Aquabalance
Balancing economic, environmental, and social sustainability in the European aquaculture industry

WP1 – Aquaculture Regions in Europe

Summary report for public dissemination

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Abbreviations and acronyms

Abbreviation or acronym used in this document	Explanation
WP	Work Package
RO	Research Objective
EU	European Union
R&D	Research and Development
CO_2-e	Carbon Dioxide Equivalent
RAS	Recirculating Aquaculture Systems
IMTA	Integrated multi-trophic aquaculture
CCS	Closed or semi-closed containment systems
Nor, Den, Ire, IT	Norway, Denmark, Ireland, Italy (case study codes)

Executive Summary

This document is produced to report on the work conducted in fulfilment of Deliverable 1 in Work Package 1.

This is a summary report of the final deliverable.

The report presents outcomes of the mapping of three regional aquaculture hubs for each country, Norway, Denmark, Ireland and Italy – leading to the identification of more specific regional case-studies. Data include a systematic desktop review, country profiles and baseline data to review the environmental, economic and social domains that inform the development of each country's regional case studies. Case studies are characterised based on the desktop review, and provided for each case study is key demographics, aquaculture species or product specialisation, and a primary and secondary thematic focus for investigation.

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1 Introduction

Significant diversity and regional variations are evident in how aquaculture firms operate, and in the competencies and resources they hold (Puszkarski & Śniadach, 2022). Different types of business models exist; moreover, some regions are characterized by organizational and institutional 'thickness' - and have strong traditions for learning and networking, while others are less dynamic and lag behind (Njøs & Jakobsen, 2018). Importantly, how key firms balance economic, environmental, and social dimensions of sustainability varies significantly (Engle & van Senten, 2022). WP1 interrogates this diversity by developing a systematic overview of European aquaculture, to inform novel insights and to feed into subsequent work-packages. The hypothesis that 'sustainability achievement for aquaculture enterprises varies according to key socio-economic, political and ecological criteria' will be comprehensively tested via WP1 tasks 1.1-1.4, in accordance with criteria of specificity, clarity and testability.

Objectives:

- RO1 Develop a detailed baseline understanding of European aquaculture hubs.
- RO2 Conduct qualitative case studies in different European regions based on interviews with both representatives of aquaculture firms and other local stakeholders (politicians, authorities, and representatives of civic society such as consumers, environmental protection NGOs, etc.) to develop rich qualitative dataset.
- RO3 Develop a shared taxonomy of business model typologies in aquaculture to map drivers and challenges for developing impactful sustainable aquaculture business models in various regions.
- RO4 Develop potential solutions and toolkits for targeted research impact through a series of workshops with relevant stakeholders.

1.1 Aims and Objectives of this Report

Task 1.1 of WP1 involves a systematic desktop review and synthesis of data from existing EC funded studies and publicly available information to establish a baseline understanding of the present state of regional aquaculture hubs, including information from reports, registers data, websites, and other accessible information. Task 1.1 provides important foundational context for Tasks 1.2, 1.3 and 1.4 and delivers a key reference resource for WP2, 3, & 4. As a foundational component of Task 1.1, a series of country profiles were developed for each of the constituent partner countries of the Aquabalance consortium, that is, for Norway, Denmark, Ireland and Italy.

Aim: To develop a summary profile of the aquaculture sector in Norway, Denmark, Ireland and Italy reflective of the most up-to-date publicly available information.
Output: Accessible summary report comprised of desktop review and synthesis of data on the aquaculture sector in the respective countries.

1.2 Intended readership

This document is intended to be read by the project partners and constitutes submission of deliverable 1 of Work Package 1.

2 Methods and research design

The Case Studies: Case studies represent diverse perspectives and perceptions of sustainability in aquaculture. In addition to focusing on a particular aquaculture species produced in the region, case studies will also revolve around a number of themes (in 'isolation' or combination) related to aquaculture:

- Aquatic species as new industry paths (e.g. seaweed)/(green) path renewal of existing industry paths based on specific species (e.g. green salmon farming)
- 'Standardised low-value paths'
- 'High-value paths' (e.g. seaweed as 'high end' cosmetic products)
- Synergies between aquatic species (e.g. cleaning fish for salmon, blue mussels/seaweed as filtering species for salmon waste or feed for salmon)
- Circular value chains as case studies (e.g. salmon waste to biogas production in Greenspot Mongstad and selected hubs within the Green Region Vestland programme)
- New technology and innovation (RAS, IMTA, Circular value chain, River-based flow through etc.) in the aquaculture industry
- New green technologies
- Nature-based solutions in the aquaculture industry
- Aquaculture's role in promoting tourism, local food, viewing centres/exhibitions etc. (leading to job creation in rural areas)

These were narrowed down into the key themes related to the balance in terms of environmental, economic and societal concerns:

- Eco-production (including organic)
- Environmental quality
- Social licence and regional embeddedness
- Economic performance (Energy, viability & competitiveness)
- Animal welfare
- Nutrition & Well-being

The selection of the regions, case studies, species and themes to be investigated are presented in this report and they offer the foundation for the primary research phase of this study, which will be conducted in 2025 and 2026 under Task 1.2 of the Aquabalance project.

3 European Overview

The Blue Economy strategy, the common fisheries policy and the European Green Deal promote aquaculture as an important growth sector that can benefit the economy and society. It is also a source of protein that contributes to food security in Europe with a relatively low carbon footprint compared with agricultural food production methods. The European Fisheries Fund (2007-2013), the European Maritime and Fisheries Fund (2014-2020) and the European Maritime, Fisheries and Aquaculture Fund (2021-2027) provided financial supports to increase development in European aquaculture, with sustainability and growth as the key objectives.

European policy aims to develop EU aquaculture sector to ensure "nutritious, healthy and tasty food with a low environmental and climate footprint," create economic opportunities and jobs, and become a global reference for sustainability and quality. Specifically to:

- build resilience and competitiveness
- ensure the participation of the sector in the green transition
- ensure social acceptance and consumer information on EU aquaculture activities and products
- increase knowledge and innovation in the EU aquaculture sector (European Commission, n.d.a).

Globally, aquaculture is one of the fastest growing food sectors, but in 2020 Europe provided only 1% of the total global figures in volume and 1.5% of the value, with 67% of production levels dominated by France (22%), Spain (15%), Greece (15%) and Italy (9%) in 2020 (European Commission, n.d.b., Eurostat 2025). More than half of European producers farm shellfish, and the total volume of fish farmed constitutes 21% from marine environments and 28% from freshwaters. Mussels, trout, oysters, seabream, seabass, carp and tuna are the most farmed species in Europe. In 2020, there was a turnover value of €3.9 billion and 57,000 people were employed across about 14,000 companies, mostly being small and family-owned (European Commission, n.d.b.).

4 Norway

4.1 Overview of aquaculture in Norway

Aquaculture activities in Norway make up a significant share of the country's GDP and take place all along the coast, particularly in the counties of Vestland, Møre og Romsdal, Trøndelag, Nordland, Troms and Finnmark. Norwegian aquaculture primarily revolves around salmon farming of which Norway is one of the world's largest producers. In total, 11 out of the 20 largest salmon producers in the world (including the top 4) are Norwegian (Berge 2020).

Table 1: Key numbers for the whole aquaculture industry in 2023 (Directorate of Fisheries, n.d.)

€9629 m & €3,6 m	**10148**	**1618965 tonnes**	**2249 tonnes**	**1310**
Value of aquaculture sector (farmed fish[1] and other species[2] respectively)	*Total no. of workers directly employed in aquaculture*	*Volume farmed fish sold*	*Volume other species sold*	*No. of currently active sites*

Norwegian aquaculture has been growing steadily since the breakthrough of salmon farming in the 1970s. The growth has been particularly significant since the early 2000s and the number of man-years in the industry has grown from approximately 3000 in year 2000, to over 10,000 in 2023 (Directorate of Fisheries, n.d.). Atlantic salmon (Salmo Salar) dominates the production, followed by rainbow trout. However, there is also production of other aquatic species, such as farmed cod (which is increasing in popularity), crustaceans, molluscs and seaweed. To foster the development of the aquaculture industry the Norwegian state has invested heavily in R&D. The dominating focus here has by far been the salmon-farming industry. This has contributed to what is today a rich sectoral innovation system involving multiple universities and research institutes, as well as private consultancy and research firms. These provide research on many parts of the value chain, from breeding to feed, fish health-related technologies and farming systems. However, while the Norwegian aquaculture sector is lucrative and continues to increase with regard to production and sales, the sector suffers from several environmental and animal welfare-related challenges. This is particularly prominent in the salmon-farming industry.

4.2 Finfish Aquaculture

Official data on production volumes and sales from Norwegian aquaculture are publicly available from the Directorate of Fisheries (n.d.,b). Atlantic salmon make up close to everything (94%) of all finfish which is farmed and sold, with rainbow trout following in second place. Moreover, as farming of finfish make up almost the entire Norwegian aquaculture sector, salmon is by far the most dominant farmed aquatic species. Still, it is

[1] Farmed fish here primarily refers to farmed salmon (Atlantic salmon) and rainbow trout. Farmed salmon is dominating the Norwegian aquaculture industry (making up 94% of the Norwegian aquaculture industry) (https://www.fiskeridir.no/Akvakultur/Nyheter/2024/nedgang-for-laks--okt-salg-av-andre-arter)
[2] Molluscs, crustaceans, echinoderms and algae

worth noting that the production of farmed cod is increasing, and sales of farmed cod more than doubled from 2022 to 2023 (Directorate of Fisheries 2024).

Table 2: Sales of aquaculture finfish in tonnes in 2023. Numbers sourced from the Directorate of Fisheries (n.d.,b).

Species	**Annual sales in tonnes**
Atlantic salmon	1 517 516
Trout	86 338
Atlantic cod	11 389
Atlantic halibut	1903
Arctic char	814
Other species	386
Total	**1 618 346**

Production locations are spread along the coast from Finnmark in the north to Agder in the south. The highest number of production sites, both in the sea and on land, are found in County Vestland. However, Trøndelag, Nordland and Troms are also important fish farming counties (see Table 3). These counties all have a long coastline with sheltered fjords and inlets, as well as ideal sea temperatures These natural conditions make these areas highly favourable for production. Still, production sites are unevenly spread within the counties and in some places they cluster in certain locations.

Table 3: Number of finfish production sites in different Norwegian counties in 2023. Numbers sourced from the Directorate of Fisheries (n.d.,b).

