2009 on the use of feed. Moreover, microalgae are not included in the latest version of the Catalogue of feed materials (Commission Regulation (EU) 2017/1017), but at the same time are widely used in bivalve and live feed culture, both fresh and as commercial products. A conclusion may be drawn on that the current regulatory framework allows the production and use of microalgal biomass in the feeding of aquaculture animals provided the ingredient complies with rules determining criteria for safety, marketing and use of feed.

4.5.3 Use of wastewater from aquaculture for the culture of macroalgae

The valorisation of dissolved nutrients in aquaculture wastewater through the culture of seaweeds is another activity, which is out of the scope of extant regulations. Currently there is no framework to

guide or direct seaweed aquaculture in the EU, apart from regulations dealing with the authorisation of activities or the deployment of structures on the sea or on the coast. Hence, clarification of the current legal status of seaweed culture is needed in order to boost this activity to its real potential for the sustainable intensification of EU aquaculture.

Recently, the PHYCOMORPH network (Wichard & Katsaros, 2017)), composed by research teams expert in seaweeds, released the report PEGASUS: Phycomorph European Guidelines for a Sustainable Seaweed Aquaculture (Barbier et al. 2019). This report provides guidelines on best practices, legislation and regulations that currently apply to seaweed production as food and food supplement, and concludes that a regulatory framework must be developed to guide seaweed aquaculture in the EU in terms of law harmonisation and simplification of procedures, the adaptation of food safety monitoring programmes, or a risk assessment for the cultivation of exotic species.

5 Regulatory Opportunities for a sustainable EU aquaculture

Although the lack of legislation supporting the circular economy in aquaculture industry can be an impediment, at the same time this could constitute an advantage or opportunity to give court to promote legislative and regulatory measures for the sector setting out the basis for developing specific "circular economy" practices and guidance on aquaculture regulation at the EU level.

5.1 Use of wastewater from Aquaculture

Implementation of valorisation processes for used aquaculture water is obviously only possible where water is confined, i.e. in land-based aquaculture in tanks or ponds. Probably, recirculating aquaculture systems (RAS) are the best example to valorise used water in aquaculture facilities. In RAS, rearing water undergoes treatment processes to remove solid and dissolved nutrients and is reintroduced back into culture tanks. The Circular Economy Action Plan identifies the reuse of treated wastewater in safe and cost-effective conditions as a means of increasing water supply with no pressure over water resources. Moreover, the use of freshwater aquaculture effluents in irrigation would also contribute to the recycling of nutrients, thus alleviating the need for solid fertilisers. The EC is expected to promote the use of treated wastewater, as part of the implementation of the Water Framework Directive and the development of legislation on minimum quality requirements for reused water.

5.2 Use of sludge from Aquaculture

In marine aquaculture, the possibilities for collection of discharge are limited in open cage systems and therefore marine IMTA is the main method to reuse nutrients. However, the use of sludge for the direct feeding of filter-feeder (bivalves, anemones)- or deposit-feeders (sea urchins, sea cucumbers) in IMTA setups is currently banned (Regulation (EC) No. 767/2009).

This material could be used in biofloc setups or as a source of nutrients for the production of microalgae (as investigated in the iFishIENCi project) or macroalgae, as an intermediate step between fish and invertebrate (bivalves, sea urchins, polychaetes, rotifers) culture. The potential for localized environmental improvement through ecosystem service provision (e.g., nutrient pollution mitigation benefits associated with shellfish aquaculture) could be a driver for new aquaculture development efforts (Theuerkauf et al., 2019).

In fresh water aquaculture systems, a new approach will be possible from 2022, when the new Regulation (EU) 2019/1009 laying down rules on the making available on the market of EU fertilising products will enter into force. This regulation will introduce harmonised rules for organic fertilisers manufactured from secondary raw materials such as agricultural by-products and recovered bio-

waste, replacing current Regulation (EC) 2003/2003, which only allows the free trade across the EU of conventional, non-organic fertilisers. The 2015 Circular Economy Action Plan had identified the need to find new valorisation routes for organic waste material, whose nutrient content makes them appropriate to be used as fertilisers. This application will reduce the need for mineral-based fertilisers, which requires the import of phosphate rock and has negative environmental impacts. This is expected to stimulate the manufacturing and marketing of alternative fertilisers and create more value for organic-rich waste such as aquaculture sludges. The SEA2LAND project for example aims to meet this challenge by improving and adapting technologies for nutrient recovery to produce bio-based fertilisers (BBFs) and Tailor Made fertilisers (TMFs) from fishery and aquaculture by-products generated in Europe.

5.3 Creation of 'One stop shop' System for aquaculture licenses

As suggested in the Strategic guidelines for a more sustainable and competitive EU aquaculture (COM(2021) 236 final), the most important elements for addressing Regulatory and administrative framework issues while ensuring due consideration of environmental aspects in licensing procedures are:

- Streamlining – and harmonising where possible – legislation and administrative guidance on aquaculture. Ideally, this streamlining should be carried out by adopting a single piece of national legislation gathering all relevant aspects. This legislation should set clear procedures and timeframes for dealing with applications for new licences or licence renewals.
- Setting up, whenever possible, a single national aquaculture entity gathering all the different relevant authorities with responsibilities for aquaculture. This entity would seek to facilitate and coordinate the work of those authorities on the planning, licensing and monitoring of aquaculture activities. This entity should involve relevant stakeholders to discuss and integrate their views in a timely manner. In cases where responsibility for aquaculture is also held at sub-national level, a national structure gathering regional/local authorities and entities is to be encouraged.
- Setting up a 'one-stop-shop' system for aquaculture licences, which facilitates both transparency on the licensing process and interaction between the applicant and the decision-making authorities.

5.4 Creation of quality schemes and labels

The use of quality schemes and labels (subject to appropriate control to safeguard their credibility), including geographical indications could be an important tool for promoting the value of EU aquaculture products. Promoting EU sustainable aquaculture as an example of local production linked to short food circuits also plays an important role in diversifying and adding value to EU aquaculture production (COM(2021) 236 final). Aquaculture economy needs to work for people and precludes cooperation of industry and academia.

The iFishIENCi project is currently assessing the current use of certification (mandatory vs. voluntary) and aims to compare the use of certification with the consumer attitude in a report to be published in July 2022 (D4.14). The iFishIENCi project aims to complete this with an analyse of social acceptance i.e. the underlying deeper attitudes, values and trusts towards the dimension of the sustainability (D4.2) to be published in Sept 2022.

One step behind…

Contribute to EU and national communication campaigns with well formulated clear messages and available information.

5.5 Standardised and Coordinated data collection and reporting

Collecting accurate data is necessary to ensure the appropriate planning of aquaculture activities. Accurate data are also necessary to assess and monitor the social, economic and environmental performance of the EU's aquaculture sector. Transparency and data reporting is also important for maintaining the trust of the consumer and other stakeholders in the sector. There are many reporting obligations on the sector under different pieces of EU and national legislation. However, the data collected are mostly socioeconomic data on marine aquaculture or animal health, and limited data are reported on environmental indicators specific to aquaculture (COM(2021) 236 final).

Therefore, the Strategic guidelines for a more sustainable and competitive EU aquaculture suggest to coordinate better reporting obligations and to streamline reporting procedures between different services. It will be necessary to provide more structured guidance to EU Member States on how to obtain and report data. Data reporting should apply to environmental indicators and cover aquaculture production beyond marine aquaculture. Providing for longer-term licensing, with regular monitoring and sanctions for non-compliance (which could include licence revocation). Licensing terms could include an obligation to monitor and report data, notably those data required under the relevant national and EU legislation.

