Intelligent Fish feeding through Integration of ENabling technologies and Circular principle

Grant Agreement (GA) No: 818036

D4.14:

Report on regulatory framework and requirements 3rd version

Version: 2.0

Date: 24.02.2023

Document type:	**Report**
Dissemination level:	**Public**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 818036

Project data

Project Title:	Intelligent Fish feeding through Integration of ENabling technologies and Circular principle
Project Grant Agreement (GA) No:	818036
Project Acronym:	iFishIENCi
Duration:	57 months, 1 November 2018 – 31 July 2023
Type of action:	Innovation Action

Deliverable Administration and Summary

Status:	Final	**Due:**	31.07.2022	**Date:**	24.02.2023
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WP	4	**Deliverable Nr.**	**4.14**	**Relative Nr.**	31
Comments					

Document change history

Version	Date	Author	Description
0.1	03.05.2021	M. Shrestha (TTZ)	Creation of report and structuring of content
1.1	19.12.2022	M. Shrestha (TTZ)	First version
1.2	22.12.2022	A. Rost and M. Shrestha (TTZ)	First version ready for internal review
2.0	24.02.2023	S. Balsells (LEITAT), B. Hávardsson (NCE Seafood), A. Rost (TTZ), I. Sanchez (LEITAT), M. Shrestha (TTZ)	Final version including comments from internal review
3.0	15.02.2024	A. Rost (TTZ)	Revision

Suggested reference to this deliverable: Deliverable D4.14, Report on regulatory framework and requirements, 3rd version (2023), Intelligent Fish feeding through Integration of Enabling technologies and Circular principle (iFishIENCi) Horizon 2020 project under Grant Agreement (GA) No: 818036.

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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 D4.14 (February 202) is to assess current use of certification and consumer attitude towards certification, as well as the impact of regulation on potential valorization routes of aquaculture waste streams and the influence of trade agreements on the development of a more sustainable aquaculture sector.

2 Introduction

Farming finfish, shellfish and aquatic plants in the sea or inland waters is one of the world's fastest growing food sectors. It already provides the global population with more than half of all the seafood and fish we consume (DG Mare, n.d.).

The EU is the fifth largest fisheries and aquaculture producer worldwide, accounting for about 3% of global production. EU aquaculture accounts for about 22% of fish and shellfish supply in the EU and directly employs about 70,000 persons. The sector consists of around 15,000 enterprises, mainly small businesses or micro-enterprises in coastal and rural areas. Overall EU production has been more or less stable since 2000, whereas global production has been growing between 5% to 7% per year. The main aquaculture-producing EU countries in terms of volume are Spain, Denmark and France (DG Mare, 2019).

Aquaculture production is diverse in terms of both species farmed and methods of production (sea cages, ponds, raceways, on-land recirculating aquaculture systems). Around 100 different species are currently farmed in aquaculture operations around the world. In the EU:

- more than 45% of aquaculture production is shellfish
- more than 30% of aquaculture production is marine fish
- more than 20% of aquaculture production is freshwater fish

Despite of the diversity of aquaculture, the EU aquaculture production is largely concentrated on a few species, the most important being mussels, salmon, seabream, rainbow trout, seabass, oysters, and carp. Algae production is still limited in the EU but is increasing.

The sustainable development of aquaculture is one of the main objectives of the common fisheries policy. Aquaculture production is also recognised by the European Green Deal as a source of "low carbon" protein for food and feed (COM (2019) 640).

2.1 Objective of the iFishIENCi Research & Innovation project

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 number 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 best practise 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).

2.2 Objective of iFishIENCi reports on regulatory framework and requirements

Aquaculture currently produces half of the seafood that is consumed globally. As the industry continues to expand, implementing robust and relevant standards is essential for ensuring food supply chains are sustainable and transparent and that those farmers who practice aquaculture are incentivised to meet industry standards and, in turn, minimise any negative environmental and social impacts. Aquaculture production is subject to licencing and monitoring procedures and must comply with strict requirements under EU and/or national legislation to ensure it respects human and animal health and the environment (DG Mare, n.d.). Another increasingly important aspect for aquaculture production in the EU and beyond is animal welfare in fish farming (TAPAS, 2018).

The aim of the iFishIENCi series of three reports on Regulatory Framework and Requirements (published in July 2019, in September 2021 and February 2023) 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.

2.2.1 Assess Legal requirements for Aquaculture

The European Commission wants to help develop the EU aquaculture sector that ensures the supply of nutritious, healthy and tasty food with a low environmental and climate footprint, creates economic opportunities and jobs, and becomes a global reference for sustainability and quality. Its policy aims specifically to:

- building resilience and competitiveness
- ensuring the participation of the sector in the green transition
- ensuring social acceptance and consumer information on EU aquaculture activities and products
- increasing knowledge and innovation in the EU aquaculture sector

Through the strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021-2030 (COM (2021) 236), the Commission provides a common vision for EU countries, the aquaculture sector and other stakeholders to develop the sector in a way that contributes directly to the European Green Deal and the Farm to Fork Strategy. EU countries have reviewed their national strategic plans to promote aquaculture to take into consideration that vision.

The European Maritime, Fisheries and Aquaculture Fund (EMFAF) is making available specific financial support available to ensure the best possible conditions for the EU aquaculture sector to develop

sustainably. Each EU country decides how it wants to spend that money, provided that this is consistent with its national strategic plan for the sector. To allow EU countries to support their producers while respecting EU competition rules and other policies, specific state aid rules apply to the fishing and aquaculture sectors.

The EU also supports research and innovation on key elements for the sustainable development of European aquaculture. From interactions with the environment, health and nutrition of farmed fish, to reproduction and breeding. Research and innovation on sustainable aquaculture is an important priority under Horizon Europe, the EU framework programme for research and innovation.

Norway follows the EU regulations regarding food quality standards and the licensing process for medicines and pesticides, with a zero-detection limit for permitted levels of medicines and pesticides in aquaculture products at harvesting (Maroni, 2000).

READ MORE
about Legal requirements for Aquaculture assessed by the iFishIENCi project:

The first iFishIENCi report on regulatory framework and requirements (Shrestha, 2020) prepared in July 2019 and revised in October 2020 is 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

The second iFishIENCi public report on regulatory framework and requirements (Hávardsson, 2021) published in September 2021 is assessing:

- Gap and Opportunities for the regulatory framework of European aquaculture considering the 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]
- the role of informal institutions in the regulatory process
- the regulatory framework, which affects circularity within EU aquaculture, supporting the iFishIENCi Task 1.5 on Zero waste and Valorisation of by-products and sludge

The current third iFishIENCi public report on regulatory framework and requirements (D4.14 – current report) from February 2023 is assessing:

- the regulatory framework for waste-valorisation/management in large aquaculture producing countries in the EU beyond Germany, Malta, Hungary, Norway and Spain
- the current and prospective policy on trade-agreements and their impact on market path for aquaculture products

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

2.2.2 Assess Responsible farming standards and Certification schemes for aquaculture

Aquaculture is a complex activity that involves many elements, from the use of space and water, taking care of the health and welfare of animals farmed, or ensuring the safety of products used in the farming process (such as feed or veterinary treatments) for the environment and human health. There is a large body of EU legislation covering these issues, which aquaculture producers have to comply with. For example, to protect aquatic habitats from impacts of non-native or locally absent species, specific rules exist on their use in aquaculture.

In addition, EU legislation and policies for organic production also apply to aquaculture. These rules promote, through certification and labelling, aquaculture that complies with stricter production requirements on environmental impact and animal welfare, as well as limited and regulated use of inputs.

The main responsibility of the application of this legislation and the management of aquaculture activities lies with public authorities in the different EU countries (DG Mare, 2021). Several Member States (Austria, the Netherlands, Spain,) refer to specific certification schemes, which must ensure sustainability, quality and social responsibility (European Union, 2016). At present at least 30 certification schemes and key international agreements relevant to aquaculture certification, as well as initiatives are also identified as addressing sustainability issues and creating a framework for differentiating sources of aquatic products in this respect (FAO, n.d.).

The aquaculture industry has made great efforts in improving the largely voluntary development of standards. Many of these standards address some of the worst environmental and social abuses associated with the early development of the aquaculture industry. However, even further attention needs to be devoted to social sustainability considerations (Haugen, 2017).

READ MORE
about Responsible farming standards and Certification schemes for Aquaculture assessed by the iFishIENCi project:

The first iFishIENCi report on regulatory framework and requirements (Shrestha, 2020) prepared in July 2019 and revised in October 2020 is outlining existing framework of Standardisation and Certification.

The second iFishIENCi public report on regulatory framework and requirements (Hávardsson, 2021) published in September 2021 evaluated the role of informal institutions in the regulatory process.

The current third iFishIENCi public report on regulatory framework and requirements (D4.14 – current report) from February 2023 is assessing:

- limitations and constraints as well as opportunities in term of standardisation and certification
- current use and potential of market-based labelling & certification schemes for different channel actors
- interactions, cost/ benefits and areas of overlap between mandatory and major voluntary certification and recommendation schemes
- complementarities with the general assessment of consumer attitudes toward certification schemes (outlined in iFishIENCi Task 4.1)

2.2.3 Assess Ethical requirements for aquaculture

The major benefits from aquaculture for household economies, human nutrition, employment, country economies, preservation of biodiversity (in cases of restocking and recovering of species), fishery resources (in case of aquaculture sustainability), respective research and development, and education and environmental awareness should always be weighed against generated ethical objections (Frankic and Hershner, 2003).

According to Grigorakis, the ethical issues raised by aquaculture cover the various aquaculture production stages i.e the breeding, the growth/feeding, the handling (that includes disease and treatment, transportation, killing procedure, vaccinations), and the commercialization (Grigorakis, 2010).

An ethical evaluation could be towards the operation of a certain farm in a specific area, about certain aquaculture procedures (e.g., vaccination), about the ethical application of a custom practice in aquaculture (e.g., is an antibiotic ethically used in aquaculture nowadays?), about certain forms of aquaculture (e.g., intensive salmon culture), about a country specific aquaculture practices/politics, or for aquaculture as activity, in general, over a geographical region (Grigorakis, 2010). Ethical aspects should also include whether it is ethical to withhold important disease management tools such as antibiotics or well managed parasite management even if they have minor, short time o reversible impact on local biota. The ethical evaluation should give ethically accepted solutions.

However, ethical evaluation should not be limited to a purely scientific analysis; it should be holistic, comparable to available alternatives, and should have the flexibility to incorporate new data generated in the fast growing/continuous changing aquaculture sector in practice, rather than a utilitarian balancing of cost and benefits of the respective actions (Grigorakis, 2010; Thompson, 1998). An ethical evaluation requires an ethical component that will give answers, i.e., how to prioritize these ethical entities (fish welfare, consumer welfare, producers' welfare, the environmental sustainability).

READ MORE
about ethical dimension in the iFishIENCi project:

The Responsible Research & Innovation (RRI) Inreach Framework document outlines the rationale and concrete protocol for the innovative "RRI-Inreach" strategy and activities that supports the iFishIENCi project (Dankel, 2022). Previously confidential to project partners, the author and iFishIENCi consortium make this method available for the benefit of the European research community to examine how project actions are accountable to our societal and scientific responsibilities.

2.2.4 Assess Environmental requirements for aquaculture

Aquaculture is one of the fastest growing food production sectors and has great potential for food security and livelihoods. However, it can generate concerning consequences for the environment, including chemical and biological pollution, disease outbreaks, unsustainable feeds and competition for coastal space. (Carballeira Brana, 2021)

The most important aspects regarding of environmental sustainability of EU aquaculture and many countries beyond relate to: the assessment, monitoring and limitation of the environmental impact of aquaculture activities (e.g. in terms of nutrients and organic matter discharge from aquaculture farms in waters), the use of alien or locally absent species, feed ingredients for carnivorous fish (alternatives

to wild fish), disease management and use of veterinary medicines and other substances with low environmental impact (DG Mare, n.d.).

Recent investigations are focusing on sustainable techniques (e.g., polyculture, offshore facilities) to improve the relationship between the industry, environment and society. Adequate environmental monitoring and location of farms, the reduction and exploitation of waste and chemicals being used is crucial to ensure the growth and continuity of aquaculture production. (Carballeira Brana, 2021)

Feed production and usage represent considerable impact, hence calling for new and more environmentally-friendly feed options. The development of aquaculture following existing governmental policies may not directly reduce greenhouse gases emissions and, hence, not support climate change mitigation objectives (Bohnes, 2022). These findings should however be cautioned as increasing seafood availability might lead to potential shifts of diets, leading to indirect environmental benefits. Bohnes et al. therefore advocate to cover the entire food system, so it can integrate such indirect effects and to support policy-making in moving towards more environmentally sustainable aquaculture systems (Bohnes, 2022).

Public regulation of a successful industry such as aquaculture needs to consider different concerns such as industry growth and development, but also environmental and societal sustainability. Governance systems are continuously challenged to respond in adequate manners to how aquaculture industry develops. This is especially noticeable when it comes to how environmental challenges are handled (Osmundsen, 2022).

“Green” licenses, “development” licenses, and “eco-technology” licenses, all aim to promote the development of more environmentally friendly production technologies. But the main contributions to regulation is to set the focus on environmental risks, and to give stimulus to technological innovation in fish farming. However, the side-effects are large administrative burden and long-lasting awarding processes which at times have been characterized by lack of transparency and predictability (Osmundsen, 2022).

READ MORE **about environmental requirements for aquaculture assessed by the iFishIENCi project:**
The second iFishIENCi public report on regulatory framework and requirements (Hávardsson, 2021) published in September 2021 thoroughly analysed existing barriers on EU and local regulations from iFishIENCi pilot 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 was needed. Apart from RAS systems, regulations on ponds and Open cages was also 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.
iFishIENCi Report on Climate change scenarios and impacts on aquaculture (Goris, 2020) intends to deliver insights into climate changed induced threats that have the potential to influence growth rates of European aquaculture species. Given the technological focus of the iFishIENCi project, this report presents only a first order estimate and is by no means a complete overview. Nevertheless, it gives an indication of the potential future threats to European aquaculture. Additionally, it discusses the potential benefits of the technological accomplishments of iFishIENCi with regards to some of the projected climate conditions.
The current third iFishIENCi public report on regulatory framework and requirements (D4.14 – current report) from February 2023 is addressing ecosystem approach to aquaculture (EAA) and its link with environmental requirements.

2.2.5 Assess Health & Safety Requirements for aquaculture

Aquaculture is recognised as being one of the most efficient solutions to feed a growing global population and now provides more fish for food than traditional fisheries. In aquaculture, health and welfare are of prime importance, as much as the water quality and environment in which they are raised.

No farmer wants to lose fish to disease and infections, so daily inspections on the health of livestock are integral to best management practice. Good welfare is essential maintain good fish health, at all stages of the life cycle – from egg to adult. Intimate understanding of the interaction between pathogens (parasites, bacteria or viruses), the dynamic environmental conditions (e.g. water temperature, source and rate of water flow…), and different life stages is an essential part of the farm management. Further, access to effective veterinary treatments is of vital importance to the producer, since prompt action is needed once an infection is observed to avoid mortalities and stock losses. All treatments are extensively controlled in Europe, requiring veterinary controls and approval. With antibiotic administration being strongly discouraged, vaccines are an integral part of fish farming for last 30 years to reduce threat from bacterial pathogens. Throughout Europe, strong measures and controls are made on the movement of live fish and ova, where disease-free certification is needed before transport. Similarly, control procedures and eradication measures are in place for all diseases that may affect the health and welfare of aquaculture stocks.