County	**Salmon- and trout localities**	**Other finfish localities**	**On-land production localities**
Finnmark	80	2	1
Troms	116	8	2
Nordland	215	15	5
Trøndelag	159	13	4
Møre- og Romsdal	81	14	8
Vestland	270	20	22
Rogaland	59	3	4
Agder	10	0	4
Other counties	0	0	14
Total	**990**	**75**	**64**

R&D on finfish farming is today carried out by multiple universities and research institutes, by some fish farming firms, as well as by private consultancy- and research firms. R&D on salmon farming is dominating here and R&D organisations provide research in many parts of the value chain, from breeding (smolt and post-smolt) to feed, fish health-related technologies and farming systems. This has contributed to continuous technical innovation, making Norwegian salmon farming firms (and associated R&D organisations) world leaders in aquaculture innovation (Afewerki *et al.* 2022). In recent years the salmon-farming industry has increasingly been incentivized to innovate in order to handle the industry's environmental problems. For instance, so-called 'green licenses' (2013) and 'development licenses' (2015)

have become some of the few available means to obtain new salmon farming licenses. However, in order to get a development license industry actors need to showcase and complete green innovation projects based on new technology. These policy tools have now been phased out, but several of the technology projects that emerged from the development licences policy are still in development.

4.3 Mollusc and Crustacean Aquaculture

Production of mollusc and crustaceans is also present in Norway, but it is still at a 'test stage' compared to salmon production (cf. Ministry of Trade, Industry and Fisheries 2023). Species within this category include: Blue mussels (which by far is the most popular species here), Great Atlantic Scallops, Oysters and various Echinoderms (such as lobster and crayfish). Still, as seen from the numbers in Table 4, the total production and sales value from this industry is dwarfed by finfish production and sales.

Table 4: Mollusc and crustacean production and sales in 2023. Numbers sourced from the Directorate of Fisheries (n.d.,b).

Species	Quantity in tonnes (2023)	Value in 1000 NOK (2023)
Blue mussels	2077	35 383
Great Atlantic Scallops	19	1210
Oysters	15	1086
Echinoderms (lobster, crayfish etc.)	0	78
Total	**2112**	**37 656**

The major share of mollusc and crustacean production takes place in County Trøndelag, which produced 60% (1266 of 2112 tonnes) of Norway's molluscs in 2023 (Directorate of Fisheries n.d.,b), but the counties of Vestland and Nordland also have a large number of production sites. It is worth mentioning that the total number of production sites has decreased significantly since 2006 (when there were 696 production sites in total). Still, this might just mean that the industry is prone to more regulation and/or that the production has been more consolidated into fewer companies and sites.

Table 5: Distribution of mollusc and crustacean production sites in Norway in 2023. Numbers sourced from the Directorate of Fisheries (n.d.,b).

County	Number of production sites
Finnmark	1
Troms	3
Nordland	36
Trøndelag	43
Møre og Romsdal	3
Vestland	36
Rogaland	4
Aust-Agder	6
Other counties	2
Total	**134**

The natural conditions in Norway are well suited for future sustainable industrial development of molluscs and crustaceans. Some of these natural conditions include access to clean seawater, sheltered coastal areas and high technological competence (Torrissen *et al.*, 2018). Of the different potential species mentioned as candidates for future growth in the Norwegian aquaculture industry, Blue mussels are seen as the most viable alternative–as this has the potential to be used both for human consumption and as feed for farmed fish (e.g. salmon) (Ibid.). Yet, while there are R&D institutions that engage with basic research on molluscs and crustaceans, and there have been prior attempts to for example develop a viable Blue mussel industry (see e.g. Winter *et al.* 2010), the potential growth of this industry remains unfulfilled.

4.4 Seaweed Cultivation

There has been a growing interest in production and consumption of seaweed for food production, as well as for other uses such as medicine, animal fodder and biofuels, over the past few years. Seaweed aquaculture is often considered an environmentally friendly alternative and an industry where Norway has a comparative advantage due to the natural conditions along the coastline. Still, seaweed production is very small scale (or also at a test stage) in Norway. The first concessions for seaweed cultivation were granted in 2014 (Haldorsen *et al.* 2023), and by 2023 the industry still only employed 78 people. 766 tonnes of algae were harvested in 2023, but only 137 tonnes of Sea Belt and Dabberlocks (with a total value of 4561000 NOK) were sold as animal feed or for human consumption in 2023 (Table 6).

Table 6: Seaweed (Sea Belt and Dabberlocks) production and sales in 2023. Numbers sourced from the Directorate of Fisheries (n.d.,b).

Species	**Quantity in tonnes (2023)**	**Value in 1000 NOK (2023)**
Sea Belt	47	1014
Dabberlocks	90	3584
Total	**137**	**4561**

There are 111 seaweed cultivation sites in Norway, most of which are located in the major aquaculture regions.

Table 7: Distribution of seaweed cultivation sites in Norway in 2023. Numbers sourced from the Directorate of Fisheries (n.d.,b).

County	**Number of production sites**
Finnmark	1
Troms	7
Nordland	18
Trøndelag	13
Møre og Romsdal	10
Vestland	54
Rogaland	2
Agder	5
Other counties	1
Total	**111**

Although the production of seaweed is still low a variety of actors, ranging from universities and research centres to marine equipment producers, have been involved in R&D for the sector (Sivertsen Våge 2022). Yet, the funding for research in seaweed cultivation and utilization of algal resources is minuscule compared to that invested in finfish aquaculture (Norderhaug *et al.* 2020). The industry also reports a regulative vacuum–for instance with regard to the lack of an agreed-upon thresholds for heavy metals in seaweed for human consumption–as a factor contributing to slowing down the development of the industry (Haldorsen *et al.* 2023). Still, seaweed was included in the law on fish exports in 2023, and this may provide a somewhat clearer framework or direction for future development for industrial production of seaweed for human consumption.

4.5 Summary of case studies - Norway

To identify such case-studies for Norway, we have considered the number of aquaculture localities, but also the presence of firms' main offices, R&D organisations and industry initiatives and collaborative organisations. This has led us to identifying three case-study regions; Vestland, western Norway, Trøndelag in mid-Norway and Nordland, northern Norway. Figure 1 provides a mapped overview.

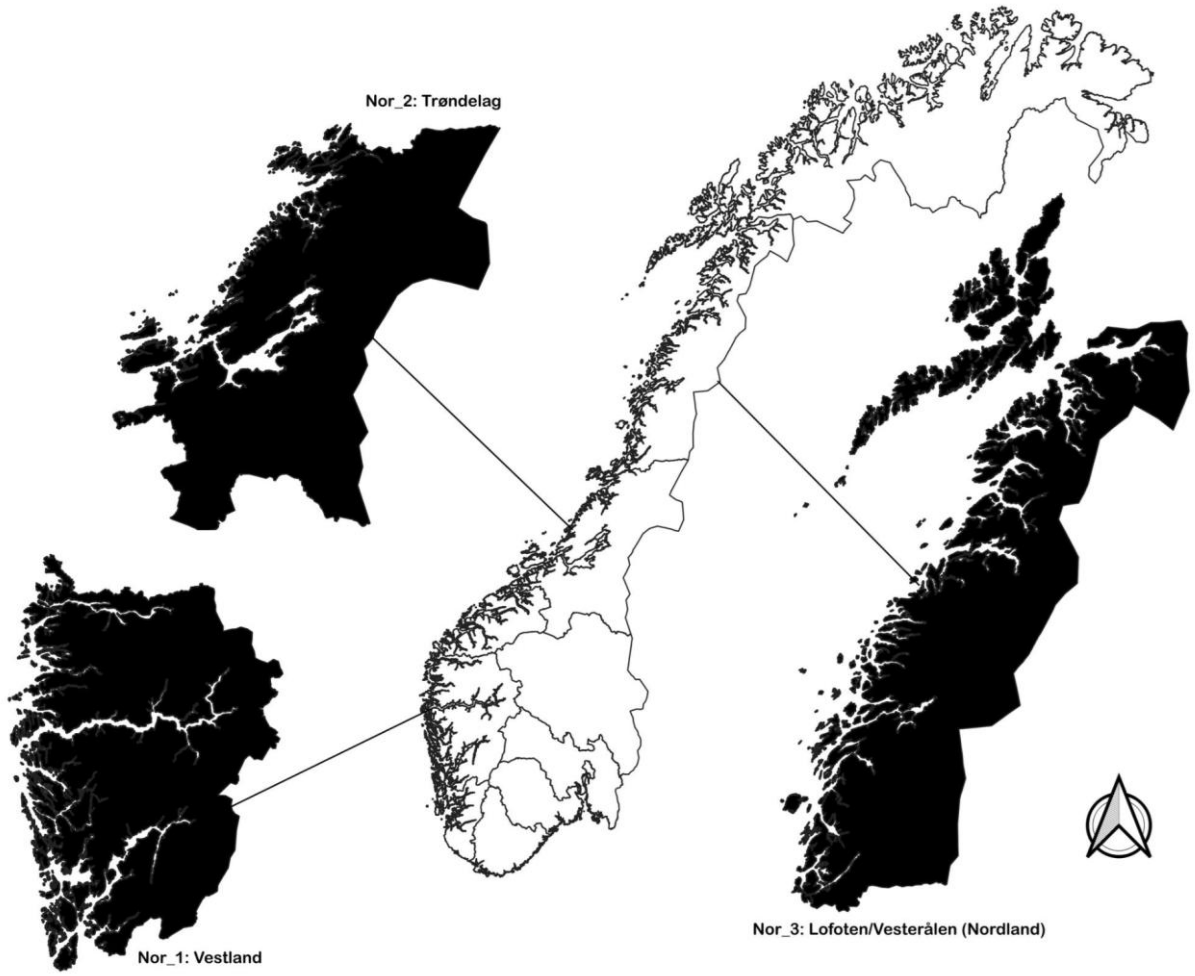

Figure 1: Map of regional case studies in Norway

4.5.1 Case study 1 (Nor_1) Vestland, Western Norway

The region of Vestland, i.e. County Vestland, has a population of 655.210 people as per 2025, which makes it the 3rd most populous county in Norway (Statistisk sentralbyrå, n.d.). Close to half of the population live in the county capital Bergen. Otherwise, the region is quite rural as it does not have other larger cities. Rather, there are several towns in the region, with Sogndal, Florø, Førde, Leirvik and Voss making up the largest of these. The main industries in the region are the oil and gas industry, maritime industry, marine industry (which include both wild fishing and aquaculture), power intensive process industries and tourism industry. It is also the county in Norway with the highest degree of exports per se. Total exports from Vestland amounted to 232 billion NOK in 2023, of which 16% was from aquaculture (almost exclusively related to salmon farming). Finally, it is the second most export intensive county per capita as export income make up 700.000 NOK per worker (Menon, 2024). Unemployment levels in Vestland are low and income levels are generally high. The median household income was 838.500 NOK as per 2023, which is above the national average (Statistisk sentralbyrå, n.d.b).