Aquaculture is a really complex food supply system existing in complex socio-ecological environment. The availability of real-time data to manage the aquaculture systems is therefore crucial. Moreover a standardised mechanism is necessary to change the data collected into information, into knowledge, into wisdom.

One step behind…

Incentivise data collection.

5.6 Lessons learned from countries already implementing responsible legislation

Multilevel governance reality is surrounding aquaculture with global, regional and national dimensions. Therefore, it is important to learn from countries that identified the need for sustainable aquaculture and implement responsible regulation accordingly. It is clear that, in general, the regulatory picture in most other advanced economies is similar to that in the EU, with similar problems being experienced. Examples of good practice from other countries includes the introduction of a longer licensing periods (20 years) and a Single permit system (United States) and establishment of a comprehensive best practice framework (Australia).

5.6.1 Australia

Aquaculture in Australia is managed under strict environmental guidelines. While the Australian Government has a number of important functions in relation to aquaculture, including national programs for research, management of biosecurity, aquatic animal health, food safety, environmental management, and market access and trade, most elements of the regulation of domestic aquaculture production rest with the states and territories.

Aquaculture operations, particularly those that operate in, or discharge into, public waters, are required to comply with stringent environmental controls monitored on an ongoing basis by state agencies. Strict food health standards also apply to both aquaculture and wild capture products.

These environmental and food safety standards ensure fish grown in Australian waters are safe to eat and that seafood production does not unduly affect aquatic environments.

The National Aquaculture Strategy sets out actions Australian, state and territory governments and aquaculture industry need to take to meet the goal to double the value of aquaculture industry to

$2 billion a year by 2027 (Department of Agriculture and Water Resources, 2017). Priorities identified in the strategy are:

- Regulatory framework — removing unnecessary burden on business.
- Research, development and extension — maximising the benefits of innovation.
- Market access — developing and improving access to domestic and international markets.
- Biosecurity — understanding and managing risks to protect Australia's aquaculture.
- Public perception — improving knowledge of aquaculture as a safe and sustainable industry.
- Environmental performance — identifying opportunities to adopt cost-effective strategies.
- Investment — encouraging and promoting investment in our aquaculture industry.
- Training and education — ensuring future employment needs are met.

5.6.2 Canada

Aquaculture facilities and activities in Canada are regulated under a number of acts, legislations, regulations, and programs related to environmental management and shared use of aquatic resources. These instruments are administered by various federal, provincial and territorial bodies. Through the *Fisheries Act*, Fisheries and Oceans Canada regulates the aquaculture industry in order to protect fish and fish habitat. The Act sets out authorities on fisheries licensing, management, protection and pollution prevention.

As outlined in the General Aquaculture Regulations (GAR) Forward Regulatory Plan, amendments are underway to improve aquaculture-related content within existing Fisheries Act regulations. It is anticipated that the General Aquaculture Regulations (GAR) will be created during 2021-2023 under a proposed new federal aquaculture act.

- Phase I – proposed amendments would exempt cultivated clams, scallops, mussels, and oysters from the application of the Atlantic Fishery Regulations and Maritime Provinces Fishery Regulations. The proposed amendments would exempt shellfish aquaculture in Atlantic Canada and Quebec from regulatory measures intended for the management and conservation of wild shellfish, such as harvest close times and minimum sizes. Existing controls over wild shellfish harvesting will be maintained.
- Phase II – proposed amendments to the Marine Mammal Regulations (MMR) and Pacific Aquaculture Regulations (PAR) to remove the Minister's authority to authorize the lethal removal of nuisance seals during the course of commercial fishing and aquaculture operations. Details on this are provided under a separate heading.
- Phase III – proposed amendments to the Aquaculture Activities Regulations (AAR) for a suite of improvements, including the introduction of a new pesticide and drug modelling and monitoring program to help better assess and mitigate potential environmental impacts. It is additionally proposed to expand the scope of deleterious substances covered under the AAR beyond pesticides and drugs to substances on the Domestic Substances List of the Canadian Environmental Protection Act, 1999. This would provide more legal certainty to industry on the deposit of chemical disinfectants used as part of aquaculture operations. Amendments to enhance reporting are also being considered.
- Phase IV – creation of the proposed GAR. In addition to consolidating federal aquaculture-related regulatory provisions into one set of regulations, the GAR would incorporate additional improvements and modernizations, such as changes to address the overlap in fish disease management responsibilities between DFO and the Canadian Food Inspection Agency. It is expected that the GAR would be created under a proposed new federal aquaculture act.

Every aquaculture site in Canada requires that a valid lease and current licence are in place before fish can be put into the water. The lease entitles the owner or operator to use the sea or lake bed for cultivation and/or anchoring of containment arrays (e.g. fish net pens, long lines, beach culture). The

licence allows the owner or operator to put fish or shellfish into the facility, subject to conditions that form part of the licence. There are three principal regulatory regimes for aquaculture in Canada:

- In British Columbia, where the province issues the lease and Fisheries and Oceans Canada (DFO) issues the licence and monitors licence conditions;
- In Prince Edward Island, where a management board with members from DFO, the province, and industry issues a lease which has a licence attached; and
- In all other provinces and territories, where provincial authorities issue both the lease and the licence.

The *Aquaculture Activities Regulations* (AAR) clarify conditions under which aquaculture operators may install, operate, maintain or remove an aquaculture facility, or undertake measures to treat their fish for disease and parasites, as well as deposit organic matter, under sections 35 and 36 of the *Fisheries Act*. The AAR allow aquaculture operators to do so within specific restrictions to avoid, minimize and mitigate any potential detriments to fish and fish habitat. The Regulations also impose specific environmental monitoring and sampling requirements on the industry.

These Regulations require aquaculture owners and operators to submit annual reports on their activities to the appropriate Regional Aquaculture Management Office no later than April 1 of the year following the year being reported on. For annual reporting, the AAR Reporting Template may be used to record required information.

As outlined in the Guidance Document, these Regulations also require aquaculture owners and operators to notify Fisheries and Oceans Canada of:

- their intent to deposit pest control products
- any morbidity events they observe
- any exceedances of biological oxygen demanding thresholds
- when they submit an application to a provincial or territorial authority for a new or expanded site

As knowledge and technology advances, other controls or modifications to existing mitigation and monitoring measures may be needed. This is why Fisheries and Oceans Canada, Environment and Climate Change Canada, and Health Canada are committed to undertake a three-year Science Review to support the Regulations' implementation.

5.6.3 Chile

Aquaculture is an important industry in Chile, particularly in some regions where the industry provides significant revenues and employment in areas otherwise lacking economic opportunities. Aquaculture in Chile is the fastest growing sector of fishery with an annual rate of increase greater than 25%. Responsible for less than 2% of total production in weight, represents close to 0.5 billion USD or 1/3 of the total value of exports. This successful expansion of this industry in Chile is based on clear structural advantages: (i) the abundance of clean waters, devoid of diffuse pollutants, such as mercury, present in the northern hemisphere, (ii) physiological optimal conditions for salmon growth in the archipelago and fjords region, and (iii) being the first producer of high-quality fish meal in the world.