To ensure that seafood consumers globally have access to the finest and safest European farmed fish products on the market, European fish farmers and their veterinarians continuously work in concert to develop Veterinary Health Plans, optimised global surveillance and monitoring programmes. The control system for the use of medicines in Norwegian aquaculture for example, makes it possible to have detailed records of the use of all medicines at site level. Norway has the most detailed database registration of this kind in the world (Maroni, 2000). Because, in the end, it is not in the interest of fish farmer to lose productivity due to reduced growth performance and loss of fish through disease and infections.

The EU animal health policy is the result of decades long development combating transmissible animal diseases (often epidemics) and covers all food animals in the EU as well for sport, companionship, entertainment and in zoos. The health policy also covers wild animals and animals used in research where their transmission risk of diseases to other animals or to humans.

The health policy protects human and animal health and welfare as well as food safety as it is working towards high animal health status of livestock, poultry and fish by controlling animal disease outbreaks and by surveillance and eradication programmes. It ensures smooth and safe internal EU market (including introduction into the EU) of live animals and products of animal origin (including animal by-products) by legislative and non-legislative measures. It works under the motto “prevention is better than cure “(FEAP, n.d.).

Fish reared for food production in aquaculture can be held in different types of rearing systems and are subjected to various husbandry routines and operations. Each of these systems or operations can present different welfare risks to the fish, which in turn are dependent upon both the species and its life stage. The farmer has access to tools to assess fish welfare during on-growing and outline relevant welfare actions that can be taken to militate welfare hazards in a wide range of existing and emerging rearing systems used for on-growing (Vis, 2020).

READ MORE **about Health & Safety Requirements for aquaculture:**
Surveillance of diseases in aquatic organisms: A 12-point checklist in the design and practical application of active surveillance of diseases in aquatic organisms (farmed and wild) has been developed to serve as a methodological approach and guidance for a multidisciplinary team

particularly in countries where surveillance expertise is limited. The checklist is based on a review of available main aquatic surveillance references and scientific literature and was further developed based on the outcomes of several aquaculture biosecurity project-related workshops hosted by the Food and Agriculture Organization of the United Nations (Bondad-Reantaso, 2021).
Tools for farmers to assess fish welfare: • Welfare Indicators for farmed Atlantic salmon: Tools for assessing fish welfare (Noble, 2018) • Curing EU aquaculture by co-creating health and welfare innovations (Cure4Aqua, 2022)
Commission Delegated Regulation (EU) 2020/990 of 28 April 2020 supplementing Regulation (EU) 2016/429 of the European Parliament and of the Council, as regards animal health and certification requirements for movements within the Union of aquatic animals and products of animal origin from aquatic animals.
In Norway, all personnel working with live fish, farmers, transporters, harvesting plants, in Norway must participate in, and receive certification in animal welfare biannually. Additionally, current change in regulations for financial penalties as stated in the Law on animal welfare. • Norwegian Animal Welfare Act (Lov om dyre-velferd of 19.6.2009). • Norwegian Regulation on fish welfare considerations on development of new technologies from 2015, Guidelines updated 2020.

3 Ecosystem approach to Aquaculture as an answer to Environmental requirements for Aquaculture

Aquaculture is growing rapidly in inland and coastal regions throughout the world. Rapid growth has fuelled concerns over the ecological and social impacts of aquaculture in crowded inland and coastal areas rife with user conflicts where “new” uses such as aquaculture compete for space and resources with traditional users of land, water, and coasts (Byron, 2013).

It is widely recognized, not only in Europe, that further aquaculture developments need to be planned and designed in a more responsible manner that minimize as much as possible negative social and environmental impacts. The European Union Water Framework (Directive 2000/60/EC), Marine Strategy Directives (Directive 2008/56/EC), the Canadian Oceans Act, and the US National Policy for the Stewardship of the Ocean, Coasts, and Great Lakes all call for spatial planning for human activities such as aquaculture to be carried out in a more sustainable fashion, including the essential components of: (i) knowledge-based approaches for decision-making, and (ii) ecosystem-based approaches for integrated management.

In 2006, the Fisheries and Aquaculture Department of the Food and Agriculture Organization (FAO) of the United Nations recognized the need to develop an ecosystem-based management approach to aquaculture similar to the Code of Conduct for Responsible Fisheries. FAO (Soto et al., 2008) suggested that an ecological approach to aquaculture (EAA) would have three main objectives: human well-being, ecological well-being, and the ability to achieve both via more effective governance within a hierarchical framework that was scalable at the farm, regional, and global levels.

In 2010, FAO defined an Ecosystem approach to Aquaculture as a strategy for the integration of aquaculture within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems (FAO, 2010). The ecosystem approach to aquaculture (EAA) emerged from discussions between the Food and Agriculture Organization (FAO) of the United Nations and international aquaculture experts on how to move aquaculture development towards greater sustainability (Brugère, 2019). Being a strategy, the ecosystem approach to aquaculture (EAA) is not what is done but rather how it is done. The participation of stakeholders is at the base of the strategy. The EAA is guided by three strategic principles:

1. Aquaculture development and management should take account of the full range of ecosystem functions and services and should not threaten the sustained delivery of these to society.
2. Aquaculture should improve human well-being and equity for all relevant stakeholders.
3. Aquaculture should be developed in the context of other sectors, policies and goals, as appropriate.

The ecosystem approach to aquaculture (EAA) is a strategy for the sustainable development of the aquaculture sector, but the question of how it can be practically implemented remains unclear. Indicators that can be applied at relevant scales of impact and that reflect the environmental status and change offer a means of operationalizing EAA. Therefore, a systematic literature review was carried out to identify environmental indicators referenced in salmon aquaculture literature and review their potential to support EAA. A scoring method for evaluating indicators based on criteria drawn from environmental indicator literature and the potential scalability of indicators to meet the needs of EAA was developed and applied to the most frequently referenced indicators. Overall, near-field indicators of benthic impacts dominated salmon aquaculture literature. Of the most frequently referenced indicators, those that scored highest based on criteria drawn from environmental indicator literature also scored highest on scalability and therefore their potential contribution to EAA. Overall, results suggest that additional research and application of far-field environmental indicators in salmon aquaculture will be required to identify a suite of indicators that can be applied as part of EAA practice (Rector, 2022).

Some consideration should be given to the considerable development of standards, however regional, some have been adopted internationally such as NS 9415, NS 9417, or non-formal standards from the Aquacloud consortium.

- **Data standard**. Sensor data standard will enable all suppliers in the aquaculture industry to work seamlessly together on sensor data, without the need for expensive integration work. Support for sensors are easily developed, and any system supporting the standard will be capable of gathering its data.
- **Industry initiatives and standards** for fish health documentation
    a. Review NS 9417 Standard Norge: *Salmon and rainbow trout – Unambiguous terminology and methods for documentation*.
    b. Data exchange on eight groups for losses and mortality data from Fishtalk and Mercatus on the AquaCloud platform
    c. Establish digital standard for classification of losses and mortality causes in aquaculture.

Implementing the EAA requires strengthening institutions and associated management systems so that an integrated approach to aquaculture development can be implemented and account fully for the needs and impacts of other sectors. Defining, developing, and adapting existing methods to estimate resilience capacity, or the limits to "acceptable environmental change" are essential tasks to moving forward with an EAA (Byron, 2013).

Mainstreaming EEA in planning processes has raised awareness of the usefulness of holistic and participatory approaches in aquaculture and helped to steer the sector towards greater sustainability, yet the approach has had varying degrees of resonance and uptake with different user groups (Brugère, 2019). Even though the literature on marine and coastal Ecosystem based Management is already diverse, its practical application has been generally impaired by the diversity of perspectives among management players on how to operationalize it. Moreover, outputs from previous marine and coastal Ecosystem Services assessments performed with the intention to inform decision-makers did not translate into the decision-making process. Thus, the application of the Ecosystem Services framework to foster a sustainable development of aquaculture will depend on the research efforts carried out in the future, the valuation methodologies chosen to correctly elicit value, the successful communication of results to key players and the actual application of conforming measures into decision-making. Additionally, government incentives towards the mapping of Ecosystem Services in marine and coastal areas most likely to be selected for and impacted by the development of aquaculture are also paramount. Only by shifting towards this approach will it be possible, in the future, to sort through different development scenarios and conscientiously support projects that sustain Ecosystem Services capacity and maintain or enhance Ecosystem Services flow to local communities and human societies (Custódio, 2020).

The widespread adoption of an EAA requires a much tighter coupling of science, policy and management. Stakeholder participation is recommended to enhance insights on the full environmental and human dimensions of marine management and for implementation of ecosystem-based marine spatial planning (Galparsoro, 2020). It will also require that governments include the EAA in their aquaculture development policies, strategies and development plans. More studies are necessary to assess Ecosystem Services trade-offs between aquaculture and the environment in which it occurs, to demonstrate the validity of Ecosystem Services conceptual frameworks to effectively support an ecosystem approach to aquaculture. Practical reasons (e.g. available data and resources, expertise), stakeholder-oriented reasons (e.g. stakeholder participation, inclusion of local knowledge, ease of communication) and decision-oriented reasons (e.g. purpose of the assessment, Ecosystem Services at stake) should be key considerations in selecting methods (Custódio, 2020).

Ongoing sustainability challenges create pressure on planning practices and institutional arrangements. Transformative policy visions, such as the circular economy and bioeconomy, create promises for designing and planning sustainable pathways in society. Moreover, research agendas on sustainability transitions, such as transition management, are developing toolkits and attempting to shift planning practice by applying evidence-based policy-making processes. The planning process act as a bidirectional intermediary space, refining both the general transition visions and established planning practices (Lukkarinen, 2023).

The European seafood and aquaculture sectors are facing important challenges in terms of environmental threats (climate change, marine debris, resources depletion), social development (worker rights, consumer's awareness) and economic growth (market and nonmarket goods and services, global competitiveness). These issues are forcing all stakeholders, from policy-makers to citizens and industries, to move to more sustainable policies, practices and processes. Consequently, an improvement in collaborations among different parties and beyond borders is required to create more efficient networks along the supply chain of seafood and aquaculture sectors. To achieve this, a "nexus thinking" approach (i.e. the analysis of actions in connected systems) combined with a life cycle thinking appears as an excellent opportunity to facilitate the transition to a circular economy (Ruiz-Salmón, 2020).

Within the European recent agenda for sustainable growth—the Green Deal—the European Commission has adopted a new circular economy action plan. The plan aims at not only ensuring substantial material savings throughout value chains and production processes but also generating extra added value and unlocks economic opportunities. Within the European Atlantic area, commercial alliances and common interests in food production and consumption are numerous, particularly for seafood. To assess the benefits and disadvantages of potential changes in the technology regimes along the value chain, stakeholders need to be provided with tools to guarantee positive environmental and economic balance of new circular economy practice. As demonstrated in other sectors other than fisheries or aquaculture, the lack of studies on socioeconomic dimension limits the ability for decision-makers to mainstream circular economy practices into existing business models (Jacob, 2021).

4 Regulatory Requirements for waste management and Potential Valorisation routes within a circular economy and zero waste strategy in large aquaculture producing countries in Europe

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 or yeast cultivation are still scarce.

The iFishIENCi project is trialling an innovative form of waste valorisation for aquaculture waste streams by using the wastewater and the dewatered sludge for recirculation of nutrients (nitrogen, phosphorus, carbon) to cultivate microalgae and yeast.

As feed industry faces legal constraints when it comes to "waste" for feed (e.g. wastewater, sludge), "intermediate steps" for valorisation, avoiding direct reuse of waste for feed are studied around the world. Some examples are:

- The project SLAM-DUNK (SLudge Appraisal teaM – Developing a sUstainable value chaiN from tanK to product), funded by the Research Council of Norway, aims to develop a sustainable value chain for the conversion of fish sludge into valuable products.
- The project SEA2LAND (Producing advanced bio-based fertilizers from fisheries wastes), funded by the EU, aims to improve and adapt technologies for nutrient recovery to produce bio-based fertilisers (BBFs) and tailor-made fertilisers (TMFs) from fishery and aquaculture by-products generated in Europe.
- The project BIOSIRKEL (Increasing innovation capacity and pace of innovation for circular bioeconomy in Western Norway) aims to enable new bioeconomic value chains by connecting actors with waste streams to actors who can achieve gains through access to the streams.

The algae "step" can be understood as an intermediate step. Due to their nutritional and functional value, algae are gaining more attention as it offers significant potential for efficient production of a wide range of products. However, many regulatory obstacles are a hurdle to bringing products derived from secondary materials to the market (ESPP, EurEau, EABA, 2021). In Norway, aquaculture sludge from Fresh Water production is restricted in use on fields due to concerns about transmission of diseases to Fresh Water systems. The question of whether algae grown in or using waste inputs are classified as "waste" or as "products" is still not clarified (ESPP, EurEau, EABA, 2021; ESPP, 2021)). In this regard, communication is being held with the European Commission to promote the use of algae grown on waste (ESPP, EurEau, EABA, 2021).

In the same direction, the EU's Algae Initiative "Blue bioeconomy - towards a strong and sustainable EU algae sector" was published in 2022 alongside an action plan to support algae to become a source of alternative protein. The EU aims to work with the algae industry and Member States to identify valid and safe alternatives to the use of nutrients and CO_2 from various sources for microalgae cultivation including using secondary nutrients (from wastewater) for microalgae cultivation in closed circles (COM, 2022).

Direct reuse of algae cultivated on aquaculture waste streams for feed or non-feed (biogas production, or fertilizers), are promising strategy to develop circular products. The new Fertilizing Products Regulation 2019/1009, applied from July 2022, lays down conditions under which waste material can

cease to be waste if it is contained in a compliant EU fertilizing product (ESPP Scope Newsletter, 2021). The material needs to comply with the specifications of materials included in fertilizing products (CMCs = Component Material Categories, Annex II) (ESPP Scope Newsletter, 2021). Fertilizing products need to comply with both a Product Function Category (PFC, Annex I) and the labelling and conformity assessment obligations (Annexes III and IV) (ESPP Scope Newsletter, 2021).

Algae offer a promising solution in recovering nutrients from waste streams: wastewater and exhaust gas, as it enables the recovery of up to 50 t Carbon/ha/year, 10 t Nitrogen/ha/year, and 2 t Phosphorus/ha/year (ESPP Scope Newsletter, 2021). Because of its effectiveness, many companies have already started algae production on large scales such as:

- AQUALIA has launched a full-scale plant near Cádiz in Spain with a capacity of 4 x 0.52 ha microalgae raceway ponds (ESPP Scope Newsletter, 2021).
- CLEARAS focuses on resources recovery from municipal and industrial wastewater in the Village of Roberts project, operational since the summer of 2021. The installation has a capacity of 570 m^3/day of secondary sewage works effluent using 12.000 m of indoor glass tubing photobioreactor (PBR) (ESPP Scope Newsletter, 2021).
- CLEARAS has other projects in both the construction and design phases such as the South Davis project in Utah, which will be the largest indoor algae installation in the world with a capacity of 23000 m^3/day using 550 m^3 of PBR (ESPP Scope Newsletter, 2021).
- The partnership between Livalta expert in new proteins for animal feeds and Canada's Pond Technology with its ground-breaking technology to create the world's First scalable algae plant utilizing carbon emission (AB Agri, 2021).