The main biomes in the region are coastal islands, fjords, mountains, forests and agricultural landscapes. As such, Vestland is a highly popular tourist destination in Norway and in 2019 the county had the third largest income from tourism of all Norwegian counties (NHO Reiseliv, n.d.). In particular, the combination of fjords and coastal islands, as well as an overall cool sea temperature all year long, have created sheltered and optimal conditions for salmon farming (Steen, 2024).

The region was among the earliest to engage in salmon farming activities. This initially started with farmers experimenting with a new form of income, which gradually was replaced by small and often family-owned firms in rural areas. Later, in the 1990s the industry became more professionalised. It went through several mergers and acquisitions, which led to several salmon producers being part of more vertically integrated value-chains and also several being listed on the stock exchange (Fløysand and Jakobsen 2017). Today the region has the highest density of salmon farming locations in Norway and the industry represents a key employer in several local communities. Vestland is also home to many of the biggest salmon producers in the industry, including MOWI, Lerøy and Grieg Seafood, which all have their headquarters in Bergen. These were initially local firms who have developed to become global industry leaders with integrated value chains. Several aquaculture firms, including suppliers, also collaborate in the regional seafood cluster NCE Seafood Innovation. The characteristics of the aquaculture industry varies within the case-study region. In some places, such as the Austevoll islands, the industry is dominated by large MNCs who grew from family-owned firms. In other places, smaller firms make up a larger share of the industry. Bergen is also home to important regional higher education institutions and research organisations involved in aquaculture, such as the University of Bergen and Institute of Marine Research, as well as public national organisations, such as the Directorate of Fisheries. Given Norway's already dominating position in the salmon farming industry, Vestland, and more specifically Bergen, is recognised as a global centre for salmon farming (Lindfors and Jakobsen, 2022).

Still, as elsewhere in Norway, the region struggles with significant environmental and salmon welfare challenges. This is, however, particularly bad in Vestland which several times, including the period of 2023-2024, received a 'red light' in the traffic light system. Wild salmon stocks in many salmon rivers in the region are at a historic low and there have been many reports of unsatisfactory animal welfare conditions among farmed fish. However, there

is significant variation between different firms and different locations, and firms with good animal welfare records can still obtain permits for increased production.

4.5.2 Case study 2 (Nor_2) Trøndelag, Mid-Norway

Per January 2025, the region Trøndeag has a population of 482 956 people (Statistisk sentralbyrå, n.d.a) and an area of 42 202 km². About half the population lives in the regions' major city, Trondheim. The Trøndelag region consists both of inland and coastal areas, including the Trondheim fjord as well as the large islands Hitra and Frøya. The Trondheim fjord area has the highest population density, while the islands and the rest of the coastline is relatively sparsely populated. This population distribution resonates with the important roles that agriculture and forestry have historically played in the region, with Trondheim being an important city also at the national level, and with industry development around the Trondheim fjord. However, it is important to note that fisheries were also a significant activity for the region and its coastal communities.

Today, Trøndelag has a mixed industry structure between traditional industries, tech industries, agriculture, tourism and aquaculture. The unemployment rates are low, as in the rest of Norway. The median household income was 792 000 NOK per 2023, which is close to the national average (Statistisk sentralbyrå, n.d.b). The income levels vary within the region, with the highest average income levels being found in Trondheim and the surrounding areas, as well as parts of the island Frøya and some coastal areas in the north of the county. The high-income levels in some of these coastal areas can be associated with salmon farming.

Trondheim hosts a large technical university (NTNU), as well as important research milieus and tech companies. Firms in the Trøndelag aquaculture industry collaborate on technology development through the cluster organisation NCE Aquatech cluster. The region is home to key salmon farming companies, such as Sinkaberg-Hansen and Salmar. The latter is among the four biggest salmon farming companies globally. The coast of Trøndelag has high density of aquaculture sites. Although salmon is by far the main species, Trøndelag is also among Norway's key regions for mollusc and crustacean aquaculture, and home to Norgeskjell, one of the main actors in Norwegian mollusc aquaculture. Trøndelag has 35 mollusc production locations and stands for approximately half the national production of molluscs and crustaceans. This activity is particularly dense around the Åfjord and Skråfjord areas, as well as the Namsefjord and Gyltfjord.

While the historic cities of Trondheim and Røros are the most visited tourist destinations in Trøndelag, the regional destination management organisation has profiled the region as a food destination (see for example www.trondelag.com). This includes culinary routes and tours in different parts of the region, from inland herding culture to coastal destinations such as the Fosen peninsula, where crabs and mussels are among the local produce. The profiling as a culinary destination has been developed over many years in collaboration between diverse actors, such as farms, small scale fisheries and aquaculture, as well as restaurants in the high-end gastronomy segment (Innovation Norway, n.d.). Thus, the interaction between aquaculture and tourism development might also be worth further investigating as a part of this case study.

4.5.3 Case study 3 (Nor_3) Nordland, Northern Norway

Nordland county, the fourth largest in Norway, spans approximately 500 kilometres and includes 41 municipalities. It has a population of 243 081, with a significant portion residing along the coast (Statistisk sentralbyrå, n.d.). Between 1950 and 2024, coastal municipalities in Nordland, which primarily relied on primary industries and lacked alternative employment

opportunities, experienced population declines of 25 to 50 percent. Conversely, urban centres within these municipalities saw population growth, indicating a trend of "local centralization" in settlement patterns (Store Norske Leksikon, 2025). The median household income was NOK 770 000(2023) (Statistisk sentralbyrå, n.d.).

Nordland features a diverse landscape with significant low-lying areas shaped by well-developed beach surfaces. Additionally, Nordland encompasses 2,397 km^2 of freshwater and 887 km^2 of glacier areas, representing 2.3 percent of Norway's total area (Store Norske Leksikon 2025). The county accounts for 26.5 percent of Norway's mainland island area, featuring over 18,400 islands, islets and reefs. Its extensive coastline measures 5,087 kilometres on the mainland and 17, 934 kilometres on the islands, comprising 20.2 percent and 30.8 percent of the total mainland coastline, respectively (Store Norske Leksikon 2025).

This region is notable for its significant contributions to Norway's economy, particularly in industrial and aquaculture sectors. It is the second-largest industrial cluster in Norway and plays a crucial role as one of the country's major exporters of raw materials and industrial goods. The county also generates 10% of the nation's electrical power, totalling approximately 15TWh, making it the second-largest hydropower producer in the country. In terms of aquaculture, Nordland stands out as the leading fish-farming county in Norway, responsible for 65% of Northern Norway's exports and supplying 10% of the world's farmed salmon, along with 70% of Norway's total salmon harvest (Nordland Fylkeskommune, n.d.). Historically, this region has always been central to cod fisheries. The natural conditions are suitable for this species (and several others) and the region hosts important spawning grounds for wild cod, which was Norway's main fish export before the growth of the salmon farming industry. Today the region houses many production localities for salmon. However, compared to regions further south, the environmental challenges linked to salmon farming in Nordland are more contained, and the region is currently green in the traffic light system.

Cod farming is an emerging activity in this region. Nordland currently has six of the fourteen localities that have been granted concessions nationally. While cod farming gives hopes for more stable fish deliveries compared to wild catch fisheries, the growth of cod aquaculture has also given rise to increasing concern regarding crossbreeding between wild and farmed fish, and risk of spreading disease. As late as September 2024 the Directorate for Fisheries reported that mature cod able to breed in the net-pens constitutes a risk for wild cod and warns the industry that this may influence decisions regarding continued concessions (Directorate of Fisheries 2024).

Table 8: Summary of case studies, Norway

Name	**Norway case study 1**	**Norway case study 2**	**Norway case study 3**
Code	**Nor_1**	**Nor_2**	**Nor_3**
Region	**Vestland**	**Trøndelag**	**Nordland**
Features	**– strong environmental and fish welfare challenges, hub for global salmon farming**	**– less environmental challenges in salmon farming, national hub for mollusc and crustacean production**	**– few problems with environmental challenges in salmon farming, emerging cod farming industry**
Focus	Social embeddedness vs. Environmental sustainability (environmental innovation)	Organic production? Competing interests between different types of aquaculture? Positive interaction with other industries (tourism)?	Interaction between aquaculture and wild catch fisheries (both biological and economic)
Scale of activities	• 312 finfish localitities	• 176 finfish localities	• 235 finfish localities

	• 36 mollusc/crustacean localities	• 43 mollusc/crustacean localitites	• 6 cod localities 8out of 14 nationally) • 36 mollusc/crustacean localities
Species	Salmon	Molluscs (blue mussels)	Cod
Integrated approaches?	Testing combination of salmon and molluscs or seaweed	No data	No data
Novel Aspects?	Testing closed in sea and closed on land. Increasing practice of letting smolt mature more before moving to sea.	Organic production and certification	Emerging cod farming industry
Technological features?	Main technology: Open net pens. RAS systems and CCS used for smolt production. Testing closed systems in sea and on land	No data	Main technology: Open net pens.
Established or emerging?	Established – at least within salmon and trout	Established?	Emerging in cod.

5 Denmark

5.1 Overview of aquaculture in Denmark

Aquaculture has been practiced in Denmark for almost 800 years, and presently the Danish secondary industries for aquaculture (e.g., feed manufacture and recirculation technology) are world renowned (Skov *et al.*, 2020). In 2021, Denmark was the 3rd largest fish producer in the EU and the 8th major producer of aquaculture products accounting for approximately 3 per cent of the EU's aquaculture output volume (Nielsen *et al.* 2020). In parts of Jutland, there is a long tradition going back over 130 years of raising trout in ponds. Today there are also land-based marine fish, mussel and macroalgae farms (FAO, 2024) and such land-based aquaculture is carried out across more than 200 farms. Modern production technology is employed across the sector, whereby, up to 95 percent of the water is recirculated; Denmark is in fact a global leader in the development of modern water recirculation technology (FAO, 2024).

Aquaculture in Denmark was estimated to be 38,000 tonnes in 2022, contributing 7.7% of the total 2022 fish production of 496 000 tonnes (FAO, 2024). The production of species such as blue mussels has shown a year-on-year increase for many years, with locations proliferating around the fjord coasts and coastlines in Denmark. The spatial exception here is the West coast of Jutland, which is unsuitable for such activities due to the severity of storms in this location (FAO, 2024).

The aquaculture industry is equally divided with about one third in classic land-based aquaculture, one third in intensive-land based recirculating aquaculture systems (RAS) and the last third mainly in marine aquaculture, and to a small extent in shellfish (FAO, 2024). In addition to primary production, the Danish aquaculture industry consists of companies that produce fish feed, technology and equipment for the global aquaculture industry (Ministery for Food Agriculture and Fisheries, 2023). Currently, companies such as BioMar and Aller Aqua are globally leading aquafeed manufacturers, with production facilities worldwide, for coldwater and warmwater species in freshwater and marine waters (Skov *et al.*, 2020).