Aquaculture is regulated by the 1989 General Law on Fisheries and Aquaculture and its modification from 1991 (Fishing and Aquaculture General Act, 1991), which sets out the legal framework for the import of hydrobiological resources, access to aquaculture areas, concessions, environmental and health conditions for its implementation, regulations to conduct aquaculture for ornamental or scientific purposes, infractions and sanction system. Different State institutions play different roles in this activity:

- The Undersecretariat for Fisheries and Aquaculture regulates the activity and establishes the technical conditions under which this activity can be conducted.

- The Undersecretariat of the Armed Forces grants the aquaculture concessions and dictates the appropriate areas for exercise of the activity.
- The Environmental Assessment Service participates in the environmental assessment of the projects.
- The National Fisheries and Aquaculture Service and the Directorate General of Maritime Territory and Marine Merchant carry out monitoring work.

Differently to other countries in the world, the Chilean government has given these marine spaces private property rights. This means it is impossible for the public scientific regulator IFOP to access the area to take benthic or water quality samples. That means through the fluid nature of the sea, the ecological impacts are felt in common while the profits are kept private by the corporation.

On January 2019, the Chilean Parliament adopted a law for strengthening the National Fisheries and Aquaculture Service, which is the agency in charge of monitoring, control and surveillance (MCS) of fisheries and aquaculture activities. The Law provides new legal means as well as increased capacity to combat illegal, unreported and unregulated (IUU) fishing and some behaviours associated with IUU fishing that are now considered a crime. More than 200 inspectors have been added to National Fisheries Service and through a model based on risk the effectiveness of supervision have been improved (OECD, 2021).

In August 2019, the National Institute for the Sustainable Development of Artisanal Fisheries and Small-Scale Aquaculture (INDESPA) was created to replace the Fund for the Promotion of Artisanal Fisheries and the Fisheries Administration Fund. The objective of this public institution is to foster and promote the development of artisanal fisheries and small-scale aquaculture. It focuses actions on the production diversification, integral development of coves, infrastructure for artisanal fisheries and small-scale aquaculture and the technical assistance and training for artisanal fishers (OECD, 2021).

A new Law related to fishing coves has been enacted, focusing on the territorial development of communities of artisanal fishers. To date 461 fishing coves have been officially identified and 100 of them have started the regulatory processes as to the use of the territory. This means that fishers are allowed to work within legal and regulated boundaries in complementary activities related to the extraction such as gastronomy and tourism, taking into account their specific conditions and local employment (OECD, 2021).

5.6.3.1 Individual Transferable Quotas

In addition to classical Fishery management tools, different types of limited entry systems are now defined in the law and applicable to Chilean fishery. These for the first time include allocation of resources in the form of Individual Fishing Quotas and Individual Transferable Quotas (IFQs and ITQs) (Bernal et al., 1999).

5.6.3.2 Territorial User's Rights

Territorial User's Rights in Fisheries (TURF's) were incorporated in the law to enhance self-regulatory practices among artisanal fishermen. TURFs have been utilized in island fisheries of Southeast Asia (e.g. Japan) for decades (Cancino et al., 2007). Among them, the Areas for Management and Exploitation for Benthic Resources (AME) represent an associative assignment of TURFs. Large-scale zoning is used to re-define Aquaculture Grants and to ritualise the conflicts between Artisanal and Industrial fishermen by establishing the Artisanal Reserve in which small-scale coastal fishermen have Priority Access (Bernal et al., 1999;).

5.6.4 New Zealand

New Zealand manage land-based aquaculture through the Freshwater Fish Farming Regulations 1983, under the Fisheries Act 1996. The regulations cover all aquaculture above the high tide mark. This includes aquaculture: in freshwater canals, in indoor aquariums, on land using fresh water and on land

using seawater or brackish water (either pumped from the sea or circulated around the farm). Under the regulations, farmers must have a fish-farm licence to farm certain listed species.

Marine aquaculture is mainly managed under the Resource Management Act 1991 (RMA). The RMA promotes sustainable management of natural resources. Marine farmers must also meet requirements under the Fisheries Act 1996 so MPI can understand who is undertaking farming and ensure traceability of stock across the aquaculture supply chain. Under the RMA, regional councils are responsible for planning and managing aquaculture in their coastal area between high tide and the 12 nautical mile limit and any new marine farm must have a resource consent from the regional council.

Under the Fisheries Act, the Ministry for Primary Industries is responsible for assessing the effects of new aquaculture on fishing, through the undue adverse effects (UAE) test and a marine farmer must be registered on the Fish Farmer Register before commencing farming at a site.

Legislation was changed in 2011 to (1) encourage sustainable aquaculture development and (2) streamline planning and approvals for marine aquaculture. Changes were made to the:

- Resource Management Act 1991
- Aquaculture Reform (Repeals and Transitional Provisions) Act 2004
- Fisheries Act 1996
- Māori Commercial Aquaculture Claims Settlement Act 2004.

Prior to this, under the Aquaculture Reform Act, farmers could apply to set up new farms only in aquaculture management areas (AMAs) established by councils. AMAs were introduced as a management tool but were found to complicate and delay approvals for new aquaculture. The 2011 changes simplified the approval process by removing the need for AMAs(Ministry for Primary Industries, 2013).

National environmental standards for marine aquaculture (NES-MA), established under the RMA, came into force on 1 December 2020. The NES-MA set national rules that replace regional council rules, except where the NES-MA allows regional council rules to remain in force. The NES-MA will make sure marine farms meet best environmental practice while providing a more certain and efficient process for:

- replacement consents for existing marine farms
- realignment
- change of species applications.

5.6.5 Norway

In the broadest analysis, aquaculture regulation in Norway is comparable to regulation in the EU – there are rules governing aquaculture production and access to aquaculture sites, and a range of related rules governing environmental protection, food safety, animal welfare, etc. To an extent, those rules are similar in nature or in standards to EU rules, and are in some cases aligned to the Community acquis. On the other hand, there are a number of fundamental differences between the EU and Norwegian regimes, in particular since the introduction of a new comprehensive and specific framework law for aquaculture in 2005 (Norwegian Ministry, 2005). The express purposes of the Aquaculture Act (s. 1) are to “promote the profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and to contribute to the creation of value on the coast”. In policy terms, a major objective of the Act was to better meet the needs of the aquaculture industry while ensuring continued protection for the environment and social needs. The 2005 Aquaculture Act provides the basic legislative and administrative framework for aquaculture regulation, and to a large extent defines the relationship between aquaculture and other regulatory processes (e.g. environmental protection) (Hedley, 2009).

The Norwegian government unveiled a new aquaculture strategy on July 6 2021, known as "A Sea of Opportunities" that aims, among other things, to simplify the country's entire licensing system. The main message delivered through the plan is that growth in the sector will come but that it must take place sustainably (Norwegian Ministry, 2021). Today's system is a patchwork of various historical schemes that can be simplified and harmonized under the new strategy, according to the plan. The new management strategy will also assess how management of the sector can become more efficient and coordinated (Furuset, 2021). The size of farming permits is currently based on the so-called maximum allowable biomass (MTB), which states how many tons of salmon can be left in the cages at any given time. The government plans to assess whether MTB, which currently delimits permits, is still the most suitable tool. There will also be a review of the framework conditions for land-based aquaculture, in particular with a view to strengthen biosafety and environmental measures. Additionally the government will continue the work of facilitating offshore aquaculture. Other aspects of the plan include:

- assessing whether the current site structure can be changed to reduce issues of infections between sites;
- facilitating suitable recirculating aquaculture systems (RAS) technology and revising regulations for environmentally friendly inland farming;
- facilitating the development of new feed raw materials for the aquaculture industry;
- work for customs conditions in the export markets that make Norwegian farmed fish competitive. Zero tariffs for farmed fish is an objective in all new free trade agreements; and
- continue the focus on aquaculture research, including research on new species and fish feed/new feed ingredients

5.6.5.1 Administrative organization

Although, as in many other countries, there are a number of agencies involved in the administration and regulation of aquaculture, the concentration of administrative functions in the Fisheries Directorate, combined with a clear definition of the roles, functions and relationships of and between the various agencies (in part provided in the Aquaculture Act itself) not only creates greater coherence but also provides a more efficient and accessible administrative structure for the industry.