The strategy to use aquaculture waste streams to produce biogas, then used to cultivate yeast could remove the waste to feed problem and could yield valuable protein to use in animal feed. New research on Microwave Assisted Pyrolysis and Gasification (MAP-G) for example has given interesting findings (Vik, 2021). Used with fuel cell technology, several pathways exist for using the gaseous phase for energy. The non-gaseous part turns into biocoal, a chemically interesting substance and one with possibilities as a GHG neutral fuel.

It is important to note that regulation needs to consider that phosphate is a finite resource, and one that is both essential to all aqua and agricultural production. The access to phosphate is largely limited by access to mined minerals. The global exploitable reserves of phosphate being mainly located in Morocco (85%). The future legal considerations for aquaculture sludge utilisation should therefore reflect the reality of phosphate scarcity.

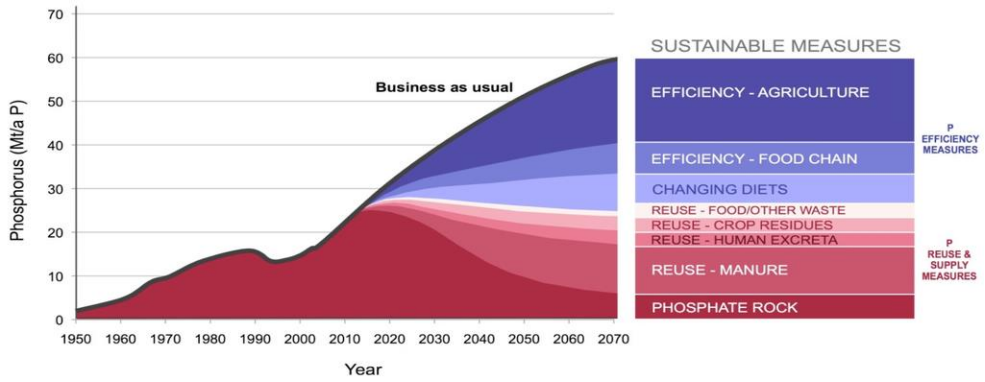


Figure 1 *Scenario for meeting long-term global phosphorus demand: integrated demand management (efficiency) measures (blue) and supply-side (reuse) measures (red). Source: Cordell & White, 2011 redrawn from Stewart et al, 2005.*

5 Aquaculture Certification standards as an answer to Responsible Farming requirements for Aquaculture

Traceability and labelling of seafood are key elements to protect the interests and health of consumers and to move towards sustainable exploitation of maritime resources (Lewis and Boyle, 2017; Tinacci et al., 2019). Labels, in addition to providing the consumer with information on aspects such as safety, quality, health, and origin of products, also allow the communication of statements on ethical issues (Penca, 2020), which, in the fisheries sector, are related to the over-exploitation of fish resources, the impoverishment of marine ecosystems, and the expression of the link between human and ecosystem wellbeing (Galati and Crescimanno, 2012; Autzen and Ounanian, 2021).

The first iFishIENCi report on regulatory framework and requirements D4.12 (Shrestha, 2020) is outlining existing framework of Standardisation and Certification, so that the current third iFishIENCi report on regulatory framework and requirements (D4.14) does not aim to repeat the outline but rather to analyse existing schemes:

- What is the current use of certification?
- What are the limitations, constraints and opportunities of existing certification standard?
- What is the consumer attitude toward certification standards?

5.1 Current Use and Potential of market-based certification standards

Aquaculture now produces half of the seafood that is consumed globally. As the industry continues to expand, implementing robust and relevant standards is essential for ensuring food supply chains are sustainable and transparent and that those farmers who practice aquaculture are incentivised to meet industry standards and, in turn, minimise any negative environmental and social impacts (Alfnes, 2018).

In response to public over- and under-regulation, several types of private governance arrangements have emerged with the intention of shaping demand for sustainable, 'fair', and organic aquaculture production. For example, 30–50 voluntary labelling, certification and rating schemes have been introduced by non-government organizations and private companies. Farm-level certification is setting new norms for sustainable aquaculture globally, yet the role of certification remains limited by low (yet growing) levels of producer compliance (Naylor, 2020).

Growth in the number of certification schemes in the aquaculture industry has been attributed to several factors. The schemes contribute to improved traceability of products, provide healthier stocks, and provide more information to customers' decision-making efforts. There is a wide range of certification schemes and standards available, addressing food safety, environmental impact, animal welfare, and worker conditions, to name a few (Nilsen, 2018).

Osmundsen identified the eight global sustainability certification schemes for aquaculture as being the ASC, GLOBAL GAP, Global Aquaculture Alliance (GAA), BRC Global Standards, International Featured Standards (IFS), Scottish Salmon Producers' Organisation (SSPO), Royal Society for the Prevention of Cruelty to Animals (RSPCA), and Friend of the Sea (FOS) (Osmundsen, 2020).

Table 1 *Most used aquaculture certification standards as identified by iFishIENCi in D4.12 (Shrestha, 2020)*

The two largest certification groups—the Aquaculture Stewardship Council (ASC) and the Global Aquaculture Alliance Best Aquaculture Practice (GAA-BAP) standards—account for 3% of global aquaculture production. Low levels of compliance have been attributed to insufficient finances, low demand for certified products, poor literacy levels, and inadequate administrative skills required for monitoring and reporting and environmental production risks beyond the control of the producer (Naylor, 2020).

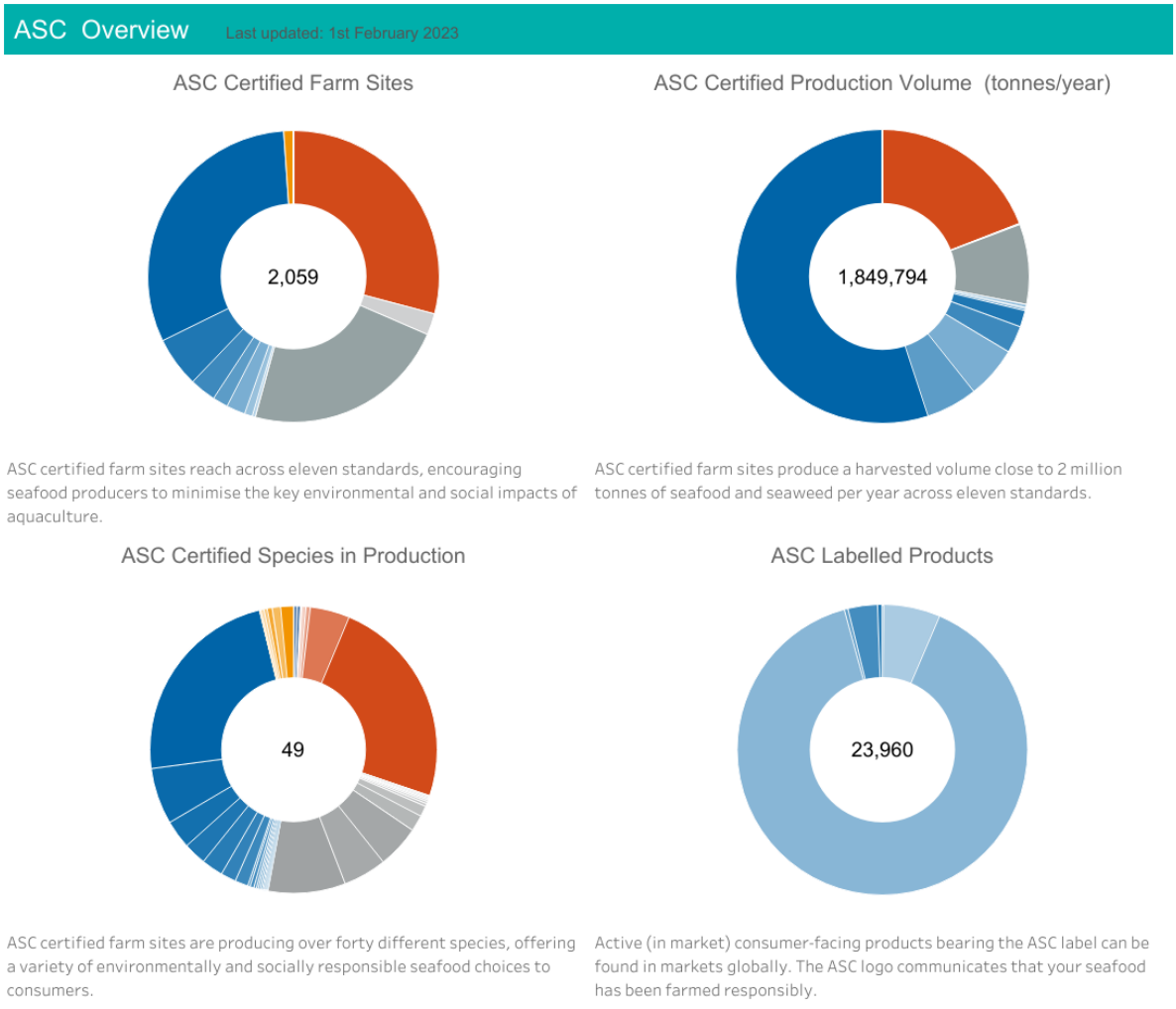
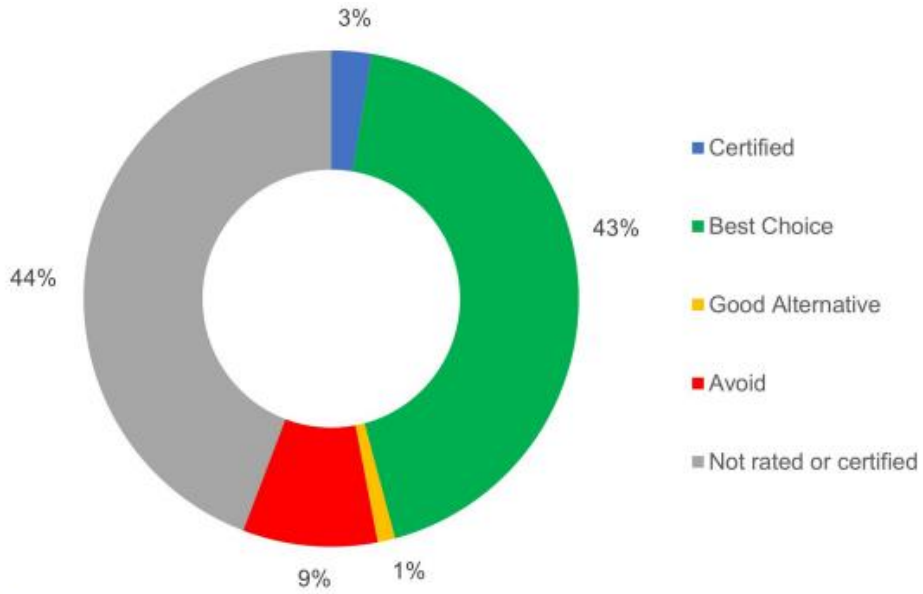


Figure 2 *Overview of ASC certified farms and products (ASC, 2023)*

Even though there is no single EU quality label for fish and seafood, there is merit to look out for labels. Some aquaculture products carry the EU organic logo, which means that strict production requirements were met related to animal welfare, water quality and sustainable feed. The most common labels on the market are MSC (Marine Stewardship Council) for wild fisheries and ASC (Aquaculture Stewardship Council) for farmed fish and seafood. Both are private initiatives with involvement from business and civil society. Currently, there is no comprehensive EU-recognised sustainability logo for fish products. The goal of the EU with the common fisheries policy is to ensure that all fish on the EU market meets the sustainability requirements. Some scientific or non-profit organisations also provide concrete online guides on which fish is more, or less, sustainable. The most developed example is probably the WWF Seafood Guide (European Union, n.d.).

Consumer guides such as the US Seafood Watch have rated a further 53% of global production. These ratings are involuntary and based on broad-scale assessments at the sector or regional level. Certified and rated production is skewed to major export species. Overall, 57% of salmon and trout, 17% of shrimp and prawns, 17% of pangasius and 11% of tilapia are certified, with higher levels of compliance observed in countries with a greater proportion of vertically integrated supply chains. Domestic demand for sustainable products in Asian seafood markets appears to be increasing, driven by food safety concerns, but considerable growth in domestic demand for sustainable seafood is needed to make aquaculture certification and rating systems effective globally (Naylor, 2020).



Extended Data Fig. 5 | Proportion of global aquaculture production that is certified or rated. Data from the Seafood Watch Sustainability of Global Seafood Data portal collating volumes certified from the Aquaculture Stewardship Council (ASC) (2020) and Global Aquaculture Alliance (GAA) Best Aquaculture Management (2020) and rated volumes from Seafood Watch (SFW) (2020). The ratings data represent the volume rates minus volumes certified based on internal assessments by SFW. The certification estimates may be overestimated as it was not possible to distinguish overlap between GAA- and ASC-certified volumes. A number of assumptions were made in these calculations as SFW does not recognize a number of species certified by ASC and GAA. These species include salmon, catfish, oysters, scallops, sturgeon, crawfish, and sea cucumber. In some cases, a surplus volume was created by adding GAA, ASC and SFW. This surplus volume was included in the 'avoid' category of SFW, under the assumption that cross-over between ratings and certification is more likely than certified and unrated production.

Figure 3 *Proportion of global alternative that is certified or rated (reproduced from Naylor, 2020)*

When talking about products with a low impact on the environment, e.g., organic, traditional, or having the European ecological label, their sales are a central element of the economy. Many variables and local cultural values influence consumer behaviour, including education and life requirements. Sustainable development involves education on consumption habits and low environmental-impact production. Tigan identified the role of education and remuneration in the choice of sustainable products. Different working hypotheses were formulated. The first hypothesis tested the existence of a direct correlation between the consumer's level of education and their opinion on consuming low-environmental-impact products, influencing the ability to make appropriate decisions. The second one

referred to the level of income and consumption behaviour. For 60% of the high-level graduate respondents, a product's source is significant in their choices. Over 70% of the responders who earn above the median income believe it is essential to consume organic products. The results obtained confirmed initial assumptions (Tigan,2021).