Table 9: Overview key headline figures, Aquaculture Denmark (FAO, 2024; The Danish Fisheries Agency, 2024)

€175	**453**	**11%**	**48,757 tonnes**	**239**
Value of aquaculture sector (2022)	*Total no. of workers directly employed in aquaculture*	*Percentage of aquaculture workforce who are women*	*Volume aquaculture 2022*	*No. of currently active sites*

Overall production, measured by weight, increased from a figure of 43,012 tonnes in 2013, to a peak of 55,154 tonnes in 2019. The headline figure for 2022 shows a decrease to 48,757 tonnes, a continuation of a declining trend since 2019 (The Danish Fisheries Agency, 2024)[3]. The production value of Danish aquaculture increased by 48 percent from 2012 (DKK 675 million (~90€million)) to 2020 (DKK 1.002 million (~134€millon) (Ministery for Food Agriculture and Fisheries, 2023). The export value of technology and equipment is estimated

[3] FOA report a lower figure of ~38,000 for the same year. The Danish Fisheries Agency data have been prioritized.

to have reached an annual level of DKK 5-6 billion kroner in 2021 (~600-800€million) (Ministery for Food Agriculture and Fisheries, 2023).

5.2 Aquaculture by Type in Denmark

A number of disparate models of aquaculture are evident in Denmark (The Danish Fisheries Agency, 2024; Danmarks Statistik, 2024):

1. On land, traditional pond farms are as well as RAS systems with a variety of recirculation intensities (low, medium, high). Across all land-based models, rainbow trout is the dominant species. However, other trout species are farmed in low volumes in traditional pond farms, while high recirculation facilities also produce smaller volumes of salmon, seriola and ell.
2. Sea farming with production of rainbow trout.
3. Shellfish farming with production of blue mussels.
4. Seaweed farming with production of sugar kelp.

A summary of facility types is provided in Tables 10 & 11:

Table 10: Overview of aquaculture in Denmark, 2022 (The Danish Fisheries Agency, 2024)

Type of facility	**Active facilities in 2022**
Traditional pond farming	67
Low recirculation (RAS)	20
Medium recirculation (RAS)	26
High recirculation (RAS)	37
Sea farming	19
Shellfish farming	62
Seaweed farming	5
Other aquaculture	3
Total	239

Table 11: Accounts Statistics for Aquaculture, 2022 (Statistics Denmark, 2024)

	All farms	Traditional farms	Farms with low recircu-lation degree	Farms with medium recirculation degree	Farms with high recircu-lation degree	Sea farms
Population, units	181	66	23	18	24	18
Sample, units	83	22	17	9	12	16
Operative assets, beginning of year, 1000 DKK	1794448	316196	157540	302448	496021	473667
Electricity, mwh	67400	12408	9799	15872	28264	1046
Production, tonnes	56259	8048	5415	8779	9770	13592
Gross output, 1000 dkk	1641502	254985	162089	253509	318756	609843
Costs, 1000 dkk	1452 724	243572	154690	228993	318549	479407
Financial expenditures, 1000 dkk	18062	4530	1524	1170	11118	- 369
Net profit, 1000 dkk	170716	6883	5875	23347	-10911	130806
Assets, end of year, 1000 dkk	2144186	358732	162898	299682	616624	643605
Net capital, beginning of year, 1000 dkk	519619	67816	38098	117730	- 137255	

Across these models, the primary production is of rainbow trout, blue mussels, salmon and other trout species. In addition, eels and other niche products such as oysters and seaweed are farmed (Danish Aquaculture Producers' Organisation, 2024). Table 12 provides an overview, by species and by location.

Table 12: Production of main species distributed by region and for rainbow trout production waters, Denmark (The Danish Fisheries Agency, 2024)

Aquaculture Type		Region					Total weight
		The capital	Central Jutland	Northern Jutland	Zealand	Southern Denmark	
Rainbow trout	**Fresh water**	3	16,426	2,132	.	7,379	25,940
	Salt water	.	2,323	.	6,457	1,009	9,790
Eel		.	.	461	.	16	477
Clam/oyster		.	2,157	8,069	.	0	10,227
Other		.	281	1,572	0	470	2,322
In total		3	21,187	12,235	6,457	8,874	48,757

5.4 Summary of case studies - Denmark

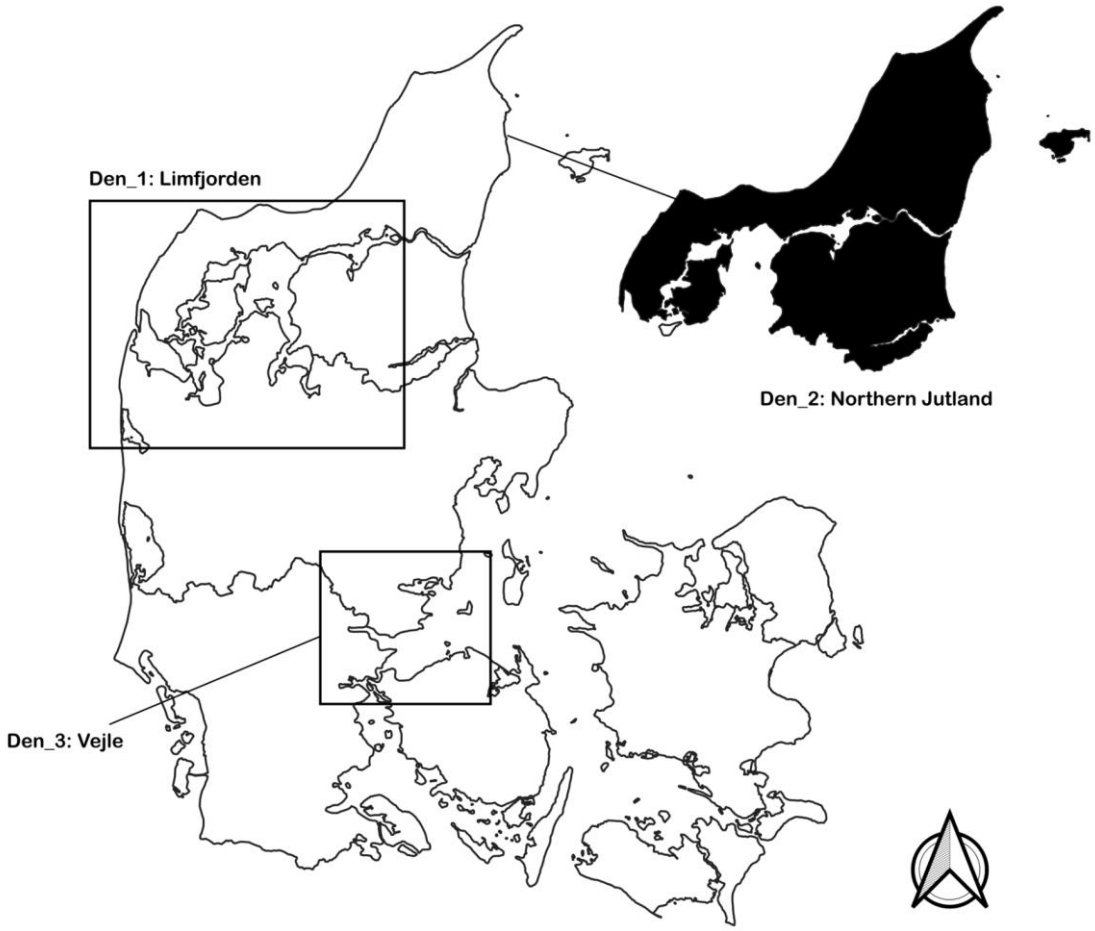

Figure 2: Map of regional case studies in Denmark

Table 13: Summary of case studies - Denmark

Name	**Denmark case study 1**	**Denmark case study 2**	**Denmark case study 3**
Code	**Den_1**	**Den_2**	**Den_3**
Region	**Limfjorden**	**Northern Jutland**	**Vejle**
Species	***Blue Mussel***	***Salmon/king fish***	***Rainbow Trout***
Primary theme	*Regional embeddedness*	*Innovation*	*Eco-production*
Secondary theme	*Eco-production*	*Eco-production*	*Economic performance*
Focus	Regional inlet / fjord	Concentration of RAS facilities (3 of the 5 largest RAS facilities in Denmark)	More traditional land-based facilities, including one of the large Danish organic producers.

5.4.1 Case study 1 (Den_1), Limfjorden

Limfjorden is Denmark's largest fjord system, stretching over approximately 1,000 kilometers of coastline and consisting of several bays, widenings, and straits. Limfjorden is located in Jutland and connects the North Sea with Kattegat (the strait between Denmark and Sweden). The net flow of water through Limfjorden goes from the North Sea toward Kattegat in the

east. Freshwater is also supplied to the fjord from several large rivers (Styrelsen for Grøn Arealomlægning og Vandmiljø, n.d.).

An important theme in this case is the role of mussel farming in relation to Limfjorden's strained ecological condition. The latest assessment of the overall ecological state of Limfjorden, conducted as part of the preparation of the River Basin Management Plan 2021–2027, shows that there is poor ecological status in the central part of Limfjorden (the worst of five assessment categories), while the western and eastern parts are in bad ecological condition (the second to worst assessment category). When discussing environmental status, both the overall ecological and chemical status are considered. The ecological status is assessed based on biological indicators such as the concentration of chlorophyll in the water, the depth distribution of eelgrass, and the composition of benthic fauna. The Danish Environmental Protection Agency assesses the chemical status of water bodies based on 21 environmentally hazardous pollutants (Styrelsen for Grøn Arealomlægning og Vandmiljø, n.d.).

In Limfjorden, oxygen depletion occurs every summer, typically during periods of weak wind. The frequency and extent of oxygen depletion depend on how many nutrients are supplied to the fjord and how often the bottom water is mixed with the surface water. The mixing of bottom and surface water is driven by wind. Several factors influence the concentration of nutrients in Limfjorden. The input of nitrogen and phosphorus from the catchment area is one factor, as is the extent of water exchange between Limfjorden and the North Sea (Styrelsen for Grøn Arealomlægning og Vandmiljø, n.d.).

The fjord is used commercially for fishing, including fishing with bottom-trawling gear including mussel fishing. Since 2000, aquaculture facilities for blue mussels have been established in Limfjorden (Hoffmann and Bregnballe, 2024). In 2011, the first blue mussel farm received organic certification (DTU Aqua, 2019). There is considerable disagreement about whether mussel farming is beneficial for the ecological condition in Limfjorden.