Digitalisation, technology and skill transfer allow for synergy between maritime industries. The public-private partnership Sjømat (“Seafood”) aqua culture value chain was established in August 2020 and will, among other things, be a driving force for digitalisation and data sharing in the aquaculture industry. The goal is to develop and implement digital solutions as a tool for increasing economic growth in the industry, while allowing authorities to receive data which is vital for effective, efficient management.

5.6.5.2 Single window administration of licensing

A “single-window” system exists for the processing of aquaculture licence applications, whereby the industry applicant deals with just one body – the Fisheries Directorate. The Directorate then coordinates with other relevant authorities as part of their own processing of the application. The Fisheries Directorate ensures that statements and decisions are obtained from the local municipality, as well as various sector authorities, such as the County Governor (environmental authorities), Norwegian Food Safety Authority and the Norwegian National Coastal Administration.

5.6.5.3 Regulation of environmental impacts

Norway has long-been, and continues to be, a leader in environmental regulation of aquaculture (see the Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry, launched in June 2009 – MFCA 2009). One of the notable features of the Norwegian approach is that much of the regulation is addressed specifically to aquaculture, or has specific conditions addressing the aquaculture sector. A second notable feature is the use made of self-regulation instruments (e.g. the NYTEK standard for fish escapes). The Government recognizes the balancing act between imposing

government measures through law and allowing the industry to undertake measures (particularly of a more technical nature) on a more quasi-voluntary basis.

Norway applies the Community acquis in relation to Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA) and public participation, but there are two significant differences between aquaculture EIA in Norway and in the EU. First, in Norway the Directorate of Fisheries is defined as the "competent authority", with responsibility for screening and conducting the EIA process in relation to aquaculture installations. Second, the Regulations include a specific threshold for the assessment of aquaculture.

A new management system for continued growth in Norwegian salmon and trout farming was established in 2017. In the "traffic light" system, the coast is divided into production areas and the production capacity in these areas is adjusted based on environmental indicators and a fiscal rule. The colour of the traffic light is based on the impact of salmon lice on the wild salmon in the area. This determines whether the fish farmers in the area are permitted to increase or need to decrease their production. In the 2021 new aquaculture strategy, the government plans to further develop the traffic light system and review the use of special permits (Norwegian Ministry, 2021).

5.6.5.4 Coastal zone planning

Coastal zone planning at regional (county) level has been introduced to deal with the problems of integration that coastal zone planning at municipal level has not been able to solve, in particular coordination between the relevant sectors at regional level.

The aquaculture industry is undergoing rapid technological developments. These developments are being driven by both research communities and the industry's need to solve environmental challenges such as escaping and sea lice. The authorities have used the allocation system to stimulate technological development through the 2013 allocation round involving "green salmon licenses", and through the scheme for development licenses that was introduced in 2015. The latter contributes to significant innovation in the development of installations in more exposed waters and in the open ocean. These developments mean that more areas will become available for the production of seafood. However, aquaculture production being able to take place in more exposed areas also entails new challenges relating to operations (including health, safety and environment), fish welfare and logistics (Norwegian Ministry, 2021).

5.6.5.5 Transfer and mortgaging of aquaculture licences

One of the key developments in the 2005 Aquaculture Act was the establishment of a legal right to transfer and mortgage aquaculture licences which permits a licence to be transferred between private parties without any public approval or additional licence. The new mortgage right means that the licence can be used as collateral for a creditor's security interest, contributing to greater predictability and improved access to capital for the industry.

5.6.6 Scotland

Scotland has a separate legal system from the rest of the United Kingdom, with aquaculture in Scotland governed by two main acts; the Marine (Scotland) Act 2010, and the Aquaculture and Fisheries Act (Scotland) 2013.

The main points of the Marine (Scotland) Act 2010 relevant to aquaculture are:

- a statutory requirement to develop regional marine plans that will facilitate the sustainable management of the marine area, and
- a simplified licensing system that allows aquaculture consents to be granted by regional authorities or the government.

The Aquaculture and Fisheries (Scotland) Act 2013 ensures that farmed and wild fisheries - and their interactions with each other - continue to be managed effectively, maximising their combined

contribution to supporting sustainable economic growth with due regard to the wider marine environment. Farmers are required to comply with farm management area (FMA) practices if the farm is located within a FMA; equipment specifications for net and mooring design, construction and maintenance; and controls to prevent the spread of commercially damaging species.

An example of polycentric governance, i.e. overlapping domains of action of multiple public bodies exists in Scotland in that of joint control of finfish development by local government and the national environmental protection agency.

5.6.7 USA

The National Aquaculture Act of 1980 established aquaculture as a national policy priority for the U.S. and created the Interagency Working Group on Aquaculture under the National Science and Technology Council in the Executive Office of the President. Now referred to as the Subcommittee on Aquaculture, through this group, NOAA coordinates with other federal agencies on aquaculture priorities and activities (NOAA, 2020).

Aquaculture producers in the USA are required to comply with federal, state and local government legislation. At the federal level, the National Environmental Policy Act (1969) (USA) requires that decisions on aquaculture developments are made with full consideration of the impact to the natural and human environment.

Under this act, aquaculture developments are assessed as to whether they require a full Environmental Impact Assessment (EIA). Co-ordination of the EIA system is the responsibility of state governments and the EIA requirements varies among states.

New aquaculture developments must also acquire up to 14 permits from various regulatory authorities, depending on the state (Wilson et al., 2009).

Discharge of aquaculture waste is governed by the Clean Water Act (1972) (USA), which is regulated through a permit process that is administered at the state level. Under the Clean Water Act (1972) (USA), all farms that produce >45 t of finfish per annum are subjected to Effluent Limitation Guidelines (EPA, 2012) and must develop and comply with BMP detailing how the Effluent Limitation Guidelines are to be achieved.

5.7 Opportunities identified by aquaculture research projects

5.7.1 Integrated Multi-Trophic Aquaculture in Europe

Despite the efforts undertaken by the European Union and the aquaculture stakeholders in recent years, the H2020 IMPAQT project identified key messages about IMTA in Europe, which need to be addressed and understood[3]:

- IMTA has seen slow development, in part through a poor understanding of the principles of IMTA by regulators, uncertainty on the part of farmers, and uncertainty in markets. (EC, 2012)
- General change of mindset is needed from production to consumption, from policy to investment, and from high IT to territorial planning.
- Need to understand that, considering the impact of climate change, the pollution of the oceans, and the alarming effects of intensive wild fisheries, aquaculture is a fundamental sector for the maintenance of food security and sustainability.
- IMTA is an available solution that offers an increase in production and revenues through a more efficient use of the space and resources; by replicating natural ecosystems. Further, it

[3] https://impaqtproject.eu/our-results/policy/

reduces the EU´s dependency on imports by increasing production in Europe, generating stronger local economies as well as employment opportunities.