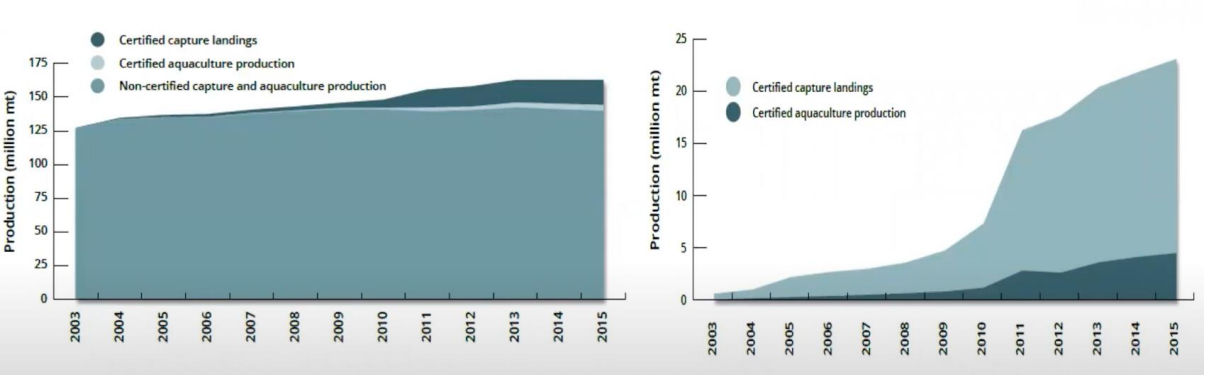


Figure 4 *Evolution of certified captures and aquaculture production (Potts, 2016)*

Aquaculture improvement projects (AIPs) have recently emerged as a new form of market-based and non-state governance in the aquaculture sector (Bottema, 2019). They embody multi-stakeholder efforts that leverage the influence of the private sector to drive improvements in aquaculture production and ensure that these changes endure through improved policy and management strategies (Sustainable Fisheries Partnership (SFP), 2019). Distinctive of AIPs is to operate within a specified area defined by the shared use of a waterbody to address the cumulative impacts and shared disease risks affecting aquaculture – an approach often referred to as zonal management or a landscape/jurisdictional level approach (FAO, 2022). Apart from a pathway to improved practices, some see AIPs as a steppingstone to aquaculture certification, such as the certification of the Aquaculture Stewardship Council (ASC), GLOBALG.A.P. and the Best Aquaculture Practices (BAP) of the Global Seafood Alliance (GSA) (CEA, 2016). While certification has become a widely accepted way to address sustainability issues within the aquaculture sector, only about 3% of global aquaculture production is certified (Naylor et al., 2021). The high costs of certification, poor literacy levels and administrative skills by producers and environmental production risks beyond the control of producers have been identified as key barriers to increased farmer compliance with sustainable aquaculture standards (Naylor et al., 2021). Small-scale aquaculture farmers, in particular, have been excluded from certification (FAO, 2022). As such, AIPs can potentially represent a more inclusive, 'developmental' way to work with small-scale farmers (Bush et al., 2019) and raise the environmental performance of multiple–not yet certified–farms and potentially increase access to markets that demand such practices (FAO, 2022). Yet, despite their ambition to address shared social and environmental impacts of aquaculture among farms (Bottema, 2019), it has been an ongoing challenge to incentivise farms to participate in AIPs – especially when processor-driven incentives are lacking or weak (Kruijssen, 2022 - Aquaculture Stewardship Council Foundation 2022).

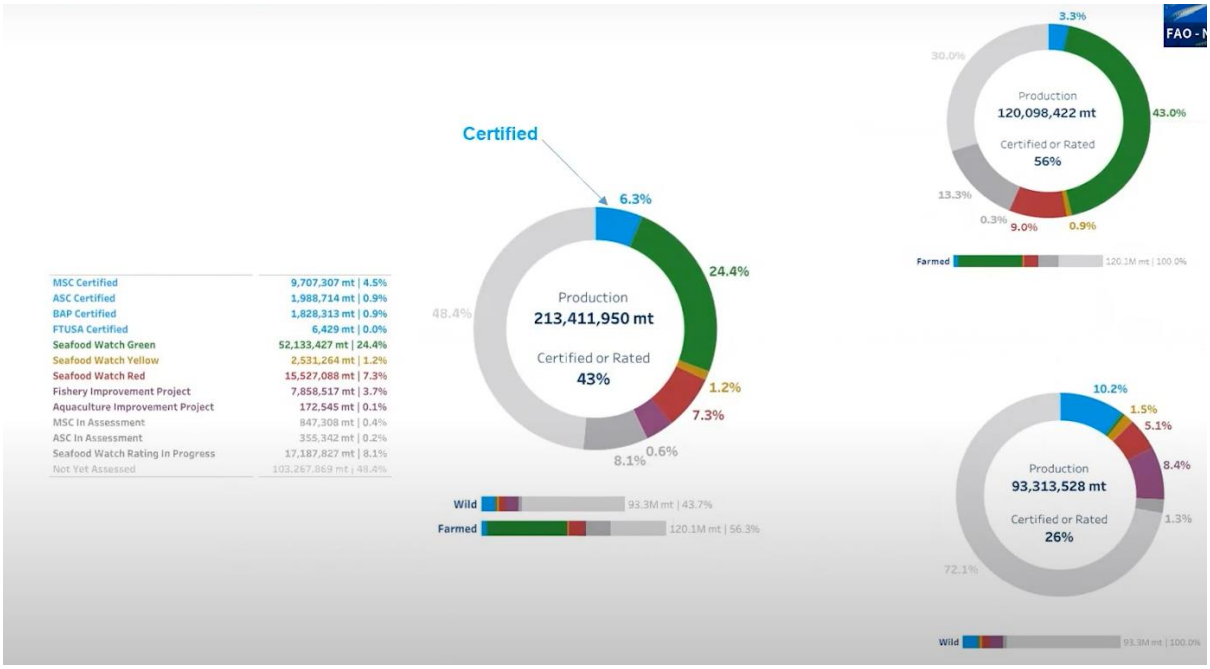


Figure 5 *Certified aquaculture and fishery products (FAO, 2020)*

5.2 Limitations, Constraints and Opportunities of existing certification standards

Intense fishing pressure has been depleting marine resources worldwide. At a time when almost a third of world stocks are overexploited, the demand for fish and seafood is growing both due to the increasing world population and to rising per capita consumption. A study for example evaluated 248 fish and seafood products sold by a major Italian retailer in terms of geographic origin, gear used, species conservation status, and stock status to gain information in view of the introduction of sustainable fishery products in Italy's outlets. Most species came from some of the most intensely exploited fishing grounds in the world, where they are usually caught by trawls. The results highlighted the importance of supplying seafood products coming from sustainable sources and fisheries through the adoption of eco-labels and certification schemes and stressed the urgency to promote more responsible fish and seafood consumption in Italy (Bonanomi, 2017).

Private standards and related certification schemes are becoming significant features of international fish trade and marketing. They have emerged in areas where there is a perception that public regulatory frameworks are not achieving the desired outcomes, such as sustainability and responsible fisheries management. Their use is also becoming more common in efforts to ensure food safety, quality and environmental sustainability in the growing aquaculture industry (FAO, 2011).

Multitude of standards existing in the market today. As seen from the literature, there is a wide range of certification schemes and standards available and the arguments for the development of these vary between the need for consumer legitimacy, market demands, quality improvement, etc (Nilsen, 2018)

Table 2 Comparison of major aquaculture certifications on some selected criteria (redrawn from Aquakulturinfo, 2022)

	asc		BIO	FRIEND OF THE SEA	GGN CERTIFIED FARMING	Naturland
Social responsibility policies	✓	✓	✗	✓	✓	✓
All types of aquaculture systems	✓	✓	✗	✓	✓	✗
Global environmental policies	✓	✓	✗	✓	✗	✗
Animal welfare	✓	✓	✓	✓	✓	✓
Concrete requirement for stocking density	✗	✓	✓	✗	✗	✓
GMO prohibited in feed	✗	✗	✓	✗	✗	✓

As far as aquaculture standards, it is interesting to understand if and how the various major standards for sustainable and responsible aquaculture have included fish welfare among their requirements (Cooke 2016).

Table 3 Comparison of major aquaculture certifications on fish welfare (Bray, 2018)

Certification standard	Inclusion of Fish welfare
Aquaculture Stewardship Council (ASC)	The focus of ASC standard is on the environmental and social impacts of aquaculture. Although animal welfare is not included explicitly, it is addressed indirectly in most of the individual ASC species standards.
Best Aquaculture Practices (BAP)	The BAP standard predominantly focuses on environmental responsibility. The animal welfare component is most comprehensively covered in the salmon standard, but it is less well covered in the general Finfish and Crustacean Farms standard, which is applicable to all other species.
Global G.A.P.	The Global G.A.P. aquaculture standard covers legal compliance, food safety, worker welfare, environmental care, ecological care and animal welfare.
EU Organic Aquaculture	The EU Organic Aquaculture regulation covers animal welfare issues to a greater extent compared to other sustainable and responsible certification standards.
Friend of the Sea (FOS)	Although animal welfare is not yet included explicitly in the FOS standards, it is addressed indirectly in most of the individual FOS species standards through water quality parameters, siting of production facilities, procedures for the treatment of sick fish, and transportation.

Certification standard	Inclusion of Fish welfare
RSPCA Assured (previously Freedom Food)	RSPCA Assured standards stipulate a high level of fish welfare. RSPCA Assured is recognized as the only scheme in Europe dedicated to farm animal welfare.

Customers' attention to sustainability labels in fishery and aquaculture products has been increasing in the last decades, and the industry has adapted to this growing interest by adopting fish ecolabels. However, there is a growing interest to widen the sustainability concept to include the social and ethical information of the fishery and aquaculture industry and to go further from the voluntary approach on the labelling of these aspects in fishery and aquaculture products (Peiro-Signes, 2022).

The EU Ecolabel is the official European Union voluntary label for environmental excellence. Established in 1992 and recognised across Europe and worldwide, the EU Ecolabel certifies products with a guaranteed, independently-verified low environmental impact. To be awarded the EU Ecolabel, goods and services should meet high environmental standards throughout their entire life cycle: from raw material extraction through production and distribution to disposal. The label also encourages companies to develop innovative products that are durable, easy to repair and recyclable. Through the EU Ecolabel, industry aim to offer true and reliable eco-friendly alternatives to conventional products, empowering consumers to make informed choices and play an active role in the green transition (DG Environment, n.d.).

The Commission carried out in 2011 a study on the feasibility of developing EU Ecolabel criteria for food and feed products (Sprong, 2011). Based on the findings, the Commission is currently not intending to develop EU Ecolabel criteria for food and feed products. The Commission could, however, revisit this issue in the future within in the context of the EU Ecolabel's potential role in the development of any wider EU food strategy, in particular in light of developments in methodologies and tools for measuring the environmental impact (including by, for example, environmental foot-printing) of food and feed products (DG Environment, n.d.).

The Common Market Organisation (CMO) Regulation (Regulation 1379/2013) is one of the pillars of the EU's common fisheries policy (CFP); it lays down general principles for managing the market in fishery and aquaculture products. Among other areas, the regulation covers common marketing standards, which define uniform characteristics for products placed on the EU market. It also sets the general objectives for the standards, while three Council regulations spell out the details of the marketing standards for specific species and products (DINU, 2021).

In February 2016, the Feasibility Report on options for an EU ecolabel scheme for fishery and aquaculture products was published. The study did not make a strong case for the introduction of a seafood EU Ecolabel and it is unlikely that the European Commission will pursue this policy option. Schebesta argues that sustainability information on seafood should not be framed through the EU Ecolabel debate. The more pressing issue concerns self-declared sustainability claims on seafood products. As a possible solution, Schebesta proposes to address these by re-invigorating the labelling rules on seafood information in the Regulation on the Common Organisation of the Markets in Fishery and Aquaculture Products (Schebesta, 2016).

In 2018, the European Commission began evaluating the marketing standards for fishery and aquaculture products, which had remained largely unchanged for more than 20 years. An initial evaluation pointed to the positive impact of the standards, but also to their limited coverage and lack of sustainability criteria. A fresh public consultation on the topic closed on 23 February 2021 (DINU, 2021). The results from the public consultation of the EU on "ecolabels for Fishery and Aquaculture Products" indicate that ecolabels should not only include environmental issues but also other types of

information, with social and ethical issues being the most relevant, followed by animal welfare issues, health and safety issues and food quality issues. The findings also show that consumers, producers and stakeholders who are more interventionist and support the fact that public bodies and governments should be involved in the control of eco-labelling are more accepting of including additional information apart from environmental issues. Synthetic indicators (SIs) have also been found to be mostly inelastic, except for the owners of ecolabels on social and ethical issues. The implications of the future implementation of the EU ecolabel for FAPs are discussed based on the findings. (Cantillo, 2020)

Eco-certification is widely considered a tool for reducing environmental impacts of aquaculture, but what are the likely environmental outcomes for the world's fastest growing animal-food production sector (Jonell, 2013)? The Norwegian aquaculture industry for example, faces pressure from stakeholders, the public, and government to ensure sustainable production. Sustainability is closely linked with solving key environmental challenges. Standards such as those created by the Aquaculture Stewardship Council (ASC) are universal and generally provide what is known as additionality to state regulation, such as more comprehensive requirements, with the goal of enhancing sustainability. Acquiring certification can be expensive, but it has been shown that the industry spends large amounts of time and resources to voluntarily become ASC certified. Olsen found several motivations for obtaining certification, even though it is no guarantee for financial gains like premium prices or better market access. Still, it may be just as valuable for industry actors to use certification to create room to manoeuvre so as to be prepared for future market claims, changes in regulations, and increased pressure for more sustainable production. Furthermore, certification is perceived as having the potential to improve producers' and retailers' reputation and standing both locally and globally. Certification and the use of labels can be tools in reputational management. By reducing complexity and uncertainty in communication, certification labelling can help consumers improve their product choices in terms of sustainability. Industry actors in this study express approval of certification and desire the potential reputational gain that comes from it; however, our findings suggest that this potential has not been fully realized. The industry experiences challenges in communicating with the local and global public and lacks influence on what is communicated to consumers through retailers. Therefore, it appears that those actually reaping the potential reputational gains of ASC certification are the non-governmental organizations behind the creation of the ASC and the retailers that demand ASC-certified salmon (Olsen, 2021).

Sustainability certification has become an increasingly important feature in aquaculture production, leading to a multitude of schemes with various criteria. However, the large number of schemes and the complexity of the standards creates confusion with respect to which sustainability objectives are targeted. As a result, what is meant by 'sustainability' is unclear. Osmundsen examined the operationalisation of the concept from the vantage point of the certifying authorities, who devise standards and grant or withhold certification of compliance. Osmundsen mapped the criteria of eight widely used certification schemes using the four domains of the Wheel of Sustainability, a reference model designed to encompass a comprehensive understanding of sustainability and showed that, overall, the sustainability certifications have an overwhelming focus on environmental and governance indicators, and only display scattered attempts at addressing cultural and economic issues. The strong focus on governance indicators is, to a large degree, due to their role in implementing and legitimising the environmental indicators. The strong bias implies that these certification schemes predominantly focus on the environmental domain and do not address sustainability as a whole, nor do they complement each other. Sustainability is by definition and by necessity a comprehensive concept, but if the cultural and economic issues are to be addressed in aquaculture, the scope of certification schemes must be expanded. The Wheel of Sustainability can serve as a valid lexicon and asset to guide such efforts (Osmundsen, 2020).

According to Jonell, the potential of eco-certification to reduce the negative environmental impacts of aquaculture at scale presently appears uncertain as: (a) certification schemes currently focus on

species predominantly consumed in the EU and US, with limited coverage of Asian markets; (b) the share of certified products in the market as currently projected is too low; (c) there is an inequitable and non-uniform applicability of certification across the sector; (d) mechanisms or incentives for improvement among the worst performers are lacking; and (e) there is incomplete coverage of environmental impacts, with biophysical sustainability and ecosystem perspectives generally lacking. (Jonell, 2013)

To contribute to the debate about sustainable seafood consumption, Penca considers the role of mandatory food labelling. Penca first flags the rise of a policy paradigm of shared responsibility and policy imperatives at various levels calling for increased integration of the citizen/consumer into public regimes, including in fisheries governance. Penca then explores the options available to citizen/consumers to engage in the fisheries regime in different stages of the value chain and evaluates their readiness to respond to the expectations. Mandatory food labelling of seafood is introduced as an under-unexplored governance tool, alongside the key enabling technological and policy trends. The rise of transparency and traceability, both as norms and a set of technological capabilities, is highlighted as an opportunity for implementation of mandatory seafood labelling. While recognizing equity challenges and various supplementary actions needed to ensure an effective behavioural and attitudinal shift toward more engaged governance (better education and enforcement and an enabling social setting), the article suggests to further explore mandatory labelling within the governance toolbox. It should be particularly relevant in the context of developed markets with global trade and political influence, and as means of fostering ocean literacy and transparent, participative and deliberative kind of governance (Penca, 2020).