5.4.2 Case study 2 (Den_2), Northern Jutland

The North Denmark Region is one of five regions in Denmark and functions as the regional authority for 592,513 residents in northern Jutland (Statistics Denmark, 2025). The region covers an area of 7,884 km² and consists of 11 municipalities, with the biggest city being Aalborg. Between 2011 and 2021, the region experienced a population growth of 2%. From 2021 to 2022, there was a sharp increase in population due to a high influx of refugees from the war in Ukraine (Regional Council of North Denmark, 2023). With 74 inhabitants per km², the North Denmark Region is the least densely populated of Denmark's regions (Region North Jutland, 2020a). There are 43 cities with over 2,000 residents, and 30% of the population lives in towns with fewer than 1,000 inhabitants or in rural areas (North Denmark Region, 2020a). The general trend is a demographic centralisation within the region, with youth moving towards Aalborg (North Denmark Region, 2020b).

Northern Denmark has strong transport and digital infrastructure, crucial for mobility and growth. Ports handle large volumes of goods and support industries like offshore energy and tourism, while Aalborg Airport connects the region globally (North Region Denmark, 2020b). The region is defined by water, with the sea on two sides and Limfjorden cutting through the

land. While these are natural assets, they also limit mobility in some areas (North Denmark Region, 2020a).

In 2020, the region had a slightly higher unemployment rate (4.9%) compared to the national average (4.7%). In 2019, it also had a 7% lower share of residents with higher education and a 6% higher share with vocational education than the national average (North Denmark Region, 2023). However, the region has seen positive development in education, with the gap between the regional and national average narrowing over the past decade (North Denmark Region, 2020b). These factors shape the region's innovation profile, which is characterised by practical, industry-driven development and small and medium-sized companies. While the region ranks low in the EU innovation index and has limited R&D investment, many companies still engage in R&D with modest budgets. Aalborg University plays a key role in research commercialisation and collaboration (North Denmark Region, 2018).

Denmark has a long history of aquaculture production, and interviews in Work Package 2 identified northern Jutland as a particularly relevant region for RAS technology. Local producers such as Danish Salmon A/S, Skagen Salmon A/S, and Sashimi Royal A/S were highlighted as profitable users of RAS systems. The production facility of Sashimi Royal A/S was established as part of the RAS2020 research project (2016–2023), which aimed to advance fish farming using best available environmental technologies, funded under the Environmental Technology Development and Demonstration Program by the Danish Ministry of Environment (Danish Ministry of Environment, 2023). A key support of the region's innovation in the sector is the North Sea Science Park in Hirtshals, which brings together key actors in aquaculture and related fields such as fisheries and sustainable energy. Actors include a research hub from the National Institute of Aquatic Resources (DTU Aqua), a department of the Danish Technical University, the aquaculture feed company BioMar, and the technology and research facility of Flume Tank North Sea (The North Sea Science Park, n.d.).

5.4.3 Case study 3 (Den_3), Vejle

Vejle is a municipality in Denmark with a population of about 122 000 located on the Southeast of the peninsula of Jutland. The largest city in the municipality is the city of Vejle with an estimated population of around 60 000 making it the ninth largest city in Denmark. The municipal population density is 116 people per km2 (Danmarks Statistik, 2025).

In terms of general economic characteristics. Vejle is a key logistical center in Denmark due to its central location in Jutland, transport infrastructure, including major highways, rail links, and proximity to Billund Airport and nearby ports, and a strong presence of logistics companies. Historically, industry and manufacturing have played a major role in the city of Vejle's economy. Over the past few decades, however, Vejle has also seen significant growth in creative industries, design, and IT sectors, reflecting a broader shift toward innovation and knowledge-based businesses (Recilient Vejle, 2016).

The average income of residents in Vejle Municipality is above the national average and higher than that of the other comparable municipalities. In addition, Vejle Municipality has a high proportion of outbound commuters. This means that many people choose to live in the municipality but commute to jobs in other municipalities. The labor force has grown in recent years, and the population is well-educated, with 83% of residents in Vejle Municipality having at least a vocational education. In addition, the municipality is experiencing a rising

number of full-time employed foreign nationals, which has increased by 286 over the past year. In 2025, 2.5% of the labor force was unemployed which is the lowest rate among comparable municipalities. Overall, Vejle Municipality has consistently had the lowest unemployment rate among comparable municipalities throughout the period from 2015 to 2025 (Vejle Kommune, 2025)

The waterscape is a key characteristic of the municipality. The city of Vejle is located at the head of Vejle Fjord where Vejle Ådal (Vejle River) and Gjers Ådal (Gjers River) and their valleys converge. The rivers were created during the Ice Age by melting glacier water that slowly wore away the land over thousands of years. The longest river, Vejle Ådal, stretches from Vejle Fjord and 20 km west of Vejle. Along this narrow valley the landscape alters between open heathlands, lakes, dense vegetation, and agricultural lands (Visit Vejle, 2025).

The flowing water has formed the basis for a fish farming culture with the highest concentration of pond farms in the country, a tradition that is still alive today with various types of trout farms in the river valley. There are currently around 20 active fish farms. Most of them are located along the Vejle River itself, though a few are also found along the Grejs River. The production varies and includes hatcheries, fry and fingerling production, as well as fish for consumption, a couple of which are organic (Vejle Kommune, 2023).

The Danish model trout farm (MTF) was an initiative to increase aquaculture sustainability. It was undertaken in the early 2000s based on recommendations from an advisory committee on Danish freshwater aquaculture (Skov *et al.*, 2020).

6 Ireland

6.1 Overview of aquaculture in Ireland

Aquaculture activities occur in a wide spread of coastal areas, and are particularly concentrated in Counties Donegal, Galway, Kerry, Waterford, Wexford and Cork. Irish aquaculture is mainly marine (fish and shellfish) inshore (European Commission, 2016).

Table 14: Overview key headline figures, Aquaculture Ireland 2022 (BIM, 2022)

€125m & €71m *Value of aquaculture sector (finfish & shellfish respectively)*	**2,019** *Total no. of workers directly employed in aquaculture*	**13,900 tonnes** *Volume farmed finfish 2022*	**29,000 tonnes** *Volume farmed shellfish 2022*	**296** *No. of currently active sites*

The value of aquaculture production increased overall by 10% in 2022 (BIM, 2022). In the decade 2009-2019, the overall value of the sector increased from €100 million to €180 million, despite limitations to output. The aquaculture sector in Ireland remains mainly export-driven and marine-based, with a smaller land-based or freshwater aquaculture (DAFM, 2022). There is also an important harvest of wild seaweed with an estimated production of about 29,500 tonnes per year, including 28,000 tonnes of rockweed which is used in the alginate and fertiliser industries (FAO (UN), 2019).

Ireland's marine governance trajectory has followed the broad evolution of objectives of wider EU policy and legislation (Troya *et al.*, 2023). The Irish Government's multi-annual ***National Strategic Plan for Sustainable Aquaculture Development (2022 – 2030)*** (DAFM, 2022), aligns with the EU's 'Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030'. This strategic plan envisages *"a sustainable, profitable, competitive, and market-focused aquaculture industry making the maximum long-term economic and social contribution to coastal communities and Ireland as a whole, while optimising environmental performance and supporting the natural capital upon which it depends"* (DAFM, 2022, p7).

However, a significant gap is evident between policy ambitions and real-world praxis. Renwick (2018) argues that for growth ambitions in Irish aquaculture to be realized, significant regulatory, biological and financial constraints need to be addressed. They point in particular to dysfunctional licensing arrangements, identified as a major constraint on the development of the sector. In addition, Carr (2019) reports that stakeholders view poor communication and narrowly defined remits of different regulatory agencies as root causes of oversight issues in the salmon sector.

"Ireland's aquaculture licensing system operates in a complex and fragmented regulatory environment, subject to various national legislative instruments and EU regulations, and consequently under the remit of various Government institutions." (Troya et al., 2023)

In the case of seaweed cultivation, the establishment of new supply chains involves numerous bottlenecks, including difficulties in licensing, a lack of regulation for seaweed products, social-acceptance of cultivation sites, as well as technical difficulties from offshore systems (Cerca *et al.*, 2023).

6.2 Finfish Aquaculture

Data on registered aquaculture establishments in Ireland were obtained from the Marine Institute. According to the Marine Institute, *"The Aquaculture Establishments listed in the Registers below have obtained either Registration or Fish Health Approval from the Marine Institute. All Registers are published and presented in accordance with the model as outlined in Article 185(2) of Regulation (EU) 2016/429. Registers are kept up-to-date and are made publicly available … by the Competent Authority"* (Marine Institute, 2024).

Table 15: Finfish Aquaculture, by Species, Ireland

Species	No. Farms
Atlantic salmon	71
Rainbow trout	10
Brown Trout	5
Lumpsucker	5
multi species	5
Wrasse	2
Rainbow Trout (marine)	2
Perch	1
Cod	1
Tilapia	1

Table 16: Finfish Aquaculture, by Location, Ireland

County	No. Farms
Galway	31
Donegal	19
Cork	11
Mayo	10
Kerry	5
Tipperary	4
Wicklow	4
Kilkenny	2
Louth	1
Offaly	1
Roscommon	1
Westmeath	1
Wexford	1
Grand Total	**91**

"The salmon industry in Ireland is under severe pressure due to competition from competitor non-EU countries in the organic salmon market which has historically

yielded high prices and thus supported profitability despite the higher cost of production in Ireland" (DAFM, 2022, p28).