- IMTA systems are a circular economy paradigm. They contribute to making European aquaculture more sustainable and competitive, thus unlocking green growth within the European aquaculture sector.

5.7.2 Green Aquaculture Intensification in Europe

As stated during the Horizon4Aquaculture event on 15th June 2021 (7.2.5)[4], the H2020 GAIN project on its side identified policy messages related to green aquaculture intensification, which need to be addressed and understood[5]:

- Are current statistical production & consumption data adequate for shaping policies?
- Identification of legislative gaps & barriers, preventing from further valorising aquaculture secondary products and waste streams
- Valuation of aquaculture ecosystem services: biosequestration of N and P
- Is the market ready for eco-intensified products?
- Are the consumers ready to accept eco-intensified products?
- Are we using the right tools to assess sustainable/ecological intensification?

6 Effective Governance for a Sustainable EU Aquaculture

According to lessons learned, the FAO stated that effective governance of modern aquaculture must reconcile ecological and human well-being so that the industry is sustainable over time. Without effective governance, there will be misallocation of resources, and perhaps stagnation of the industry and irreversible environmental damage. In addition to governments, other stakeholders such as communities, non-governmental organizations and producers should also be involved in the governance of the industry (Hishamunda et al., 2014).

6.1 Formal and Informal institutions

There is indeed growing scholarly and policy awareness of the fact that public authority is rarely exercised only by the state. In fact, a host of actors and institutions – some visible and recognised, others invisible and less obvious – exercise authority over and regulate the everyday life of local populations across large parts of the world, with important implications for public policy (Khan, 2016).

Understanding how institutions operate is crucial to the protection of ecosystems and the communities that depend on them. Institutions can be defined as the rules, norms, and practices that govern resource users' interactions with common-pool resources (Pellowe & Leslie, 2020).

Formal institutions include constitutions, contracts, and the coercive power of governments. This regulatory pillars are established and communicated through channels that are widely accepted as official (North 1990, 1991; Lowndes 1996; Farrell & Héritier 2003; Helmke & Levitsky, 2004).

Informal institutions are socially shared rules, usually unwritten, that are created, communicated, and enforced outside of officially sanctioned channels such as traditions, customs, moral values and other norms of behaviour (Helmke & Levitsky, 2004; Pejovich, 2006).

[4] http://ifishienci.eu/challenges-and-opportunities-for-aquaculture-policy-and-market/
[5] https://www.youtube.com/watch?v=9MaTPkrx1ig

There are two main supportive pillars: normative and cognitive. Both formal and informal institutions govern fisheries and aquaculture around the world. Some reinforce one another, and others are in conflict. Institutional diversity can enhance social-ecological system resilience by providing multiple ways of responding to change. Identifying institutions and their effects on producing practices is key to improving management for sustainable fisheries and aquaculture (De Soysa, 2007; Pellowe & Leslie, 2020). Informal structures shape the performance of formal institutions in important and often unexpected ways. Informal institutions also shape formal institutional outcomes in a less visible way: by creating or strengthening incentives to comply with formal rules (Torniainen & Saastamoinen, 2007; Vabulas & Snidal, 2011). Greater community participation in management, via polycentric and collaborative governance that accounts for and legitimizes local norms in a system like co-management, would foster enhanced sustainability and benefits to coastal communities (Pellowe & Leslie, 2020).

The crucial role of institutions in the economic development of countries and specific sectors is increasingly widely accepted in economic research (Harms, 2010). Nevertheless, there is demand for further research, especially when the aim is to measure and to compare institutions not only in a qualitative, but in a quantitative way. Some cases in recent history revealed that political restructurings of formal institutions without considering the informal institutions can cause severe (economic and social) problems. One well-known example is the transformation process of Eastern Europe. Developing a tool that is able to operationalize and measure the informal institutions of a country and compare them to those of other countries can help to solve this problem (Theurl, 2012).

6.2 The role of other stakeholders

Increasingly, corporate self-regulation and decentralization are extending the role of stakeholders, other than governments, in managing aquaculture. Costs of monitoring and enforcement have encouraged delegation of certain husbandry decisions to a collection of neighbouring farms, which are then subject to peer pressure. In addition, communities wish to be part of decision-making in allocating aquaculture sites. Flexibility of legislation and expert opinions seem to be highly valued as investigated on a group of stakeholders representing the aquaculture industry and municipal, regional, and sector management in northern Norway (Tiller et al., 2017).

6.2.1 Community groups and Participation

Participation allows all interests to be heard and contributes to resolving conflicts. A consensus-driven approach provides legitimacy and reconciliation of different perspectives. However, each jurisdiction has different procedures for the preparation of legislation and the degree of participation by stakeholders will vary. At one extreme is participatory governance, particularly community partnership and environmental stewardship, where the civil society participates fully in decision-making. At the other extreme, with hierarchical governance, policy-makers may not accept participation for cultural and political reasons, and “consultation” may be merely a means of informing stakeholders about decisions already taken.

The methods for participatory governance have advantages and disadvantages. Thus, the method used will depend on factors such as the literacy of stakeholders, the willingness of potential participants to state their true preferences, and the hierarchical structure of society. There are also limits to participation owing to scarce resources. Participatory methods involve expenditure of money, time and skills. The Delphi method, an adaptive iterative survey method that offers adaptability, anonymity and absence of peer pressure, has also been used in policy formulation in one global study of aquaculture opportunities and constraints. Another application of this method is the development of aquaculture plans, as was the case in Chile. While time-consuming, the Delphi method involves little

direct cost (organizing meetings), and may be a cost-effective method for certain purposes (Hishamunda, 2014).

6.2.2 Non-governmental organizations

Non-governmental organizations have certain inherent deficiencies. They are not accountable, unlike politicians who are often democratically elected. They do not have to compromise but merely satisfy a narrow interest or place group, and single issue partisans may not be representative of the broader society.

6.2.3 Producer associations

Producer associations take many forms. They vary from local institutions, sometimes called "one-stop aqua shops", to sophisticated national organizations. In most countries, aquaculture does not have the economic weight of agriculture or even that of capture fisheries. Thus, its interests are often overlooked, and producer organizations can be useful just as a lobby group.

In addition, they are frequently used as a means of exchanging information and diffusing technical knowledge. In Africa, producer associations have managed shared water supplies, and acted as financial intermediaries issuing credit (Hishamunda and Ridler, 2004).

Producer associations can also be marketing agents and monitors for environmental self-policing, as with the Chilean Salmon and Trout Growers' Association. The association maintains HACCP and quality standards, thereby ensuring that all products exported are of a uniformly high quality. It has also played a major role in marketing farmed salmon, collaborating with other producing countries in generic advertising of salmon, and also in differentiating Chilean salmon by brand marketing.

7 Contribution of research and Innovation results from the iFishIENCi project to regulatory requirements of aquaculture

7.1 iFishIENCi Research and Innovation results

The European Commission issued a H2020 Innovation Action call under the title 'Sustainable European aquaculture 4.0: nutrition and breeding'. Aquaculture 4.0 refers to the digitalisation and automation of the processes which contribute to the aquaculture value-chain. Aquaculture 4.0 is the basis of iFishIENCi, a project which is using an Internet-of-Things (IoT) approach towards integrating advanced digital monitoring technology, automated feeding, and artificial intelligence (AI) based technologies.