Table 4 *SWOT analyse of existing aquaculture certification standards*

STRENGTHS	**WEAKNESSES**
Feature of international trade and marketing Industry spends large amounts of time and resources to voluntarily become certified	Multitude of standards existing in the market (confusing for the consumer) Focus on species predominantly consumed in the EU and US Mechanisms or incentives for improvement among the worst performers are lacking Incomplete coverage of environmental impacts, with biophysical sustainability and ecosystem perspectives generally lacking
OPPORTUNITIES	**THREATS**
Need to promote more responsible fish and seafood consumption Certification labelling can help consumers improve their product choices in terms of sustainability Consumer attention to ecolabels is increasing Potential to improve producers' and retailers' reputation	Inequitable and non-uniform applicability of certification across the sector Ecolabels include only environmental issues and no social & ethical issues, animal welfare issues, health and safety issues or food quality issues

5.3 Assessment of consumer attitudes toward common certification standards

Fisheries and aquaculture products are an important source of protein and a crucial component of a healthy diet. This is particularly true for the average person living in the EU, who consumes 24 kg (live weight) of fish or seafood per year (3.3 kg more than in the rest of the world). Consumption, however, varies greatly across the EU: from 6 kg per person per year in Czech Republic to 59.9 kg in Portugal. In Germany the Consumption of seafood products averaged 13,08 kg/inhabitant/year in 2019 (DG Mare, 2019).

Certification schemes have taken on the role of guiding consumers and the general public towards making sustainable choices. And while some of these standards have labels that are recognised by consumers, seldom do consumers comprehend what the standards require and how this relates to what sustainability is and should be (Osmundsen, 2020). Moreover, the abundance of certification schemes has resulted in concerns about consumers becoming confused with the number of labels and that certification schemes themselves may become a barrier to trade (Nilsen, 2018).

In order to assess the attitude of consumers, iFishIENCi implemented in December 2022 a test using the innovative eye-tracking technology with 14 test persons for five salmon packages in the sensory laboratory from ttz Bremerhaven in Bremerhaven, Germany.

Gender distribution		Age distribution		Consumption of fish	
2	12 0	20-35 years	100%	More than once a month	100%

Figure 6 *Sociodemographic data of test persons*

5.3.1 Methodology to assess Consumer attitude

TTZ decided to use eye tracking technology to assess the consumer attitude. Eye tracking technology can measure the eye movement activity. Eye tracking examines where and how a person is looking. Eye Tracking measures the gaze points generated by our eye relative to the head. For this purpose, tracker glasses were used to record the movement of the eyes. These movements were then analysed in order to make a statement about a person's gaze behaviour. Basically, people only perceive the information on which they direct their concentration through fixation, because people only take in information in the state of fixation (e.g. when reading or looking at a picture). Nowadays, Eye Tracking is being employed in almost all field including psychology, human computer interaction, marketers, designers, academics, medical, research and many more (Punde, 2017).

Figure 7 *Test person with adjusted eye tracking glasses*

Figure 8 *Five salmon packages presented to the test persons*

Following procedure was used for the experiment:

0. The iFishIENCi project was described to the test persons.
1. A first open question was asked to the test persons: “What information is important to you when you buy portioned salmon filets?”.
2. The test persons were instructed to wear and adjust the eye tracking glasses
3. Five different locally commercially available salmon packages were presented to the test persons one after the other and following question was asked: “Could you imagine buying the product shown? Please explain.”.
4. A second open question was asked to the test persons: “Do you look out for certain labels when purchasing fish products, especially salmon?”
5. A multiple-choice question was asked to the test persons: “Which of the labels shown do you know from fish products?”.
6. A third open question was asked to the test persons: “Which information on the packaging of fish products from aquaculture would be important to you?”
7. Test persons were presented.
8. An information sheet about the ASC label including the seven principles and criteria to minimize environmental and social impacts was presented to the test persons and following question was asked: “Do you have any statement or questions regarding aquaculture products with the ASC label?”

The selected products were portioned salmon filet, being one of the most consumed fish products in Germany. The five different salmon packages presented to the test persons have differences in term of design and information content. However, the focus was set on the presence of the different aquaculture certification labels:

- ASC- label
- Naturland, a German organic label
- GGN-label
- MSC label
- One package without any label

Various key parameters were measured using eye tracking and contributed to interpret the graphical result represented on the Heat maps presented below (Table 7).

Table 5 *Key parameters determined during the eye-tracking investigation and their related interpretation*

Key parameters[2]	**Interpretation of the parameter**
Total fixation time	The higher the total duration, the more information on the packaging sparked interest.
Average duration of fixation	Depending how long or short the duration of fixation is, a statement can be made about how interesting the information was at the individual fixation points.
Number of fixations	The higher the number of fixations, the more information is perceived.
Time to first fixation	The time to first fixation measures of how long the test person "searched" to find something of interest and focus its attention on it.

The test persons were asked to have a look at a picture of the fish package. The gaze behaviour of the test persons during their “viewing process” was examined. The analysis of gaze behaviour captures (1) Number of gaze fixations, (2) Duration of gaze fixations and (3) Gaze jumps between gaze fixations. In general, looking at the generated Heat maps (Table 7), the greener or lighter an area is coloured, the

[2] The Fixation is when the participant focuses on the object (field of sharp vision).

less frequently or for a shorter time it was observed by the participants. The darker or redder the area, the more frequently or longer the area was observed.

5.3.2 Results regarding Information influencing the buying behaviour

To the first **question about important information for buying behaviour**, eight consumers addressed a sustainability certification or label, but names of labels were only mentioned twice (ASC and MSC).

Table 6 *Answers of test persons to the question: "What information is important to you when you buy portioned salmon filets?"*

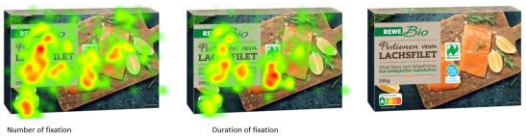
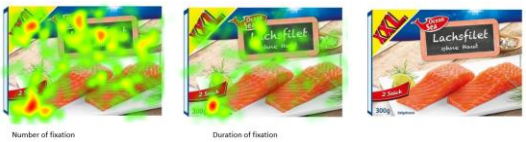
Attribute mentioned as important	Number of times the attribute was mentioned
portion size	11
origin	10
price	7
appearance	7
Shelf life	3
certification/ label	3
appealing packaging	2
nutritional information (for portion size)	2
preparation recommendation	2
quality	1
how produced	1
ASC label	1
Faire fishing: free of whale fishing/free of small fish	1
label wild catch	1
manufacturer	1
organic certification	1
sustainability	1
no artificial additives	1
certified sustainable aquaculture	1
WWF	1
MSC	1
ingredients	1
method of catch	1
colour of fish	1

5.3.3 Results regarding Information perceived from the packaging

Looking at the **heat maps** and the **metric data** of the five selected salmon packages using Eye-tracking measurments, differences were observed as described below.

Table 7 Heat maps of the five different product packages

Label	Heat Maps	Interpretation
ASC label	 Number of fixation Duration of fixation	**Number of fixations:** Most of the fixations fell on the ASC label, the portion size and the description of the filet such as „salmon filets", „skinless", „practical", „boneless" and „deep frozen". The Nutri Score and the trade „gut & günstig" were also able to draw a few looks.

Label	Heat Maps	Interpretation
		Duration of fixations The longest fixations were at the ASC label and the product description.
GGN Label		**Number of fixations:** Most of the fixations fell on the trade „Golden Seafood“ and the wording „certified aquaculture“. Here it seems that the fixations are high when the writing is not recognized immediately or some information is unclear to the consumers.
		Duration of fixations The longest fixations are at the wording „certified aquaculture“.
Naturland label		**Number of fixations:** Most of the fixations fell on the description of the salmon „Portion of salmon filet“, „skinless“, „deep frozen“. The „pro planet” information did draw attention, as well as the Nutri Score. Less attention was given to the Naturland label.
		Duration of fixations The longest fixations were at the „pro planet info“.
MSC label		**Number of fixations**: Most of the fixations fell on the MSC label and the symbol of the Olympic games. But the Nutri Score and description of the WWF logo were also able to draw a few looks.
		Duration of fixations: The longest fixations were at the MSC label.
no label		**Number of fixations:** Most of the fixations fell on the portion size. The „XXL“-package size information was also able to draw a few looks. Consumers fixed the entire package.
		Duration of fixations: The longest fixations are at the portion size.

The MSC label does show the highest numbers of fixations in the Areas of Interest, meaning the most information is perceived for this label. The purpose of including the MSC label in the study, although it is a label only for fisheries products and not for aquaculture products, was not to compare wild and farmed fish, but rather to assess the impact of awareness on the consumer attitude, since the MSC label is better known in Germany than any other fish label including the ASC label.

The average duration of visit is the highest for Naturland label, meaning this label was the most interesting to the test consumers.

Table 8 Metric Data of the five different product packages

Label	Average duration of fixation in AOI* in ms	Fixation count/ Number of fixations in AOI*	Average duration of Visit in ms
ASC	0,67	34,50	5,99
GGN	1	34,42	5,09
Naturland	0,68	36,17	**7,77**
MSC	0,72	**80,00**	6,28
without Label	0,59	41,42	4,06

*AOI: Area of interest, picture as it is presented to the consumers

5.3.4 Results regarding Aquaculture Labels as purchasing trigger

As shown in Figure 9, 70 to 79% of the test persons intend to buy the products with the ASC, GGN, Naturland or MSC label. Only 21% of the test persons would buy the product with no label. The **Purchase intention** is significantly higher for the four products with sustainability labels. The majority of the consumers do not accept the product without an ecolabel.

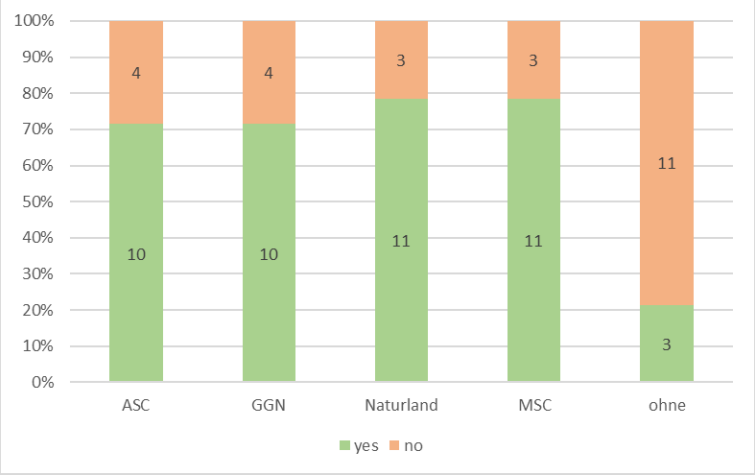


Figure 9 Answers to the question related to the purchase intention for the product shown: "Could you imagine buying the product shown? Yes/No."

Regarding the justification of the Purchase intention for the ASC label, the package is appealing for the consumer, the products design is positive, the Nutri-Score and portion size are satisfying. However, only one person addressed the ASC label directly. Test persons were not familiar with the ASC label which is clearly indicated by their comments on information they miss: "no sustainability label/ breeding information/ catch" (Table 9).

Table 9 Justification given by test persons for positive or negative purchase intention for the product with ASC label.

Positive purchase intention		Negative purchase intention	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
appealing design (blue, fjord, water i.e. freshness)	5	no information about catch	2
Nutri Score	4	I do not like the brand "gut & günstig" for fish and meat	2
portion size: appropriate for 2 persons	4	Nutri Score B	1

Positive purchase intention		Negative purchase intention	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
appealing	3	looks like low quality	1
label/ certification	2	no sustainability label	1
"boneless"	2	no information about breeding	1
"natural"	2	looks like perfect Norwegian world	1
The brand "gut & günstig" is good price and tasty	2	label looks not trustworthy	1
important information on print	2	colour of salmon not appealing	1
ASC label	**1**	*but*	
serving suggestion appealing	1	*ASC is positiv*	*1*
origin (flag only)	1	*"natural" is positiv*	*1*
product information short (boneless)	1		
confidence-inspiring seals shown	1		
"skinless"	1		
only if there is no other product with information towards ecology	1		

Regarding the justification of Purchase intention for the GGN label, test persons responded positively to the certification and to the portion size (visible due to transparent packaging). Consumers are not familiar with the GGN label, they responded to the wording on the package rather than to the label, e.g. „it seems to be sustainable “, label unknown, „certified aquaculture“ not concrete (Table 10).

Table 10 Justification given by test persons for positive or negative purchase intention for the product with GGN label.

Positive purchase intention		Negative purchase intention	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
certification/GGN	**4**	plastic package	2
appealing	4	not deep frozen, fish could be older	1
portion size	4	Label unknown and unclear, hopefully explanation on the back	1
transparent packaging	3	picture is very small, you see a lot of product	1
salmon looks fresh/ filet appealing	3	too expensive	1
origin	3	small amount	1
wording "responsible and trustworthy aquaculture" gives a good feeling	2	origin: Norway? Question: Why?	1
high quality	1	no Nutri Score	1
seems to be sustainable	1	wording " certified aquaculture" is not concrete	1
label " golden seafood" with the face of a fisherman creates proximity to the catch/ origin of product	1	no ingredients listed	1
low prize and label	1	no label that I usually buy	1
package size (500g) too big	1	*but*	
nutritional information per serving size	1	*appearance appealing*	*1*
colouring of product information	1		
but			
with skin	*1*		
packaging is overloaded, too much labels on small space	*1*		

Regarding the justification of the Purchase intention for the Naturland label (organic), Seven consumers liked the organic origin of the product, five named explicitly the Naturland label. Picture and serving suggestion are considered appealing. Some consumers expect a high price for the product and have concerns (Table 11).

Table 11 Justification given by test persons for positive or negative purchase intention for product with Naturland label.

Positive purchase intention		**Negative purchase intention**	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
organic	7	no certification like ASC	1
Naturland Label	**5**	what does organic aquaculture mean? Not clear	1
appealing	4	number of portions is missing	1
serving suggestion appealing	4	salmon takes a back seat (title/rosemary)	1
picture very appealing	4	serving suggestion: I do not like fresh fish next to other food	1
"without skin"	2	organic, too expensive	1
pro planet information	2	expect higher price because of organic, not for daily use, rather for special occasions, guests	1
good for the environment	1		
good for the animals	1		
packaging looks sustainable	1		
origin	1		
appealing colours	1		
information about portion size easy to find	1		
"organic aquaculture" i.e. good feeling	1		
sustainable	1		
natural conservation	1		
colouring appealing	1		
picture (wood/herbs -> sustainability)	1		
label suggests sustainability	1		
but			
origin: not visible on first sight	*1*		

Regarding the justification of the Purchase intention for the MSC label, test persons do know the MSC label and were positive towards the product. The package is appealing and additional product information such as natural, boneless and skinless is positive. WWF label and Nutri-Score pleased the test persons. No comments were given in relation to the origin of the product: wild catch versus aquaculture products (Table 12).

Table 12 Justification given by test consumers for positive or negative purchase intention for the product with MSC label.