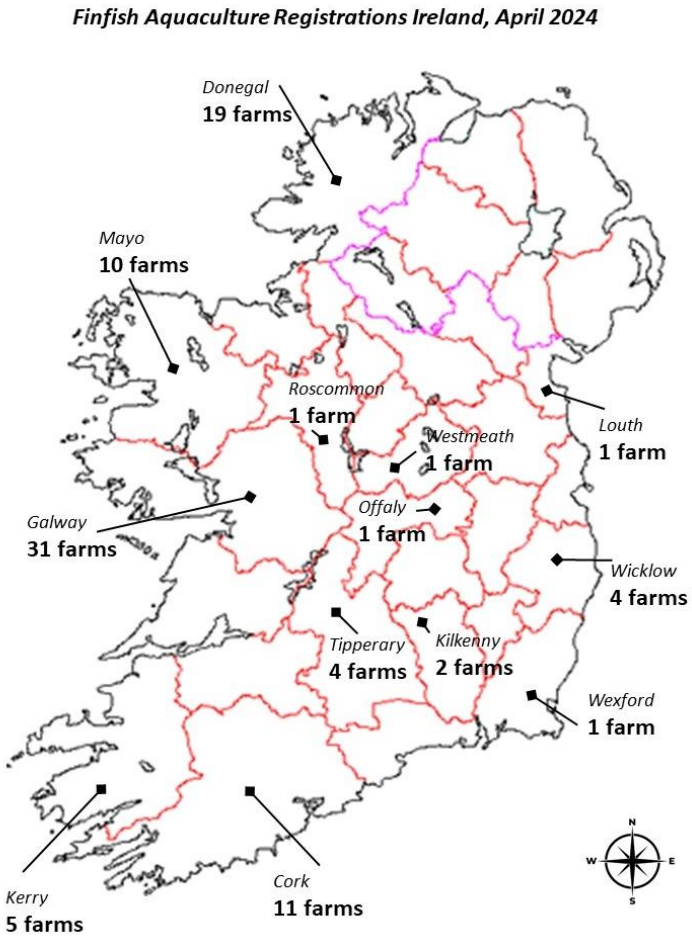

Figure 3: Finfish Aquaculture, by Location, Ireland

6.3 Mollusc and Crustacean Aquaculture

Table 17: Mollusc and Crustacean Aquaculture, by Species, Ireland

Species		**No. Farms**
Pacific oyster	*C. gigas*	221
Blue mussel	*M. edulis*	118
European flat oyster	*O. edulis*	18
King scallop	*P. maximus*	8
Manila clam	*R. philippinarum*	8
Lobster, Prawn, Shrimp		6
Clam	*Clam*	3
Multi-species		3
Abalone	*Abalone*	2
Common periwinkle	*Littorina littorea*	2
Palourde clam	*R. decussatus*	2
Softshell Clam	*M. arenaria*	1
Warty venus clam	*V. verrucosa*	1
Total		393

Table 18: Mollusc and Crustacean Aquaculture, by Location, Ireland

Location	No. Farms
Donegal	75
Mayo	55
Cork	54
Galway	53
Kerry	52
Waterford	28
Clare	24
Wexford	18
Louth	17
Sligo	15
Wicklow	2
Total	393

"Total sale value of pacific oyster (Magallana gigas) in 2020 was estimated at €36.6 million. The increasing use of branding and an attention to quality and food safety management has led to an increased recognition and concomitant increased market penetration of Irish premium oysters into the top end of the markets in China and also more recently in Holland and Belgium" (DAFM, 2022, p31)

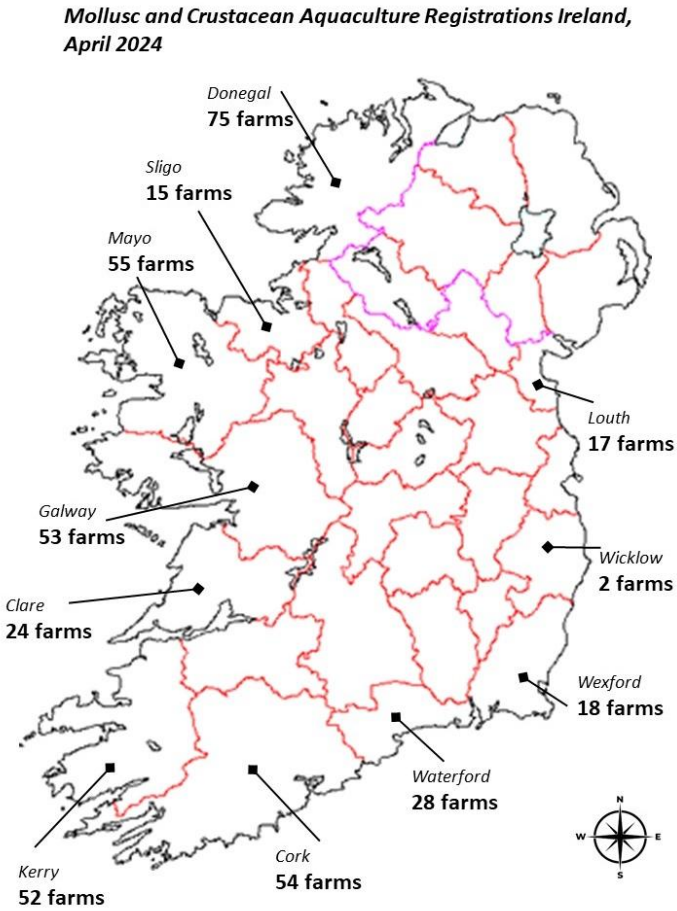

Figure 4: Mollusc and Crustacean Aquaculture, by Location, Ireland

6.7 Summary of case studies - Ireland

The three case studies in Ireland were determined by administrative, county divisions. Including all the islands off of Ireland, there is a total of 7,524 kilometres of coastline in Ireland, and 2,500 km of this is the scenic driving route, the Wild Atlantic Way, along the west coast (Wilderness Ireland, 2025). There are three regional case studies in Ireland, and each is focused to investigate a single, prevalent species produced by aquaculture in the region, and then classified according to a primary and secondary key theme and issue. Figure 5 demonstrates the three regional case studies in Ireland. Case Study 1 (Ire_1) explores Kenmare Bay in the southwest county of Kerry, Case Study 2 (Ire_2) explores west coast counties of Galway and Mayo, and Case Study 3 (Ire_3) is in the North-West region in the county of Donegal.

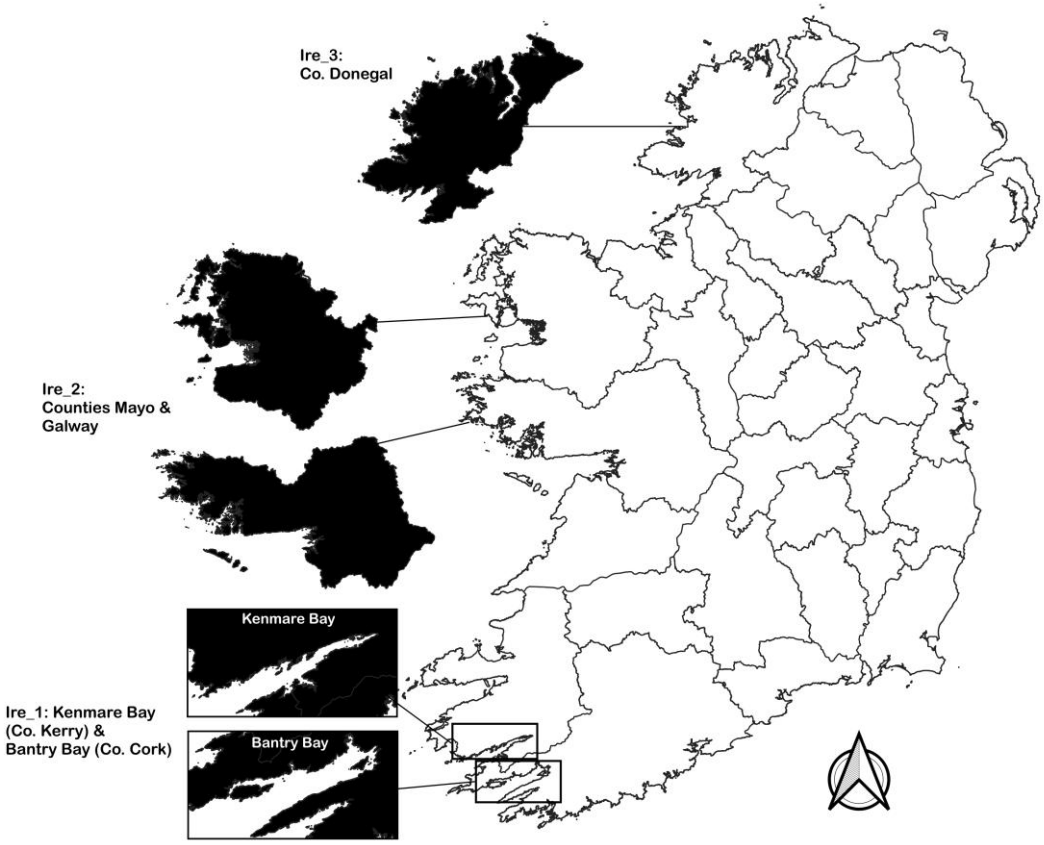

Figure 5: Map of regional case studies in Ireland[4]

Table 19 summarises the case study regions in Ireland and provides details on the species and the key themes investigated. Case Study 1 compares methods and materials of mussel production as well as the scale of production as they relate to economic performance, sustainability and impacts to the environment. Case Study 2 relates to the production of salmon and considers the environmental and social impacts as well as supply chains. Case Study 3 focuses on the regional embeddedness and social licence of oyster production, as well as the differences between the culture of native versus non-native oyster species.

[4] More detailed maps showing Salmonid farms at these hubs can be seen @: https://www.marine.ie/site-area/areas-activity/aquaculture/locations-salmonid-farms

Table 19: Summary of case studies - Ireland

Name	Ireland Case Study 1	Ireland Case Study 2	Ireland Case Study 3
Code	**Ire_1**	**Ire_2**	**Ire_3**
Region	**Kenmare Bay (Kerry) Bantry Bay (Cork)**	**Counties Galway & Mayo**	**Co. Donegal**
Species	***Mussels***	***Salmon***	***Oysters***
Size of region	**146**	**149**	**94**
Primary theme	Eco-production	Social licence	Regional embeddedness
Secondary theme	Economic performance	Eco-production	Economic performance
Environmental Aspects	Habitat, Materials (plastic/cotton)	Disease, water quality (inland and coastal), ecosystem	Invasive species
Social Aspects			Family businesses
Economic Aspects	Scale of production		
Features	Organic mussel farms	Organic salmon farming	Economic importance
Focus	Comparison between production methods - bottom vs off-bottom culture, and small vs large scale.	Organic Production, Environmental Quality & Animal Welfare. Source of smolt supply.	Social embeddedness & licence. Traditional native species producers and non-native species producers.

6.7.1 Case study 1 (Ire_1), Kenmare Bay (Kerry) and Bantry Bay (Cork)

Case study 1 in Ireland investigates mussel production in Bantry Bay in County Cork and Kenmare Bay in County Kerry in the southwest of Ireland. County Kerry is the most westerly region in the southwest of Ireland, with an area of 4,807 km^2, and is known for its natural beauty, mountain range, lakes and 885.7 kilometres of rugged Atlantic coastline of peninsulas with sea cliffs and small islands (Costello, 1999). The county is a popular tourist destination for nature enthusiasts due to its scenic beauty and areas such as the Dingle peninsula, Killarney national park, the Ring of Kerry, the Beara Way and the UNESCO world heritage site, Skellig Michael. According to the census, the population of County Kerry in 2022 was 156,458, up by 6% from 2016, as opposed to the national increase of 8%. Tralee is the most populous town (26,079), followed by Killarney (14,412) and then Listowel (4,794), the population density in County Kerry is 32.5 per km^2 (CSO,2022). The economy is predominantly dependent on tourism (over €400 Million/year), while there is also wholesale and retail, agriculture and manufacturing. Urban areas in Kerry are experiencing growth, but there are also areas in decline as Kerry is mostly rural.