The annex to Strategic guidelines for sustainable EU aquaculture (COM(2021) 236 final) includes recommended actions for the Commission, for the member states and for the aquaculture advisory council. The opportunity for the iFishIENCi project and other Research & Innovation projects is to work on scientifically supported policy recommendations to support (1) building resilience and competitiveness, (2) the green transition, a (3) the social acceptance and (4) increase knowledge and innovation.

7.1.1 Building Resilience and Competitiveness

New digital sensors and other emerging technologies are being used to monitor a variety of parameters important to fish cultivation, such as those relating to water quality, fish health, and the efficiency of feeding methods. This information is combined and analysed by 'fish-talk-to-me,' the product name given to the cloud-based artificial intelligence being developed within the iFishIENCi project. Fish-Talk-To-Me will identify trends and relationships and use them to predict deviations from

optimal cultivation conditions. Through communication with farming equipment such as feed dispensers, it is able to make automated decisions to ensure these optimal conditions are maintained.

The innovative features of this IoT system are combined into a marketable product called iBOSS. The iBOSS system is required to operate within a variety of conditions, and several kinds of aquaculture systems are being used to test this technology. The most relevant and important cultivation parameters of each system type have been identified by those project partners with the relevant experience. Amongst those chosen were parameters describing water quality, environmental characteristics, feeding methods, and the physiological and health status of fish. The most suitable monitoring technology, such as probes, electronic fish tags, acoustic sensors and cameras have been selected according to their capacity to function within the farming environment and their ability to operate as part of an IoT based monitoring system. Water quality sensors have been calibrated and installed at a cage farming facility along with a camera for monitoring fish behaviour and an echosounder for recording the vertical distribution of fish.

These data are used as inputs to the development of the AI model, along with data already collected from a trial investigating the biological responses of fish to different environmental conditions. Additional aquaculture sites for testing and demonstrating the developed products are being prepared. This includes SMART-RAS, a condition controlled high technology Recirculation Aquaculture System (RAS) integrated with iBOSS technology (Figure 3). A RAS facility is being built purposely to serve this function and its completion is imminent. SMART RAS is intended to provide a platform for testing and monitoring the performance of new aquafeed formulations and other innovations, including fish species of emerging interest.

7.1.2 Participating in the Green Transition

The identification of novel, sustainable feed ingredients, to be produced as part of circular economy-based value chains, is a key goal of iFishIENCi. Two species of microalgae and one species of fungi have been evaluated for their potential to be used as a feed ingredient and for their ability to provide functional feed supplements. The outcome of this evaluation is the selection of the phototrophic algae, *Nanochloropsis gaditana*, its extract since it has antioxidative properties, and also yeast *Candida utilis*. The algae are being added to feed, and the growth performance, and quality of fish receiving this diet is being investigated. A trial in which Rainbow trout received feed containing *N. gaditana* delivered promising results. In addition, the antioxidant dietary supplement extracted from the algae awas added as a liquid coating to feed pellets. The effects of this supplement upon Rainbow trout was also tested in feed trials.

Wastewater and ‘sludge’ from aquaculture are analysed for their ability to meet the nutrient requirements of *N. gaditana* and *C. utilis*, as part of an iFishIENCi ‘waste-to-value’ circular economy approach. Indicators that can provide a quantitative measure of circularity have been defined and the methods of calculation have been further developed. Life-cycle-Assessment is being used to understand how iFishIENCi innovations influence the environmental impacts of aquaculture. The economic pillar of sustainability is being investigated using the Life Cycle Costing methods under development within the project.

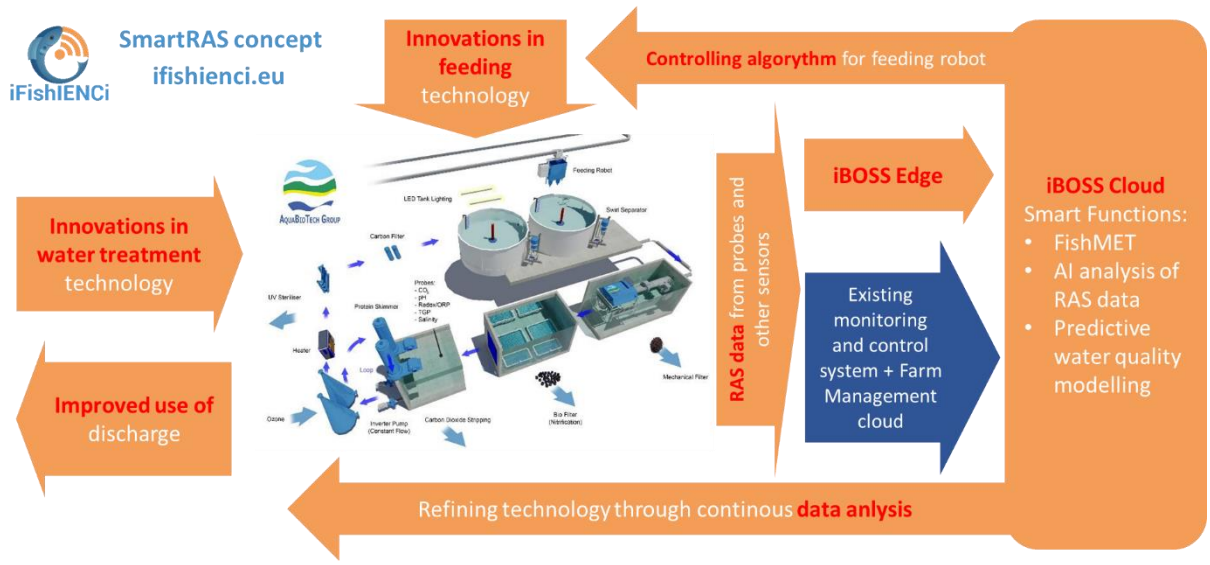

Figure 3 iFishIENCi SmartRAS concept

Other aspects of the interaction between aquaculture and the environment are also considered within iFishIENCi. A model has been produced that predicts the impacts of climate change upon the cultivation of different commercially important species in different regions of Europe.

7.1.3 Ensuring Social Acceptance and Consumer Information

In order to understand the marketability of iFishIENCi innovations, social acceptance studies are performed. To begin this process, focus group surveys have been performed to illicit data describing consumer perceptions of aquaculture food products, with participants from Hungary and Germany. Methodologies have selected and developed for performing market assessments and business models and business plans. A workshop has been held to identify

key exploitable results have been identitfied and a methodology has been developed for creating an exploitation plan to bring the innovations to market. Various activities have taken place to ensure that information about the project's progress, results, and product developments, is effectively communicated throughout the community of iFishIENCi partners and to policy makers, aquaculture industry members, and other relevant stakeholders.

7.1.4 Increasing Knowledge and Innovation

iFishIENCi aims to further develop and increase the competitive edge of the European aquaculture landscape by reconciling and strengthen the competencies of present and future fish farmers and educators. The rapid technology development and intensification of modern aquaculture industry necessitate enhanced integration of research, innovations and knowledge. Coupling of research innovations and educational programs in iFishIENCi will ensure education of candidates with suitable competence for the industry.

7.2 iFishIENCi contribution to regulatory development of aquaculture

7.2.1 Contribution to Public Consultation for the update of Strategic Guidelines[6]

iFishIENCi, in a joint initiative with H2020 projects AquaIMPACT, ASTRAL and IMPAQT, took the opportunity of the review of the Strategic Guidelines for the sustainable development of EU

[6] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12261-EU-fish-farms-aquaculture-updated-guidelines_en

aquaculture (public consultation from July to October 2020) to address in a jointly endorsed position paper, the **needs in relation to circularity in EU aquaculture** to the European Commission and relevant policy makers:

(1) The need to discuss and share views on a common way forward in relation to how circularity in aquaculture should be addressed/measured.