Positive purchase intention		**Negative purchase intention**	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
MSC label	**6**	package not transparent	1
WWF Label	6	salmon on picture is not appealing	1
Nutri Score A	6	I do not like the brand "gut & günstig" for fish and meat	1
maritime presentation	3	colouring has cheap appearance	1
appealing colouring	3	*but*	
appealing packaging	2	*WWF label*	*2*
appealing serving suggestion	2	*MSC label*	*2*

Positive purchase intention		Negative purchase intention	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
brand "gut & günstig"	2	*Edeka is partner of Olympic sport club, sounds like healthy food*	*1*
fish seems to be fresh and natural	2	*Nutri score*	*1*
portion size	2	*"name " of product and origin "pacific salmon" not good*	*1*
sustainable	1		
FSC label	1		
"vacuum packed"	1		
"boneless"	1		
labels	1		
looks high quality	1		
Wild salmon is usually very tasty	1		
supermarket "Edeka" is sponsoring the Olympic games	1		
"natural"	1		
supermarket "Edeka" is good	1		
but			
looks pale	*1*		

Regarding the justification of the Purchase intention for the products with no ecolabel, only three consumers would buy the product. Consumers miss information and feel the package as not trustworthy and cheap due to the colouring and serving suggestion (Table 13).

Table 13 Justification given by test persons for positive or negative purchase intention for the product with no label.

Positive purchase intention		Negative purchase intention	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
I know that product, price is ok	1	hardly any information	6
XXL size	1	cheap appearance due to XXL	6
price is good	1	**no label/ certification**	**5**
"skinless"	1	no nutriscore	4
but		simply designed packaging	3
not appealing	*1*	no origin	2
cheap appearance due to XXL	*1*	colouring too bright	2
		no information about animal welfare	1
		no information about environment	1
		wording XXL not appealing	1
		cheap appearance due to colouring	1
		cheap appearance due to serving suggestion	1
		the picture looks a bit sad	1
		lime does not fit to fish, I prefer lemon	1
		salmon unnatural and artificial	1
		not high quality	1
		not trustworthy	1
		XXL I do not associate with 300g	1
		no information about boneless/ skinless	1
		portion too big	1
		no information about catch/ breeding	1
		but	

Positive purchase intention		Negative purchase intention	
Justification	**Number of occurrences**	**Justification**	**Number of occurrences**
		XXL is positive and portion size 300g	*1*
		could be used for pasta dishes or pies	*1*
		salmon on picture looks nice	*1*
		only if it is really cheap	*1*

In contrast to question 1 regarding important product information, the test persons addressed here different sustainability labels such as MSC, ASC, organic. Four consumers did not explicitly look at a sustainability label, but they claim to know about the higher quality of those products.

Table 14 Answers to the question: "Do you look out for certain labels when purchasing fish products, especially salmon?"

Label mentioned	Number of times label was mentioned
MSC label	4
ASC label	3
Organic label	2
label in general (sustainable)	2
Nutri Score	2
WWF label	2
Yes	1
number of labels, but not specific ones (WWF very trustworthy)	1
I prefer a product with label to a product without label (if the price is not too high)	1
certified sustainable aquaculture	1
ASC or MSC "feel better" than organic	1
I do not know the difference between ASC and MSC	1
no, but if there are any, I rather buy those products	1
No	1
no, but labels might indicate a better quality	1
no, but labels in general are good	1

5.3.5 Results regarding Awareness of aquaculture labels

The MSC label is known by 93% of the test persons, the ASC label is only known by 57% of test persons, which could explain the reserved answers against the ASC label in term of buying intention. The organic label of the EU is known by all the testers, the Naturland label is known by 43% of the German test persons (Table 15).

Table 15 Answers to the question: "Which of the labels shown do you know from fish products?"

Labels for fish products	Number of times label was mentioned
bio (organic EU)	14 (100%)
MSC	13 (93%)
Nutri Score	13 (93%)
WWF	12 (86%)
ASC	8 (57%)
Naturland (organic)	6 (43%)
GGN	3 (21%)
BAP	1 (7%)
Friend of the sea	0 (0%)

5.3.6 Results regarding Information needed on packaging of aquaculture fish products

Consumers are interested in social and ecologic responsibility. 12 test persons cared for ecological effects such as biodiversity and the quality of water resources. 11 test persons were interested in animal welfare and the responsible use of antibiotics and chemicals. The social responsibility is only addressed by one third of the consumers (Table 16).

Table 16 Answers to the question: "Which information on packaging of fish products from aquaculture would be important to you?"

Important Information needed on packaging of aquaculture products	Number of times this information was mentioned as important
The conservation of natural habitats, local biodiversity and ecosystem by aquaculture producers	12
The conservation of water resources and quality by aquaculture producers	12
Improved fish health and controlled and responsible use of antibiotics and chemicals by aquaculture producers	11
The legal compliance of aquaculture producers with national and local laws and regulations	8
The conservation of wild population diversity by aquaculture producers	5
The responsible use of feed and other resources by aquaculture producers	5
A social responsibility of aquaculture producers towards their workers and the local community	4

5.3.7 Results of the Analysis of the ASC label

Consumers see greater value in purchasing products with the ASC label, but only half of the test persons fully agreed that it is important that a product comes from sustainable production. 57% of test persons did not agree to pay significantly more money for a fish product with the ASC label compared to a fish product without label. All of the consumers agree about their ability to influence the developments towards sustainable aquaculture through their shopping behaviour (Table 17).

Table 17 Answer to the question: "Regarding aquaculture products with ASC label, please answer the following statements:"

Statements about products labelled with the ASC label	Fully agree	Somehow agree	Somehow disagree	do not agree
Aquaculture products that carry the ASC label are of great value to me	7	6	1	0
The ASC quality label is trustworthy	8	6	0	0
I would rather by a fish product with the ASC quality label than without	11	2	1	0
I would pay somewhat more money for a fish product with the ASC quality label than without	4	6	4	0
I would pay significantly more money for a fish product with the ASC quality label than without	1	5	4	4
For me it is important that a product comes from sustainable aquaculture	7	4	3	0
I do believe in sustainable aquaculture	5	7	2	0
Through my purchasing behaviour I can influence developments towards sustainable aquaculture	10	3	1	0

5.3.8 Preliminary conclusions regarding Consumer attitude toward aquaculture certification schemes

The consumers in this study show a higher buying intention for products with sustainability labels than for the product without a label. As shown both in the eye-tracking analysis (heat maps) and the answers to the questionnaire, the focus of the consumers was not driven primarily by the presence of a label, but rather by appealing design, portions size, Nutri-Score, the WWF label or other information they are familiar with. Consumers do know the MSC Label, as a label for sustainable fishery, but many are still unaware of the ASC label as a label for sustainable aquaculture. 93% of test persons knew the MSC label and recognized it as an established seal of quality. This might simply be linked with the fact that around 2,500 products are currently ASC labelled versus 20,000 MSC certified products. Moreover, the products belong to different product categories. The little knowledge of the ASC label leads the consumers to not- buying the ASC product. Only one person out of the 14 test persons mentioned the ASC label directly as a reason for buying the product.

Consumers are influenced by the supermarket and the brands they know and trust. Consumers are not familiar with the GGN label, they rather respond to the wording on the package rather than to the label. In case of the Naturland label (organic label) the consumers did fix the „Planet Pro Info“ and the Nutri-Score more often than the label Naturland (which was only known by six of the test persons). Only three consumers would buy the fish product without a label. Consumers miss information and feel the package as not trustworthy and cheap.

The first question addressed information which is important to the consumer when buying salmon filets. Only one person named the ASC label, and one person named the MSC label, showing that the importance of sustainability labels/certifications and the conscious purchase of these is rather low. Along the testh, the labels were presented and explained to the consumers and the consumers worked with them. This and also the information about the ASC label and the underlying principles promoted the importance of sustainability towards the end of the study.

Consumers are interested in social and ecologic responsibility. Consumers do care for ecological effects such as biodiversity and the quality of water resources. Further, consumers are interested in animal welfare and the responsible use of antibiotics and chemicals. All test persons agreed about their ability to influence the developments towards sustainable aquaculture through their shopping behaviour. Most of the consumers who consider environmental, social, and ethical aspects when buying Fish and aquaculture products also think that this information should be labelled (Peiro-Signes, 2022). According to Peiro-Signes, young, educated, and environmentally aware consumers in high-income countries are more likely to request this information in the fishery and aquaculture products label (Peiro-Signes, 2022). Consumers see greater value in purchasing products with the ASC label or other sustainability labels, but still, it is no priority for them when buying a fish product. They consider the ASC label as trustworthy, but do not set their focus on it when actually buying a product. According to Yi, consumer attitude, subjective norm, and perceived behavioural control are significant factors that affect behavioural intention to purchase ASC-labelled products (Yi, 2019). Such results are consistent with previous studies on food selection (Al-Swidi, 2014; Honkanen, 2006; Alam, 2011; Tarkiainen, 2005; Yazdanpanah, 2015).

The study outcomes can be beneficial for policymakers to design future public policies regarding Fish and Aquaculture Products labelling, as well as to be taken into consideration in the marketing policies of fishery and aquaculture producers and retailers (Peiro-Signes, 2022).

Note: It is important to underline the caveat to this iFishIENCi study of consumer attitude towards aquaculture certification labels. The test group used for the study was limited in size, nationality, age range and sex balance and no information about for education or income were asked. Therefore, although the preliminary conclusions talk about Consumers as a whole, further research is needed to confirm the results.

6 Trade agreements for EU aquaculture products

6.1 Trade of EU aquaculture products

The EU is the leading trader of fisheries and aquaculture products in the world in terms of value. EU trade (i.e. imports and exports) has increased over the past few years, reaching €31.2 billion in 2020 (DG Mare, 2021).

Table 18 Value of EU-27 imports from the main suppliers - Trade of fisheries and aquaculture products between EU Member States and non-EU countries (Eumofa elaboration of Eurostat data, 2020)

Main suppliers	Value (in thousand EUR)	Percentage of total
Norway	6 410 680	26,5%
United Kingdom	1 739 687	7,2%
China	1 519 346	6,3%
Morocco	1 296 956	5,4%
Ecuador	1 240 983	5,1%
Iceland	1 017 935	4,2%

Table 19 Value of EU-27 exports from the main customers - Trade of fisheries and aquaculture products between EU Member States and non-EU countries (Eumofa elaboration of Eurostat data, 2020)

Main customers	Value (in thousand EUR)	Percentage of total
United Kingdom	1 683 325,82	24,2%
United States	644 177,67	9,3%
China	577 743,42	8,3%
Norway	560 139,51	8,0%
Switzerland	499 387,06	7,2%

The EU is a net importer of fisheries and aquaculture products, mostly frozen, fresh and chilled.

Table 20 Main Member States importing from non-EU countries - Trade of fisheries and aquaculture products between EU Member States and non-EU countries (Eumofa elaboration of Eurostat data, 2020)

Main Member States importing from non-EU countries	Value (in thousand EUR)	Percentage of total
Spain	4 267 911	17,6%
Sweden	4 047 063	16,7%
Denmark	2 856 808	11,8%
Netherlands	2 843 950	11,7%
France	2 559 115	10,6%

In 2020 exports to non-EU countries increased to €6.96 billion (DG Mare, 2021).

Table 21 Main Member States exporting from non-EU countries - Trade of fisheries and aquaculture products between EU Member States and non-EU countries (Eumofa elaboration of Eurostat data, 2020)

Main Member States exporting from non-EU countries	Value (in thousand EUR)	Percentage of total
Denmark	1 451 647	20,8%
Netherlands	1 193 059	17,1%
Spain	1 041 232	15,0%

Trade between the Member States is very significant, totalling €23.25 billion in 2020. The main exporters to other Member States are the Netherlands, Sweden, Spain and Denmark. The main importers are Germany, France, Italy, and Spain (DG Mare, 2021).

6.2 Existing trade agreements

The EU collaborates with foreign partners to manage fish resources over which it does not have sole control. International agreements govern the management of fish populations shared by the EU and non-EU nations (European Council, 2021).

International fisheries agreements are classified into two types:

- Bilateral agreements with countries outside than the EU
- Multilateral agreements inside international organizations

There are two types of fishing agreement between the EU and non-EU countries (European Council, 2021):

- Northern agreements with the following countries Norway, Faroe Islands, United Kingdom. This agreement entails the cooperative management of common stocks in the North Sea and the North East Atlantic.
- Sustainable fisheries partnership agreements (SEPA) which entails the EU providing financial and technical assistance in exchange for fishing rights, often with southern partner nations. The SEPA can be further classified into two kinds of agreements (European Commission, 2020):
  - Tuna agreements - enable EU vessels to hunt migratory tuna populations as they travel along Africa's coasts and into the Indian Ocean. In this regard, currently, the EU has 13 conventions in place with the following countries: Cabo Verde, Ivory Coast, Sao Tomé and Principe, Gabon, Cook Islands, Seychelles, Mauritius, Senegal, and The Gambia have all signed tuna treaties (with a hake component for the last two)
  - Mixed agreements - provide access to a variety of fish populations in the partner country's exclusive economic zone. Accordingly, Greenland, Morocco, Mauritania, and Guinea-Bissau have all signed mixed treaties with the EU

Moreover, the EU also has seven "dormant" agreements with the following countries: Equatorial Guinea, Kiribati, Liberia, Madagascar, Micronesia, Mozambique, and the Solomon Islands. "Dormant agreements" refer to nations that have a fisheries collaboration agreement in effect but no implementing protocol in place. As a result, EU vessels are not permitted to fish in seas subject to the regime of dormant agreements (European Commission, 2020).

In addition to bilateral agreements, the EU's fisheries external ties include international cooperation. The EU is a contractual party to a number of regional fisheries management organizations that manage fisheries in certain parts of the world (European Council, 2021).

Table 22 List of fisheries agreements (European Commission, 2020).

Country	Expiry date	type	Total EU contribution per year	Sectorial support per year
Cabo Verde	19.05.2024	Tuna	€750 000	€350,000
Cook Islands	13.12.2024	Tuna	€700,000	€350,000
Cote d'Ivoire	31.7.2024	Tuna	€682,000	€352,000 (2yrs) - €407,000
Gabon	28.06.2026	Tuna	€2,600,000	€1,000,000
Greenland	21.04.2025	Mixed	€13,590,754	€2,931,000
Guinea-Bissau	14.06.2024	Mixed	€15,600,000	€4,000,000
Mauritania	15.11.2026	Mixed	€57,500,000 (access only)	€3,300,000 (for the entire period)
Mauritius	7.12.2021	Tuna	€575,000	€220,000
Morocco	17.07.2023	Mixed	€208 million over a 4 year period	€17.9 - €20.5 million
São Tomé and Principe	18.12.2024	Tuna	€840,000	€440,000
Senegal	17.11.2024	Tuna + hake	€1,700,000	€900,000
Seychelles	23.02.2026	Tuna	€5,300,000	€2,800,000
The Gambia	30.07.2025	Tuna + hake	€550,000	€275,000

6.3 World Trade Organization

International trade has been accelerated by the creation of the World Trade Organization (WTO), and also within the context of multilateral, regional and bilateral trade agreements. These agreements, which establish preferential terms of trade between two or more trading partners, have become increasingly important in facilitating international trade by reducing or removing barriers including tariffs and technical barriers to trade (TBT). In particular, interregional trade has been enabled by regional trade agreements (RTAs), which have been increasing since the 1990s (FAO, 2022).