County Cork is a largest county in Ireland in terms of landmass (7,500 km^2) in the southern-most region of Ireland with a coastline of 1,198.5 km. It is known for its rivers, fertile lowlands, mountains and coastlines with small islands. According to the census, the population of County Cork in 2022 was 584,156, and it is the third most populous county on the island of Ireland (after Dublin and Antrim in Northern Ireland). Cork city is the most populous (224,004), followed by Carrigaline (18,239), Cobh (14,148) and Midleton (13,906), the population density in County Cork is 77.5 per km^2 (CSO,2022). The main industries in the county are pharmaceuticals, technology, financial services, agriculture and there are many multinational companies in Cork. The Munster region in Ireland (which includes Kerry and Cork) is considered the richest in the EU based on having the highest gross domestic product (GDP) per person in all of the EU in 2022 (Cork County Council, 2025).

The study site was focused on Bantry Bay in County Cork and Kenmare Bay in County Kerry to explore mussel production, which is prevalent in the regions, and compare the differences between the methods used (either bottom or off-bottom culture), the materials used and the differing scales of production and some of the challenges and drivers of adopting innovative procedures and how these influence on various measures of sustainability. Also considered are the links to water quality and the perspectives related to impacts to the environment and due to climate change and governmental supports.

6.7.2 Case study 2 (Ire_2), Counties Galway and Mayo

Case study 2 in Ireland covers the counties of Galway and Mayo on the mid-western coast. County Galway is known for its scenic beauty, the mountains of Connemara, Aran islands, the Burren and its coasts, including Killary fjord which borders County Mayo. It spans 6,148 km^2 with a long coastline of 1,086 km. Galway is a very popular tourist destination for its traditional music, festivals, cultural events and food, and it is the second most visited county after Dublin for both overseas and domestic tourism. Tourists spend €754 million annually. According to the census, the population of County Galway in 2022 was 277,737, with 85,910 living in Galway City located in the harbour, with projections of increasing by 50% in the next fifteen years to 122k (Western Development Commission, n.d.). Following Galway city, the largest towns are Tuam (9,647) and Ballinasloe (6,597), the population density in County Galway is 45 per km^2 (CSO, 2022). The main industries in County Galway are medical technology and ICT, manufacturing, tourism. construction, retail and wholesale, professional, science and technology.

County Mayo borders Galway to the north encompassing an area of 5,351km^2 with 1,168 kilometres of Atlantic Ocean coastline which borders Mayo to the west and north, with high sea cliffs (City Population, 2022). The largest island off of Ireland, Achill Island, is off of the coast of Mayo. The population in Mayo is 137, 970 with the largest towns being Castlebar (13,054) and Ballina (10,556), the population density in County Mayo is 24.7 per km^2 (CSO, 2022). The main economic sectors in Mayo are tourism, agriculture and marine industries, with an outlook to expand its blue economic development and attract investment into its extensive coastal zone (Mayo County Council, 2020).

There are high levels of salmon aquaculture in the case study 2 region, as well as conflict with environmental and community groups. To be investigated are perspectives regarding the eco-production and social acceptance of salmon farming in open cages as well as the environmental and water quality impacts, animal welfare issues, diseases and the organic nature of salmon production. Also explored are how these relate to sustainability as well as that of smolt and sprat feed supply for salmon.

6.7.3 Case study 3 (Ire_3), County Donegal

Case study 3 focuses on County Donegal in the north-west of Ireland. County Donegal's 4,860 km^2 of area is known for its mountain ranges, a long 1,134 km mainland coastline with high sea cliffs and remote landscapes (Costello 1999). There is a relatively lower disposable income per capita compared with Ireland's other counties, and there are areas with high unemployment rates. The main industries are agriculture, tourism and technology, with a tradition of marine engineering. According to the census, the population of County Donegal in 2022 was 167,084, and the largest towns are Letterkenny (22,549) and Buncrana (6,971), the population density in County Donegal is 34.4 per km^2 (CSO, 2022). Oysters are the aquaculture product to be investigated for this case study. The themes relate to the economic performance and regional embeddedness in the region as well as the impacts and drivers of production of non-native, *Gigas*, Pacific oyster species. These are considered in terms of

regional embeddedness and social licence, and the impacts and activism related to invasive species as well as to family businesses and traditional native species producers.

7 Italy

7.1 Overview of aquaculture in Italy

Italy has a coastline that spans 9,136 km, which amounts to 8.75% of the EU total coastline. Aquaculture in Italy has long traditions and is characterised by large-scale production and specialisation (Eurofish 2023). Aquaculture (and fisheries) constitute a small share of GDP, but are important sectors in certain regions. The density of aquaculture activities is highest along the Adriatic coast, especially in the north. Italy is among the four largest aquaculture countries in the EU.

Table 20: Key numbers for the Italian aquaculture industry. Sources: Eurofish (2023), Acquacoltura.org (2024), (CREA 2023)

€304.5[5]m finfish €271.0 shellfish	**Approx. 4500**	**Approx. 54,400 tonnes**	**Approx. 85,400 tonnes**	**About 700 active plants (60% in the North, 15% in the Centre and 25% in the South.)[6]**
Value of aquaculture sector	*Total no. of workers directly employed in aquaculture*	*Volume farmed fish sold*	*Volume other species sold*	*No. of currently active sites*

More than 30 species are produced in the Italian aquaculture sector. The traditional way of farming, which dates back to Roman times, occurs in brackish lagoons ("valli"), especially in the North-East of the country. Modern aquaculture techniques are used both for sea- and freshwater-based farming. This includes onshore farms, cage systems (sea), and the use of ropes and bags to cultivate mussels. Clams are farmed directly in intertidal substrates (Eurofish 2023).

Table 21: Production of aquaculture sector in Italy 2023. Source: Acquacoltura.org (2024)

Species	Onshore and offshore installations (tonnes)	Valley and brackish plants (tonnes)	Total (tonnes)	Value – Gross sale production value (.000 euros)
Sea Bass	6.000	300	6.300	54.200
Sea Bream	10.500	250	10.750	89.200

[5] This value does not include the production of alevin and embryonated eggs (€41m) (Source: https://www.acquacoltura.org/dati-produttivi-2023/). Also, the value of caviar and trout eggs for human consumption production is not included. Italy is the largest European producer of caviar (62 tonnes), and at the second position in the world after China. Italy produces more than 22% of the global production of a caviar (https://www.businesscoot.com/it/studio-di-mercato/il-mercato-del-caviale-italia). The production of embryonated eggs is 40 tonnes (CREA 2023)

Croaker	300		300	2.400
Eel	300	100	400	6.400
Mullet		2.500	2.500	8.200
Trout	30.150		30.150	117.900
"Spring" Char	900		900	4.700
Catfish	300		300	1.950
Carp	550		550	2.900
Sturgeon*	1.050		1.050	5.250
Other Species**	1.200		1.200	11.400
Total	**51.250**	**3.150**	**54.400**	**304.500**

**caviar not included*

*** red "corba", largemouth bass, arctic char, bream, amberjack, tench, whitefish, grayling, pike, etc*

Table 22: Production of shellfish farming in Italy (2021). Source: (CREA 2023)

Species	Volume (tonnes)	Value (.000 euros)
Philippine clam	23,053	211,808
Native clam	29	433
Mediterranean mussel	61,921	55,698
flat oyster	5	295
and concave oyster	346	2,716
Total	85,354	270,950

Table 23: Distribution of aquaculture farming plants in Italy 2022.[7]

Region	Crustaceans	Molluscs	Finfish	Total
Abruzzo	3	9	62	74
Basilicata			14	14
Calabria		2	7	9
Campania		81	55	136
Emilia Romagna	9	194	322	525
Friuli Venezia Giulia	2	89	122	213
Lazio	3	13	108	124
Liguria	1	10	18	29
Lombardia	4		340	344
Marche	1	26	69	96
Molise	3	7	13	23
Piemonte			387	387
Puglia	4	143	26	173
Sardinia	8	62	30	100
Sicily	1	4	15	20
Tuscany		2	193	195
Trentino – Alto Adige	5		190	195
Umbria			78	78
Valle d'Aosta			12	12
Veneto	7	582	343	932
Total	**51**	**1224**	**2404**	**3679**

Statistics and overviews for the Italian aquaculture sector differ with regards to scope. For example, Eurofish (2023) puts the total number of aquaculture enterprises (note however that this includes hatcheries, sites for fattening for consumption, sport fishing lakes and nurseries) in 2021 at 3,463, most of which have less than 5 employees. Most of the enterprises are according to this source found in the regions of Veneto, Emilia-Romagna, Piedmont and Lombardy. This is supported by the overview in Table 23, which puts the total number of

[7] Analisi del settore ittico italiano (2023) from data BMTI and «Sistema Informativo Veterinario-Anagrafe Nazionale Zootecnica».

plants in 2022 at 3679. Veneto appears to be a clear hub in terms of farms (for molluscs and fish), whereas both Emilia-Romagna and Puglia have many shellfish farms (Eurofish 2023). The NSPA (EC n.d.) provides different numbers, which are (probably) restricted to fish farming plants: 504 enterprises in 2021, and a total employment of 4,488 in 2017.

Table 24: Geographical and sectoral distribution of aquaculture 2019 and 2020[8]

	2019			2020		
Plants (number)	**663**			**618**		
Geographical distribution						
North	*444*			*406*		
Central	*68*			*70*		
South and islands	*151*			*142*		
Breakdown by sector						
Molluscs	363			357		
Fish	309			269		
Crustaceans	2			2		
National production (tonnes)	**132 312**			**122 760**		
Geographical distribution						
North	*86 915*			*80 499*		
Central	*22 670*			*21 958*		
South and islands	*22 727*			*20 303*		
Breakdown by sector						
Molluscs	*78 614*			*74 990*		
Freshwater fish farming	*41 396*			*36 483*		
Marine fish farming	*12 297*			*11 287*		
Crustaceans	*4,6*			*0,5*		
Main species produced and contr. to national sector (tonnes, %)						
Molluscs	**t**	**% sector**	**% (ITA)**	**t**	**% sector**	**% (ITA)**
Mussel (*Mytylus galloprovincialis*)	52 547	66,8	39,7	50 338	67,1	41,0
Phillipine clam (*Ruditapes philippinarum*)	25 907	33,0	19,6	24 337	32,5	19,8
Fish						
Rainbow trout (*Oncorhyncus mykiss*)	37 340	69,5	28,2	33 231	69,6	27,1
Gilt-head bream (*Sparus aurata*)	6 783	12,6	5,1	6 201	13,0	5,1
Seabass (*Dicentrarchus labrax*)	4 948	9,2	3,7	4 693	9,8	3,8
Sturgeon (*Acipenseridae*)	1 301	2,4	1,0	1 125	2,4	0,9
Eel (*Anguilla anguilla*)	464	0,9	0,4	222	0,5	0,2
Value of production (mill. €)	**446**			**392**		
Molluscs	*213*			*187*		
Fish	*233*			*205*		

Updated data on the regional distribution of aquaculture production in tonnes and value per species were difficult to identify.[9] Bianchini *et al.* (2013) provide an overview of (ocean) mariculture activities in Italian regions. The five main regions in terms of numbers of fish farms according to this paper were Sardinia, Apulia, Veneto, Tuscany, Venetia Giulia and Sicily.