With an aim to facilitate development and increase the sustainability of EU aquaculture the updated guidelines need to include and progress a move towards a more circular aquaculture approach. Increased circularity, also involving the IMTA approach, is a method which allows increased compatibility between sustainable aquaculture and environmental protection. There is a need to discuss and identify ways forward in which circularity can be developed within production, and to help ensure sustainability, in a practical, efficient and economically sound way.

(2) The value of having a joint and coordinated contribution from relevant H2020 projects to the revised Strategic Guidelines for the sustainable development of EU aquaculture in relation to circularity.

We consider circularity from the aquaculture point of view - in a food production system. We need to address the strengths of circularity considering, but not limited to, the importance of biological flows within aquaculture production systems.

The circular economy is defined as the action plan in which the value of the products, materials and resources last within the economy for as long as possible, which aims to minimize waste generation. From our perspective, the circular economy as it may be applied to aquaculture, aims to produce renewable biological resources, facilitating a conversion of these resources and waste streams into value added products, such as food, feed, biobased products and bioenergy.

Giving this specific dimension to circular economy, when addressing the nutrient flow mass and assessing the impacts of recirculating them from one biological species to another, or capturing them to be recirculated as new feed, the circular economy in aquaculture can also be defined and described as a circular bioeconomy.

(3) The proposal to discuss and share views on a common way forward for circularity in aquaculture

With the EU Aquaculture circular economy/bioeconomy objective in view, we suggest that the European Commission creates a “space” where knowledge and views on how circularity within EU aquaculture should be addressed and measured for example in the form of a thematic workshop gathering key stakeholders. As part of the outcome, we suggest a joint and coordinated contribution from relevant H2020 projects to the revised Strategic Guidelines for the sustainable development of EU aquaculture in relation to circularity.

In the context of this consultation process, the iFishIENCi project made a relevant contribution to recognise the recycling of nutrients as a sustainable solution for the aquaculture industry, highlighting the circularity embedded.

7.2.2 Organisation of the “Aquaculture Going Circular” event

iFishIENCi is organising a thematic workshop under the title “**Aquaculture Going Circular**” which aims to take place digitally on 9th November 2021.

Figure 4 Graphic Launch of registration to the Aquaculture going circular event[7]

Within "Aquaculture Going Circular" iFishIENCi aims to bring the circularity concept closer to the aquaculture sector through the development of an interactive event with the participation of high-level speakers, who are experts in circular economy, experts in the aquaculture industry and experts in policy. As concrete outcomes of the event, iFishIENCi aims towards:

- Further understanding circularity within the aquaculture framework;
- Determining how circularity can become part of the business for aquaculture industry; and
- Gathering key information for policy recommendations to be sent to the EC after the event.

Among the attendees, iFishIENCi foresees the following profiles to attend the event:

- Key actors in circularity / circular economy in Europe.
- Key aquaculture industry / organisations and associations.
- European Commission / policymakers
- National policymakers / regulators.
- Research & innovation community working on circularity in aquaculture (E.g. H2020 projects specifically delivering on circularity in EU aquaculture (e.g. AquaIMPACT, AquaVitae, ASTRAL, FutureEUAqua, GAIN, i-FishIENCI, IMPAQT, NewTechAqua).
- iFishIENCi advisory board members.

7.2.3 Contribution to Public Consultation for the update of Marketing Standards for Fish & Seafood products[8]

iFishIENCi took the opportunity of the review of the EU marketing standards framework for fishery and aquaculture products (public consultation from November 2020 to February 2021)to address the need for criteria to measure environmental, social and economic sustainability in EU aquaculture to the European Commission and relevant policy makers:

[7] https://www.eventbrite.ca/e/169812336269
[8] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12262-Review-of-the-marketing-standards-framework-for-fishery-and-aquaculture-products/public-consultation_en

(1) The need to harmonise information on sustainability aspects specifically for seafood products.
(2) The need to define criteria committed to supporting Sustainable Development Goals of the United Nations to measure environmental, social and economic sustainability in EU aquaculture.

iFishIENCi project aims to improve fish production standards with sustainable healthy feeds and better fish welfare to promote Europe´s perception of aquaculture products and boost consumption. iFishIENCi therefore expressed willingness to answer more detailed questions on sustainability criteria in the revision process of marketing standards. We think that circularity, digitalisation and monitoring can contribute to define sustainability criteria for marketing of fish & seafood products:

- Address and measure circularity as important part of sustainability within EU aquaculture: a thematic workshop with H2020 relevant projects, key actors, aquaculture organisation and European and national policymakers will be organised in 2021.
- Digitalisation in aquaculture as a key to reduce the use of resources.
- Improved monitoring, data collection and data accessibility to support the definition and transparency of sustainability criteria.

7.2.4 Contribution to additional public consultation

iFishIENCi partners involved in the production of algae for feed, took the opportunity of the assessment setting out how the EU can increase the sustainable production, safe consumption and innovative use of algae and algae-based products (public consultation from May to August 2021)[9] to address the needs of the algae sector especially in term of circularity.

7.2.5 Co-organisation of the Horizon4Aquaculture events[10]

Confirmed by the European Commission in their strategic guidelines for EU aquaculture 2021-2030, and understood by initiatives working to achieve eco-intensification, preserve biodiversity, and develop better practices and technologies, Aquaculture is paving the way to be both a more environmentally friendly and more efficient industry. Sharing this goal, the EU H2020 funded projects GAIN, iFishIENCi and IMPAQT launched **Horizon4Aquaculture**, a three-day online event — 15th, 22nd and 29th June 2021—to work together in 3 key aspects:

1. **Policy and Regulation**,
2. **Circularity**, and
3. **Precision Aquaculture**.

Horizon4Aquaculture invited researchers, aquaculture farmers, policymakers, national and pan-national aquaculture development organizations to join the conversation and contribute to the present and future of the sector.

The Horizon4Aquaculture event started on the 15th of June 2021, with a session dedicated to discussing policies, practices, and regulations, analyzing gaps and opportunities along the entire value chain of aquaculture production, from pre-production to the consumer market[11]. This workshop aimed at disseminating emergent policy outcomes of the iFishIENCi, IMPAQT and GAIN H2020 projects and at identifying common themes, in order to support the implementation of the recently published "E*U Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to*

[9] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12780-Blue-bioeconomy-towards-a-strong-and-sustainable-EU-algae-sector_en
[10] http://ifishienci.eu/horizon4aquaculture/
[11] http://ifishienci.eu/challenges-and-opportunities-for-aquaculture-policy-and-market/

2030" as well as to foster international benchmarking and cross fertilisation. All sessions started with short introductory presentations, followed by a panel discussion, with iterative audience participation through synchronous polling. Panels included experts from the three Consortia organizing "Horizon4Aquaculture", representatives of EU and National European policymakers, and private sector and third sector (producer organisations, standards organisations).