RTAs such as the European Union Customs Union, the North American Free Trade Agreement, the Association of Southeast Asian Nations, the Southern African Development Community and the Southern Common Market have been key drivers of global trade expansion in recent decades, and trade in fisheries and aquaculture products has benefited as part of this broader trend. RTAs often extend beyond trade terms and may also include provisions covering fisheries management and traceability, which can strengthen institutional oversight of shared resources and contribute to sustainable fisheries management. (FAO, 2022).

Tariff policies have historically been used by governments to generate income from trade, to protect domestic industries from international competition and as punitive measures taken against other nations in the context of trade disputes. Aquatic products are classified as industrial goods by the WTO, meaning they are grouped under non-agricultural market access negotiations. Under the WTO principle of most-favoured nation, applied tariffs for fisheries and aquaculture products range from 0 percent to 30 percent, with an average of 14 percent. Bound tariffs, which are effectively the maximum tariff in a given category under WTO rules, range from 0 percent to 60 percent, with an average of 35 percent. These figures point to the generally low level of applied tariffs on imports of fisheries and aquaculture products, despite some reintroduced tariffs and some concern over tariff escalation in the case of processed and value-added products. The large high-income importing countries, such as the European Union, the United States of America and Japan, apply reduced or zero

tariffs on the majority of imports from countries qualifying for such treatment under the Generalized System of Preferences, which contributed to the rapid development of aquatic product exports in economically emerging countries. In contrast, many emerging countries still apply relatively high tariffs for fisheries and aquaculture products that can reflect fiscal policies or protective measures. Tariff escalation continues to be a serious issue for many countries and products, particularly in accessing some high-income markets and expanding regional trade (FAO, 2022).

Technical barriers to trade (TBT) are non-tariff barriers that can include any regulations, requirements or standards that impose an additional burden on trading parties. These may include both mandatory requirements or regulations and voluntary standards. Product standards, sanitary and phytosanitary measures, procedures for import licensing and rules of origin, and labelling requirements are all examples of TBTs applied to aquatic products. Traders of perishable aquatic products are also affected by customs and clearance procedures. The WTO TBT Agreement recognizes that these requirements, standards and procedures are necessary to protect human health, ensure product quality and safeguard the environment, but they should be non-discriminatory. In practice, TBTs can effectively block market access for countries lacking the necessary capacity, infrastructure, technology and technical knowledge to address them. TBTs are an important topic for fisheries and aquaculture products. In particular, the United Nations Conference on Trade and Development estimates there are on average 2.5 times more technical measures applied to fisheries and aquaculture products than to manufactured products (FAO, 2022).

Traceability and catch documentation are core components of compliance with food safety regulations and controls to combat illegal, unreported and unregulated fishing (IUU fishing). Ecolabels and certification schemes communicating to buyers and consumers that aquatic products are sourced from well-managed fisheries can impose additional burdens on exporters. Thus, it has become increasingly important to ensure that TBTs applied to aquatic products strike a fair balance between allowing market access and protecting both consumers and the resource. International cooperation in the design and assessment of TBTs, and subsequent efforts to facilitate compliance by streamlining procedures and harmonizing standards, are important prerequisites for achieving this balance. The FAO Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing also contributes to protect both consumers and the resource, by allowing countries to impose trade restrictions at the port of entry in order to avoid the unloading of products originating from IUU fishing. The WTO Trade Facilitation Agreement that entered into force in February 2017 is expected to help overcome some of the challenges associated with customs procedures and expedite the movement, release and clearance of goods across borders (FAO, 2022).

Growth in trade of aquatic products in the long term is driven by trade policy shifts in addition to economic and demographic fundamentals, but over shorter time horizons, trade dynamics are dependent on a number of different factors. First, as for trade in general, trade in aquatic products is quite sensitive to economic conditions. Levels of aquatic food consumption correlate positively with income, meaning that periods of economic recession typically led to a contraction in trade of aquatic products. Other important factors include geopolitical shifts, currency trends, logistical costs and delays, and major shocks to supply such as disease outbreaks or climatic events (FAO, 2022).

For example, in recent years, two significant developments have affected aquatic product trade. First, in 2018 new tariff regimes between the United States of America and China, two of the world's largest trading partners, affected several heavily traded fisheries and aquaculture products, including lobster and tilapia. While new tariff regimes represent obstacles for existing suppliers, the new environment creates opportunities for alternative suppliers. An example is how the additional costs borne by China's tilapia sector, traditionally the major supplier to the top market of the United States of America, have translated into a competitive advantage for the emerging Latin American tilapia export industry (FAO, 2022).

Another change affecting the dynamics of trade in fisheries and aquaculture products is the exit of the United Kingdom from the European Union. This transition has resulted in the introduction of new procedures for customs checks, food safety inspections and documentation, and product labelling. The additional administrative burden led to severe logistical bottlenecks for aquatic product traders of the United Kingdom in early 2021, disproportionally affecting small and medium businesses. Although progress has been made in streamlining these processes, uncertainties remain regarding the specifics of the framework under which trade will be conducted in the future (FAO, 2022).

The COVID-19 pandemic has brought an array of challenges for international trade of aquatic products. The pandemic caused an estimated 7.0 percent drop in the value of global aquatic product exports, falling to USD 151 billion in 2020. In 2020, traded volumes fell by an estimated 10.1 percent, with declines in trade recorded across all regions. As fishing and aquaculture resumed and international markets opened, 2021 recorded a strong recovery in trade. In 2021, the total value of global exports of aquatic products went up 12 percent compared with 2020. Meanwhile, growth in traded volumes was more limited, due to the impact of conservative planning on aquaculture supply and continued logistical challenges (FAO, 2022).

6.4 Import conditions for aquaculture products focussing on food safety

Any product entering the European market must meet an increasing number of conditions. Meeting all standards begins in the exporting country. The exporting country's government needs to enforce these regulations through a responsible authority.

Your goods must be properly labelled, have evidence of origin as well as all applicable health certificates.

In the following part, we will provide an outline of the most significant conditions to consider.

6.4.1 Country and processing facilities need to be accredited

Before exporting to Europe, the exporting country must be accredited by European authorities. As a result, your government must have rules and capabilities in place to ensure that the fish and seafood produced in the exporting country fulfil European food safety standards and do not endanger European consumers (CBI, 2021).

A "competent authority" nominated by European authorities will be in charge of creating and implementing legislation that satisfy European standards. The European Union concludes an agreement with this department, giving them responsibility for the mandatory control measures before export (CBI, 2021).

This authority is in charge of conducting official controls along the entire manufacturing chain is required in exporting nations. To carry out effective inspection and provide reliable public health and animal health attestations in the health certificate to accompany fishing goods that are headed for the EU (European Commission).

The application of hazard analysis and critical control points (HACCP) standards, as well as the capacity to track your products back to registered fishing vessels or aquaculture farms, are key needs for you as an exporter (CBI, 2021).

In addition, the responsible authority must ensure that the appropriate hygiene and public health criteria are satisfied. EU hygiene regulation includes precise criteria for vessel structure, landing sites, processing establishments, operating operations, freezing, and storage. These regulations are intended to ensure that food is produced safely and that product contamination during processing is avoided (European Commission).

6.4.2 Maximum residual levels are not to be exceeded

To ensure compliance with EU rules, aquaculture goods must have a residue monitoring strategy in place that includes testing for veterinary medication, pesticide, heavy metal, and contaminant residues. The plan (together with the results of the previous year's monitoring) must be presented to the European Commission for approval on a yearly basis.

Maximum residue levels (MRL) for fish and seafood are strictly regulated in the European Union. These thresholds are specified in many regulatory regulations. Depending on the species and source (fisheries or aquaculture), you must provide a health certificate generated by an approved laboratory with each shipment to demonstrate that your goods do not exceed the appropriate maximum residue levels (CBI, 2021).

If you want to export to Europe, you must have mechanisms in place not only at your processing facilities, but also upstream in your supply chain. You must guarantee that the raw materials you acquire fulfil European requirements and are not polluted before entering your facility. You must ensure that your suppliers handle items with care by keeping a proper cold chain and sanitary storage facilities. If a container is denied when it arrives at a European port, you will be held accountable.

6.4.3 Labelling regulations must be strictly followed

Labelling requirements in Europe are straightforward. There may be minor changes in labelling between unprocessed and processed fish and seafood, as well as between wild and domesticated fish and shellfish. In general, information such as The name of the product, including the commercial and scientific names, list of ingredients, origin, production method, net weight, the European Union approval number, and others must be labelled on seafood items, with pre-packaged products having extra information requirements (CBI, 2021).

6.4.4 Proof that fish and seafood come from legal sources

The European Union wants you to show that the exported fish and seafood do not come from illegal, unreported, or unregulated fisheries. Your wild fish items must be accompanied by a catch certificate certified by your competent authorities. The capture certificate must include all of the information stated in Annex II of the European IUU Act. A catch certificate may only be obtained for fish and seafood acquired from vessels that have been registered and licensed by your country's regulatory authorities. (CBI, 2021)

6.4.5 Inspection of fishery products at the EU border

Non-EU imports of fisheries products must enter the EU through an authorized Border Inspection Post under the authority of an official veterinarian in the EU Member State in issue. Each consignment is subjected to a thorough paperwork review, identification verification, and, if necessary, physical inspection. The frequency of physical checks is determined by the product's risk profile as well as the outcomes of prior tests. Consignments discovered to be in violation of EU rules must be destroyed or, under certain cases, re-dispatched within 60 days (European Commission).

7 iFishIENCi Guidance aligned with current legislation

7.1 Policy Recommendations for a More Circular Aquaculture

As stated in the Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030, "the EU aquaculture sector, like other sectors of the EU economy, has 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". Traditional aquaculture technologies, like polyculture pond production of fish, as well as new production methods, like Integrated Multi Trophic Aquaculture (IMTA) approach and Recirculating Aquaculture Systems (RAS), already integrate principles of circular economy. The improvement of these technologies and the increased circularity in predominant aquaculture production systems (open-cages), in which waste collection is challenging, might increase the compatibility between sustainable aquaculture and environmental protection. Considering the need to discuss and identify ways forward in which circularity can be developed within production in a practical, efficient and economically sound way, the H2020 iFishIENCi project organised the "Aquaculture Going Circular" event in November 2021. The outcome of this event was to share co-created policy recommendations to ensure regulators, officials, and the European Commission can support actions to make aquaculture more circular.

The iFishIENCi policy recommendations For a More Circular Aquaculture[3] aim to help the EU aquaculture sector to apply a circular-economy approach in order to participate in the green transition set by the European Green Deal:

- Define circularity in aquaculture
- Define a common methodology to measure circularity in aquaculture
- Increase circularity in aquaculture production by increasing circularity in feed production and by valorising aquaculture wastes (effluent and sludge)
- Encourage sectorial and cross-sectorial co-governance

The iFishIENCi Policy Recommendations For a More Circular Aquaculture have been endorsed by numerous Projects, organisations and persons: H2020 AquaIMPACT, H2020 AquaVitae, H2020 ASTRAL, H2020 FutureEUAqua, H2020 GAIN, H2020 iFishIENCi, H2020 IMPAQT, H2020 NewTechAqua, Evagoras Isaias, IsaiaSEA.com; Mohammad Nadjib, INVENDO; Abderrahim Ouaach, Polydisciplinary Faculty of Larache, Abdelmalek Essaadi University; Tamara Rubilar, CESIMAR-CCT CENPATCONICET; Koukaras Konstantinos; Benoît Wuatelet, Blue Economy Team leader – SwitchMed, Department of Environment, United Nations Industrial Development Organization; Anwarullah Khan; Luis Poersch, Federal University of Rio Grande, Institute of Oceanography.

The iFishIENCi Policy Recommendations For a More Circular Aquaculture were sent to the European Commission, DG MARE, Director, A Maritime Policy and Blue Economy with copies to

- DG MARE. A1 - Maritime Innovation, Marine Knowledge and Investment
- DG MARE. A2 - Blue Economy Sectors, Aquaculture and Maritime Spatial Planning
- DG MARE. A3 - Sea basin strategies, Maritime Regional Cooperation and Maritime Security
- DG JRC.D2 - Water and Marine Resources
- DG RTD. B4 - Healthy Oceans & Seas
- DG RTD. B4 - Healthy Oceans & Seas
- DG ENV.B1 – Circular Economy, Sustainable Production & Consumption
- DG ENV.C2 - Marine Environment & Clean Water Services
- DG AGRI.B4 – Organics

[3] https://zenodo.org/record/6641752#.Y6MHvXbMKUk

7.2 Waste2Value: Guidelines for potential valorization routes from aquaculture waste streams

Since 2000, the use of wild fish inputs in the production of farm raised fish outputs, also known as the Fish In: Fish Out (FI:FO) ratio, has been a primary concern of the sustainability dialogue surrounding aquaculture production. Far less attention has been placed on the sustainability of downstream processing, including how by-products are managed. For example, there is considerable potential to increase the sustainability of the Scottish Atlantic salmon industry through maximising human edible yield by strategically managing by-products. Supporting the movement towards the full utilisation of by-products, Stevens emphases the need to maximise their use in human consumption and select animal feeds, highlighting the economic, food security, and environmental benefits of doing so. Through exploratory scenarios, Scotland could increase food production from fish farming by over 60%, increase by-product revenue by 803%, and increase the industry bottom-line by over 5%, all without having to put any new cages in the water, or use any more marine resources As the aquaculture industry moves into a new era of production and processing, where a diverse range of products can be produced from a single species, sustainability will be sought throughout the value chain (Stevens, 2018). This goes with traditional fisheries as well as is clearly demonstrated by the value increase of the Icelandic cod quota, even as volumes are reduced. The Icelandic cod management and introduction of the 100% utilisation strategy is clearly showing the potential that comes with such strategy set in action (Sigfusson, 2014).

iFishIENCi therefore is developing guidelines for potential valorisation routes from aquaculture waste streams to be published in 2023[4]. Potential applications indicated are based on chemical characterisation analysed in iFishIENCi (in Task1.5) and bibliography research for 13 type of waste identified in iFishIENCi from RAS and land-based flow-through system with various farmed species (rainbow trout, barramundi and African catfish) as well as different feed type (conventional, new iFishIENCi feed with algae or yeast). The idea of the guidelines is to provide for each type of waste identified, information on following aspects:

- Characteristics of this type of aquaculture waste: Dry matter, Ash, Total Kjeldahl Nitrogen, TKN-N, Ammonium, Nitrite, nitrate, Total Nitrogen, Total Phosphorus, Total Organic Carbon, Phosphate, Chlorine, sulphate, Lipids, Microorganisms (Salmonella, E.coli, Total Aerobic count, Total Fungi and Yeast count, Enterobacteriaceae), Persistent Organic Pollutants, Heavy metals, sodium, potassium
- Valorisation routes as feed as tested in iFishIENCi: yeast production for feed, other microorganisms for feed, nutrients recovery for algae/yeast production for feed
- Other potential valorisation routes such as IMTA/Aquaponics, Biogas, platform chemicals, fertilizer/composting
- Identification of Potential End-users
- Summary of Regulatory framework for this type of aquaculture waste and valorisation route
- Further research needed for this type of aquaculture waste

Experimental work has been conducted in iFishIENCi only for Feed application. Other potential applications will be theoretically based on the characterisation and literature.