7.2.6 Development of guidelines to valorise waste: Waste2Value

iFishIENCi aims to develop know-how/guidelines to valorise waste (experimental methodology) as a non-commercial product for valorisation of aquaculture waste streams (Wastewater, Sludge, Other streams). This would include guidelines and recommendations for aquaculture waste streams, aquaculture effluent models, regulatory framework/legislation, technical aspects (such as infrastructure, know-how, final products, by-products etc.), as well as sustainability framework (ESG analysis – environmental, social, and economical performance). Aquaculture waste go through waste valorisation process and could then be used in production of algae and yeast (as investigated in the iFishIENCi project), or if wider scope is interested in aquaponics, biogas, and/or platform chemicals or even circle back to agriculture as fertilizer.

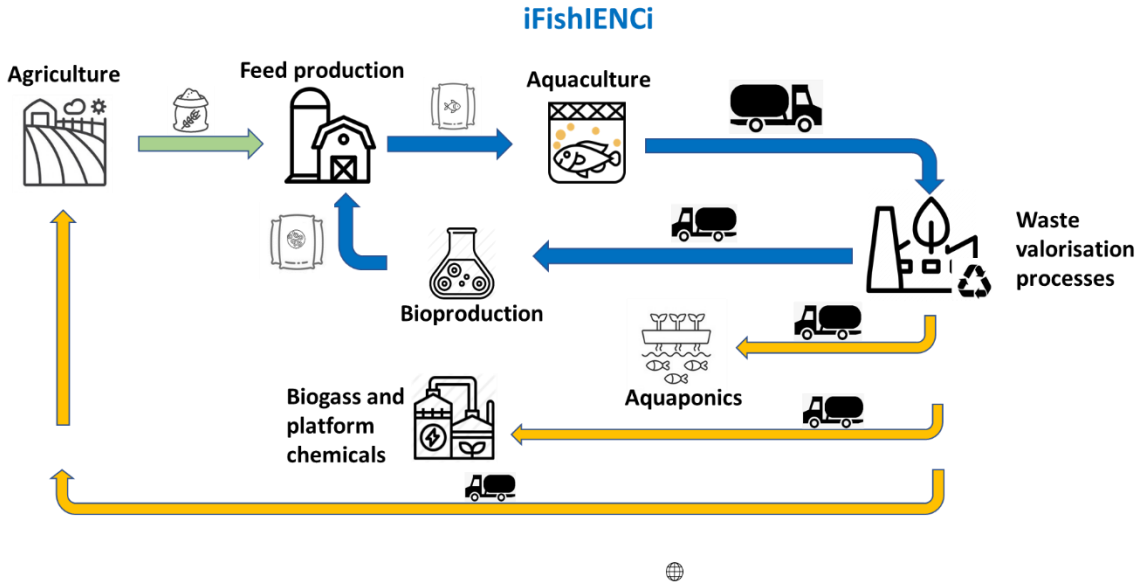

Figure 5 Schematic representation of the Waste2Value web-based decision support tool

Targeted users are Fish producers, algae feed and feed ingredient companies, bioprocessing companies, aquaponics, but also researchers investigated related topics, Policymakers developing the circular economy policy and regulatory framework as well as Stakeholders who wish to get involved in aquaculture waste reuse value chains.

8 Conclusion and Outlook

During the last three decades, aquaculture has been the fastest growing animal-food-producing sector in the world, accounting for half of the present seafood supply. However, there is a significant growth disparity among aquaculture-producing countries. The reasons why some countries have achieved remarkable growth in aquaculture while others have stagnated or even declined have not been determined. However, empirical results suggest that stricter environmental regulations in developed countries have contributed to lower growth rates and that these countries are falling behind emerging and developing economies that have more lenient environmental regulations (Abate et al., 2016).

The impact of the legal framework on the setting up and running of an aquaculture business should not be underestimated. For many producers in the EU, this is one of the main barriers to the development of the aquaculture sector. In some Member States, the procedure for obtaining authorisation for an aquaculture farm can take two to three years (EU Commission, 2013). Several Member States have launched processes to simplify aquaculture legislation. Greece, for example, where previously there were 14 different administrative bodies involved in issuing a licence, is now a new legal framework with a simplified procedure involving a one-stop-shop for investors. Ireland has carried out a complete review of licensing procedures, through a participatory process, which involved a stakeholder consultation and a survey to identify obstacles and propose improvements. Some of the recommendations include:

- setting a time limit of six months for a decision on a licence application
- a licencing period of up to 20 years to make it commercially viable for businesses, which have the possibility of adjusting their operations during implementation
- an on-line application and monitoring system; a pre-application process which helps ensure applications are complete before the full procedure is launched
- training for the staff of the licensing authority; a transparent system of informing the public about applications, etc.

The review has also helped to identify the need to better link aquaculture licencing with Maritime Spatial Planning (MSP), e.g. the online management system indicate areas that are available for aquaculture (Budzich et al., 2018).

The wide diversity of aquaculture systems across species, geographies, producers, and consumers prevents the development of a single strategy to achieve sustainable and healthy products. Governance systems need to be designed with clearly articulated, science-informed goals, but without overly proscriptive standards and regulations for realizing those goals. Such flexibility is needed to support the abilities of industries, governments, and non-government organizations to innovate while still providing clear end points and requirements for monitoring, reporting, transparency, and accountability. The aquaculture sector will continue to face large uncertainties in the future, including climate change, evolving pathogens, parasites, and pests (PPP) pressures, pandemics, and market disruptions and changes in food systems more broadly (Naylor et al., 2021).

Unlocking aquaculture's full potential is unlikely to occur through sole focus on increasing production. Policy coherence and benefit sharing should become key considerations in the planning and future development of sustainable and equitable aquaculture in order to close existing "people-policy gap" (Brugere et al., 2021). "people–policy gap" needs to be overcome before worldwide food security can be achieved from aquatic environments (Krause et al., 2015):

- equal consideration of ecological, social and economic issues in aquaculture policy-making;
- pre-emptive identification of likely social impacts;
- integration of people- and context-specific social framing conditions into planning and policy review; addressing the social disconnection between global consumption and production;
- and, encouragement of creative combinations of theories and methods to assess and interpret the social dimensions of aquaculture in multiple contexts.

Coming back to key findings about regulatory and legal constraints for European aquaculture (Hedley & Huntington, 2009), that still have validity, the key constraints relate to licensing, marine spatial planning, animal health and welfare, regulations of environment impacts and others.

- There is no such thing as an EU aquaculture licence, although one could be established. Licensing systems developed at the Member State level are subject to a number of criticisms.
- Access to suitable sites for aquaculture production is a difficult problem for the aquaculture industry.
- Under aquatic animal health legislation, there remain some issues about fish welfare.
- There is scope for improved governance, including better coordination of policies and better coordination at EU, national and local/stakeholder levels.

Looking ahead, the effective spatial planning and regulation of aquaculture sites will be paramount for achieving positive environmental outcomes, especially as aquaculture systems increase in scale and production intensifies. The industry is investigating recirculating and offshore technologies to reduce its exposure to and impact on aquatic environments; however, these systems will require innovative financial and environmental management to have any chance of widespread success. In addition, investments are needed in an array of pathogens, parasites, and pests prevention strategies across different aquaculture sub-sectors, recognizing that treatments after pathogens, parasites, and pests problems emerge are largely futile. Finally, future policies and programmes to promote aquaculture will require a food systems approach that examines nutrition, equity, justice, and environmental outcomes and trade-offs across land and sea. Tools such as life cycle analysis will need to be refined and deployed to ensure comparability between terrestrial livestock and aquaculture production on the basis of nutritional value and global environmental outcomes. Aquaculture systems can be designed and implemented to be highly sustainable. The human dimension presents both the opportunity and the challenge (Naylor et al., 2021).

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