[4] https://zenodo.org/communities/ifishienci/?page=1&size=20

7.3 Actionable solutions to compliance barriers for small scale farmers

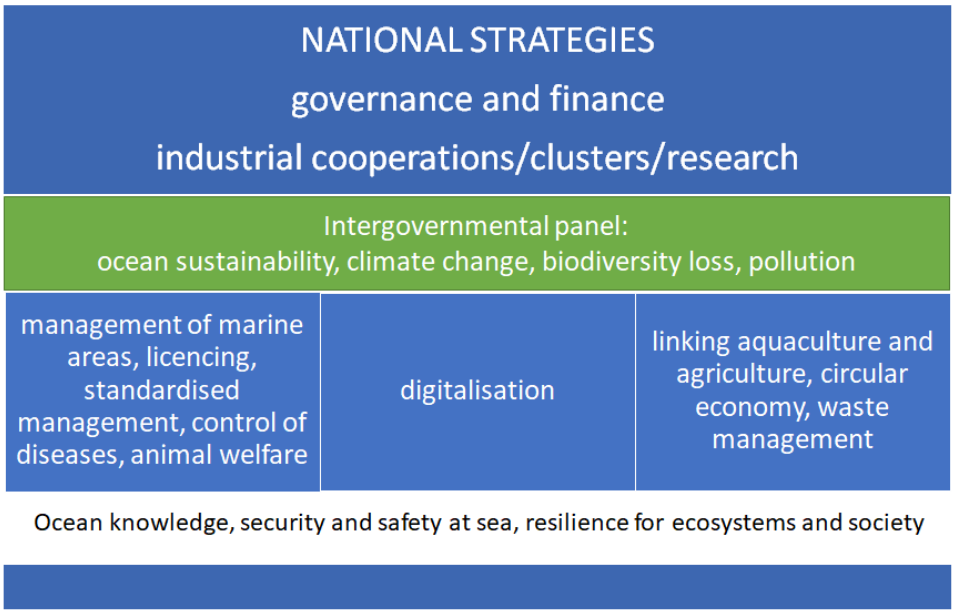
Most aquaculture companies are organized as smaller companies. This is particularly true for developing countries, but there is also a vast majority of smaller aquaculture companies in the EU. Improving the economic conditions for small aquaculture companies is a global goal. Their integration into local and national food systems determines their importance in terms of food production and availability. The more stable the production and supply to the markets, the more profitable these businesses can be. Small farms also often play a key role in the rural world, not only in the EU, but especially globally. With the help of well-organized agricultural structures, socio-economic structures can be significantly improved. Furthermore, small farms serve to protect landscape features and promote biodiversity. By managing or creating aquaculture farms in remote areas or in rural areas (e.g. pond systems), the migration of the population to cities can be remedied. In this way, jobs can be created, and the identity of existing regional production systems can be preserved. Only with the existence of employment opportunities can both the provision of education and healthcare systems be guaranteed. Unfortunately, more and more small farms are disappearing; demographic change is one reason for this, but it is often the challenges of the agricultural sector that make it unprofitable to continue farming. Market pressure, but also other exogenous influences such as climate change with its associated weather extremes, present small farms with immense challenges. Small businesses must therefore make even greater efforts to invest in new innovations and technologies in order to keep up with the market and communicate the unique selling points of their products. It is therefore all the more important that the EU develops measures that are tailored to the needs of small companies. Strategic plans should be flexible enough to take into account the location conditions of small businesses and at the same time promote economic, ecological and social structures in rural areas. The aim, of course, is to integrate small aquaculture farms into the EU food system in the long term and to maintain their ability to compete with large companies.

In order for smaller aquaculture farms to operate successfully, economically and ecologically in the future, a number of structural measures are required:

- The development and commissioning of small aquaculture operations must be simplified, including corresponding licences. There is a need to standardize the management and control of diseases and animal welfare (regulatory obstacles/model standards).
- The implementation of circular economy systems must be simplified and promoted. New solutions must be found when it comes to waste management. There is huge potential in linking aquaculture and agriculture, especially when it comes to valorisation of waste. Agriculture and aquaculture need to explore their potential to utilize material from both sectors (knowledge transfer). Targeted research programmes could combine research topics, e.g. seaweed and mussel research, research into new locations with social impact and resilience of the ecosystem and society (holistic approach).
- Digital transformation will be the core of future management systems; simple implementations and solutions must be found that are individually adaptable, but can also be used across departments, accessible and affordable (digital solutions).
- The labelling of aquaculture products should be simplified to enhance consumers' acceptance (certification schemes/labelling).
- The development of sustainable aquaculture should be promoted in national strategies (investment).
- The main focus has to be on ocean sustainability. The creation of an intergovernmental panel of experts on ocean sustainability could be set up by researchers in the field (knowledge transfer).

- SMEs would benefit from partnerships with large agribusiness companies when implementing and investing in new technologies, and leasing offers could also bridge financial barriers. Strategic partnerships would thus reduce risks, enhance the image of the companies involved and increase confidence in the product fish.

In order to be able to act in a targeted manner, a wide variety of actors must be brought together, which is in particular important for SMEs. Comprehensive industrial cooperation should be promoted, therefore structures of both governance and financial nature must be created. Early-stage industrial processes require support from clusters and government/industry funding programs. Key priorities set under the European Green deal such as climate change, biodiversity loss, and pollution are already part of the new communication on international governance.



7.4 Aquaculture practices in non-EU countries

As aquaculture is a very dynamic sector, its growth and common practices are strongly influenced by the geographical location, applied technologies and management experience, as well as the infrastructure and economic situation of the respective countries. Meaning that government policies have strongly shaped existing systems. Regulatory mechanisms have a particular influence here and determine whether systems can still grow and how economically and sustainably this is possible. Particular attention must be paid to aquaculture disease management, in this case the use of medicines and chemicals. Aquaculture policies must be designed in such a way that they take into account economic growth, disease management, environmental impact and trade protection.

China

China is a member of:

- World Trade Organization (WTO).
- Network of Aquaculture Centres in Asia and the Pacific (NACA).

China is a party of the Convention on Biological Diversity (CBD). It has signed the Biosafety Protocol on 8 August 2000 but is not yet a party to the Protocol. China is also a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

China has been the world's leading aquaculture producer since 1989 and remains so today. Due to urbanization and industrialization, the number of traditional fish farms has been reduced and marine ranching has taken on a special role. Artificial reefs are created to attract fish and other marine life. The National Mariculture Development Plan (2017-2025) published by the Ministry of Agriculture and Rural Affairs stated that China planned to build 200 national-level demonstration sites in 2022. In order to counteract the scarcity of natural resources, aquaculture is increasingly being used in China. Science and technology play a primary role here; high-tech breeding with new technologies and the use of artificial intelligence and robotics is promoted. In the area of feed, too, new substitute feed should replace the use of small fish, which are a valuable part of the ecosystem. One of China's goals is to replace fish fuel subsidies with fishing subsidies, which would lead to a change in overall regulation. Unregulated and illegal fishing in particular could be stopped in this way, but effective regulatory measures are still needed to build technology-based sustainable aquaculture and fisheries. As a major fishing technology power, China is seeking cooperation across the region. In recent years, China and various Southeast Asian countries have concluded cooperation agreements on fisheries infrastructure development, fisheries management, processing, and fisheries science and technology. We see that research and technological advances are laying the foundations for a more sustainable fishing industry and that political framework conditions are also being laid for this development.

Indonesia

Indonesia is a member of:

- World Trade Organization (WTO).
- Association of Southeast Asian Nations (ASEAN), which promotes cooperation for the development of aquaculture through the ASEAN Ministerial Understanding on Fisheries Cooperation (1983).
- ASEAN Free Trade Area (AFTA).
- Indonesia is also a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and to both the Convention on Biological Diversity (CBD) and the Biosafety Protocol.

With regard to regional arrangements, Indonesia is a non-member participating State to the Agreement on the Network of Aquaculture Centers in Asia and the Pacific (NACA) (1988). NACA members are: Australia, Bangladesh, Cambodia, China, Hong Kong, India, Korea, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand and Viet Nam.

Moreover, as part of the Southeast Asian Fisheries Development Centre (SEAFDEC), Indonesia participates not only in the several Departmental Programmes on aquaculture, but also in the SEAFDEC-ASEAN programmes, which include the promotion of mangrove-friendly aquaculture and the regionalization of the Code of Conduct for Responsible Fisheries.

Indonesia, as one of the top exporters of farmed seafood, here shrimp, lobster, crab and seaweed, will continue to expand its production in the next few years. Particular ecological challenges are the protection of mangroves and coastal ecosystems. According to the Centre for International Forestry research (CIFOR), half of all mangrove forests have been destroyed in the last 30 years. Here the government is required to ensure sustainable environmental planning, especially in terms of land clearing and waste management. Deforestation, pollution and destructive fishing practices pose major challenges for the region. The allocation of areas for the use of aquaculture must be regulated and coordinated, the status of land areas must be defined, and water and waste-water management must be regulated. The need for a reformative change in the aquaculture sector is great, because only sustainable fishing can strengthen the region in the long term. Legal reforms and a restructuring of strategies to improve aquaculture must be politically demanded. Cross-sectoral participation, including NGOs, the corporate sector and local communities, would be desirable to support

sustainability. This is the only way to recover destroyed mangrove areas and to ensure effective control and monitoring of the use of marine resources.

India

India is a member of:

- World Trade Organization (WTO)
- South Asian Association for Regional Cooperation (SAARC)
- Network of Aquaculture Centres in Asia and the Pacific (NACA).

India is a party to the Convention on Biological Diversity (CBD) and has signed the Biosafety Protocol. India is also a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Major changes to the domestic aquaculture landscape have been passed by the Indian Parliament (CAA Coastal Aquaculture Authority). Legislation has been amended to clarify that small, marginal aquaculture farmers do not need to obtain Coastal Regulatory Zone (CRZ) permits from multiple authorities. These areas were originally created to protect coastal areas; sustaining the livelihoods of small fishermen and strengthening local communities; also, to manage entire regions sustainably. New forms of aquaculture, such as cage culture, seaweed culture, oyster culture are now promoted. The National Fisheries development board (NFDB) provides technical assistance, financial support and capacity building. The aim is to promote productivity through research and development in a sustainable way. The Marine Products Development Authority (MPEDA) is responsible for the development of the relevant infrastructure and for international quality standards. In order to achieve a robust and sustainable development in the aquaculture sector, government initiatives must focus on responsible aquaculture practices and waste management strategies, on disease management and the access to finance and technology.

Vietnam

Viet Nam is a member of:

- The Food and Agriculture Organization (FAO) of the United Nations
- The World Trade Organization (WTO)
- The World Organization for Animal Health (OIE)
- The Global Environment Facility (GEF)
- The Association of Southeast Nations (ASEAN), which promotes cooperation in all aspects of Aquaculture through the ASEAN Ministerial Understanding on Fisheries Cooperation (1983)
- The ASEAN Free Trade Area (AFTA)
- Network of Aquaculture Centres in Asia-Pacific (NACA), an intergovernmental organization that promotes rural development through sustainable aquaculture.
- The Agreement on the Cooperation for the Sustainable Development of the Mekong River, which establishes the Mekong River Commission.
- The Southeast Asian Fisheries Development Centre (SEAFDEC), an intergovernmental organization that promotes sustainable fisheries development in the region. It maintains an aquaculture department in the Philippines for aquaculture research and development.

Viet Nam is a party to:

- The Convention on Biological Diversity (CBD);
- The Cartagena Protocol on Biosafety (CPB);
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); and
- The United Nations Convention on the Law of the Sea (UNCLOS).
- RAMSAR Convention.

The masterplan of Vietnam Fisheries and Aquaculture Development (through 2020 and vision to 2030) has the aim to increase international competitiveness and productivity in the context of globalisation and regional integration. Further, the modernisation of the industry while protecting coasts and marine ecosystems. This transformation should be sustainable on a social, ecological and economic level. Particularly in rural areas, a certain degree of industrialization and modernization must take place, as well as urbanization, population control and environmental protection. Food safety is one major issue, as well as the lack of infrastructure and the exchange between stakeholders, sea food supply chains and governmental agencies to enable traceability. Vietnam has achieved high growth rates, nonetheless, problems in the policy making progress occur. Building a comprehensive conceptual framework for sustainability development is essential. Awareness and education about this global issue for all stakeholders in the industry should be reinforced.

Bangladesh

International arrangements:

Bangladesh is a member of the World Trade Organization (WTO), the South Asian Association for Regional Cooperation (SAARC) and the Network of Aquaculture Centres in Asia and the Pacific (NACA). Bangladesh is a party to the Convention on Biological Diversity (CBD) and the Biosafety Protocol. Bangladesh is also a party to the Convention on International Trade in Endangered Species of. Wild Fauna and Flora (CITES).

A legal definition of aquaculture does not exist. There are no guidelines or codes for aquaculture activities.

Bangladesh follows the National Aquaculture Development Strategy and Action Plan of Bangladesh 2013-2020. This action plan is a multi-institutional collaboration between the government, civil society organisations, the private industry, farmers, suppliers, traders and academic institutions. Developments should be socially, economically, ecologically and institutionally sustainable. The aim is to create food security and better supplies for the rural population in particular. Better access to local and international markets should be created. Management programs and management programs should be developed jointly by the relevant ministries and the Ministry of Fisheries and Livestock. Spatial planning and environmental monitoring systems to ensure the safety of aquaculture and minimize the impact of aquaculture on surrounding ecosystems. Farmers should be supported through clusters and associations. (Management Practices (BMPs) in compliance with, among others, environmental standards, food safety standards and traceability). Ambitious goals exist that require reliable laws and guidelines, as well as control mechanisms and sustainable living standards at all levels.

In summary, aquaculture is the fastest growing food production technology of the last decade. It is predicted that aquaculture will continue to grow. It is also certain that aquaculture will remain very

heterogeneous. In many Asian and African countries, it serves to provide livelihoods and income and requires different regulations than export-oriented aquaculture, which has different impacts on the environment and economy. Production locations that are growing particularly rapidly require regulations that can make a sustainable contribution to food security on an ecological, social, economic and institutional level. Political decision-makers are required to lay the foundations for this development.

8 Conclusion and Outlook

Over the past 20 years the aquaculture sector has evolved from having a relatively minor role to playing a mainstream part in the global food system. The aquaculture literature reflects the increased attention to food system outcomes, with consumers, value chains, and sustainability criteria progressively shaping the direction of the industry. Continued growth in the sector has important implications for achieving the United Nations Sustainable Development Goals (Naylor, 2021).

The iFishIENCi series of three reports on Regulatory Framework and Requirements (Shrestha, 2020; Hávardsson, 2021; and current report) aimed to identify and assess the requirements linked with the fish farming industry and the nutrition and breeding especially in Europe in order to contribute towards a more sustainable and competitive EU aquaculture.

- Legal requirements developed by the EU and large aquaculture producing countries such as Norway, Scotland, Turkey, Australia, Canada or Chile as well as existing regulatory barriers in term of governance, social licensing and use of aquaculture waste streams (Shrestha, 2020; Hávardsson, 2021; and current report).
- Responsible farming standards and certifications including current use, limitations & opportunities, as well as consumer attitude (Shrestha, 2020; and current report)
- Environmental requirements for production and waste management towards sustainable and circular aquaculture in Europe (Hávardsson, 2021; and current report)
- Influence of trade agreements on the development of sustainable aquaculture (Shrestha, 2020; and current report).

The aquaculture sector is facing various regulatory challenges that need to be overcome in order to move towards a more sustainable and competitive sector.

9 Reference List

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