[8] ISPRA processing on MiPAAF-CREA, EUROSTAT data

[9] Overview from 2001: https://www.fao.org/4/a0141e/A0141E03.htm

7.2 Finfish Aquaculture

In terms of volume and value, rainbow trout is the main species in Italian aquaculture, followed by sea bream and sea bass (Acquacoltura.org 2024). While the latter two are salt-water species, rainbow trout is farmed inland. According to Maiolo *et al.* (2021) there are around 310 freshwater farming companies in Italy, and most of these produce rainbow trout in monoculture flow-through systems (concrete raceways or earthen ponds). This production method is especially present in the North-East. According to (ibid.), there are ca. 20 large integrated companies, which account for approx. 60% of the total domestic production of rainbow trout. The bulk of companies producing trout are thus very small. The distribution of rainbow trout farming in the Trentino-Alto Adige region in the north demonstrates many small sites along rivers and streams.

7.3 Mollusc and Crustacean Aquaculture

Italy is a significant producer of mollusc (mussels and clams) (Tudini and Forgione 2024), whereas the production of crustaceans (in Italy: shrimps, prawns and crayfish) is very limited[10]. In 2020, the total volume of shellfish was approx. 75000 tonnes, at a sales value of approx. €186 million (Commission *et al.* 2023). According Tudini and Forgione (2024), mussel production faces economic challenges whereas clam production thrives. Another source (based on MASAF-CREA data) suggests that total shellfish production (farming) in 2021 was at 85,300 tonnes, of which 72% mussels and 27% clams. The farming of other species, such as oysters, is marginal (Tudini and Forgione 2024). The value of the production was divided as such: 78% for clams and 21% for mussels.

7.4 Summary of case studies - Italy

To identify case studies in Italy, we have considered various information from secondary sources and the number of aquaculture localities. The boundary setting for ‘regions’ is flexible. It can be synonymous with an administrative region, but can also encompass a broader geographical area (e.g. the ‘North-East’). As seen, different forms of aquaculture exist along the entire coast of Italy and its islands, and also inland in freshwater systems. The aquaculture sector is most prominent in the North, and especially along the Adriatic coast as well as in inland areas in the north-east (freshwater). In summary, the classification of aquaculture case-studies in Italy should consider both the type of farming/product and the geographical area.

Shellfish farming (mainly clams and mussels) is the most important aquaculture industry in terms of volume, and it is practised along the entire Italian sea cost, but some specific sites concentrate the most relevant shares of production (e.g. Veneto mainly for clams, and Emilia Romagna for clams and mussels).

Finfish farming is an important aquaculture activity in terms of value. It is practised in all Italian regions, particularly in Northern Italy. The main regions are Veneto, Emilia Romagna, Piedmont, Lombardy, Trentino-South Tirol and Friuli Venezia Giulia. Fish farming in Italy includes various species. The main species are trout in fresh water, and sea bass and sea bream in marine and brackish waters.

[10] https://www.fao.org/fishery/en/countrysector/it/en

The location of farming is still affected by the historical roots of national aquaculture, characterized by valley farming in the North regions (Piedmont, Lombardy, Veneto, Emilia Romagna, Trentino-Alto Adige and Friuli Venezia Giulia), stag farming in central (Tuscany) and insular Italy (Sardinia), and by shellfish farming in the Adriatic (Veneto, Emilia Romagna and Marche) and Apulia.

On this basis we suggest three regional case-studies in Italy. The geographical and sectoral (species) scope of these can be defined in different ways. It may be concentrated to one administrative region per case-study or cover two or more. The 'boundary-setting' may also rely on which types of aquaculture to include in which cases. Figure 6 provides an overview.

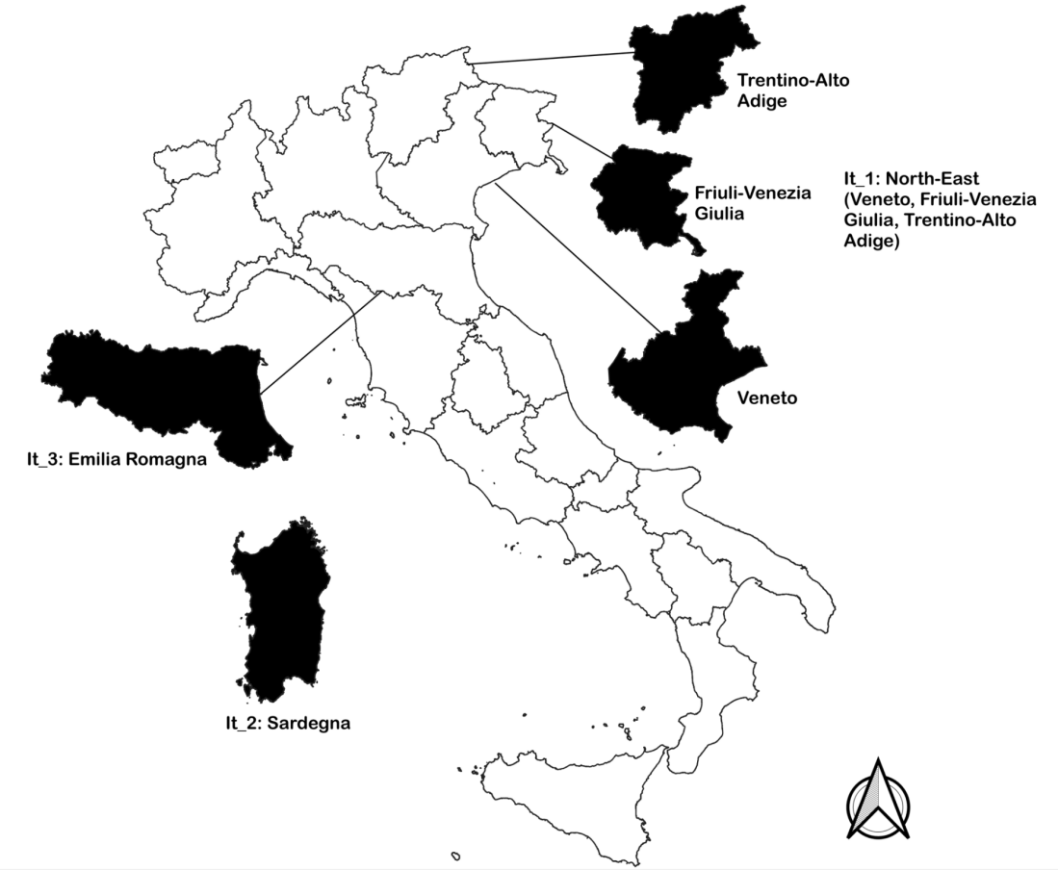

Figure 6: Map of regional case studies in Italy

7.4.1 Case study 1 (IT_1), North-East: Veneto

North-Eastern Italy is normally defined as consisting of the regions Friuli Venezia Giulia, Veneto, and sometimes Trentino. As this is a relatively large area with varied characteristics, the case study will focus on the Trentino province and the Veneto region. These are among the main regions in Italian freshwater aquaculture, together with Friuli Venezia Giulia and Lombardy. Trentino is one of two provinces in the autonomous region of Trentino-Alto Adige/Südtirol, but most of the aquaculture activities in the region take place in Trentino. Trentino neighbours Veneto, and there is frequent interaction between firms in these areas. Therefore, it is natural to study the trout farming of the Trentino and Veneto as part of the same case study.

Trentino is a landlocked and mountainous province, while Veneto has a long coastline, as well as mountainous areas and plains with rivers of various size. In the Po-river delta in the

Veneto region there is significant shellfish farming, in particular clams (Tamburini *et al.* 2022), including traditional aquaculture practices[11] as well as the use of more modern techniques. However, the case study will focus on freshwater aquaculture – in particular trout farming, which is the main freshwater species farmed in Italy.

Trentino had a population of 542 050 people per January 2023. The province stretches over an area of 6,212 km^2, about 80% of which are mountainous areas. The population density is highest in the Adige valley, where the regional capital Trento (118 360 inhabitants) and the second largest city, Rovereto (35 730 inhabitants), are located. The rest of the province is more sparsely populated. Trentino has low unemployment rates and relatively high average incomes (OECD 2023). The average annual salary in Trentino is 20.738 euros (Camera di Commercio 2023). The region has a mixed industry structure, with trade and business services making up the major share. Trentino's manufacturing industries have shrunk in terms of employment, but made a successful move from traditional manufacturing to high-tech sectors (OECD 2023). Agriculture still has a role to play in the regional economy – with apples and grapes (wine) being the main products. Furthermore, tourism also gives a noteworthy contribution, especially to employment in the less urbanised parts of the province.

With its 18 345 km^2 and 4 849 553 inhabitants (Istat 2022), the Veneto region is much larger and more populous than the Trentino province. More than half the region consists of plains. The rest is split between mountains and hills. Veneto has several larger cities, most notably Venice (254 000 inhabitants), Verona (257 000 inhabitants) and Padova (208 000 inhabitants). About 20% of the population lives in urban areas. However, there is also a significant share that lives in "hinterlands", which can have mixed land-use between residential areas, light industry, agriculture and aquaculture.

Similarly to Trentino, the Veneto region also has low unemployment rates (Regione del Veneto 2024). The annual average income is 23.691 euros, which is relatively good compared to many other Italian regions, although well behind the regions with the highest average incomes (Lombardy and Lazio) (Veneto Economia 2024). Similarly to other western economies, the tertiary sector is the biggest sector also in the Veneto region. However, the region has a relatively high share of industry activities for being in Western Europe. Key industrial sectors are fashion and furniture and mechatronics and metal (Regione del Veneto 2012). Machinery and fashion are the region's largest categories of export, followed by chemistry and materials, and agri-foods (Regione del Veneto 2020). In fact, agriculture and food processing are also important to the regional economy. In addition, tourism is important. SME's make up the majority of firms in the region, counting for 99,8% of all firms in industry and services (Regione del Veneto 2020).

Both the Veneto region and the Autonomous province of Trentino have significant aquaculture sectors. In Veneto, molluscs are the major product, followed by finfish (Eurofish 2023). This includes both marine and freshwater aquaculture. Being landlocked, aquaulture in Trentino is exclusively farming of freshwater fish (Maiolo *et al.* 2021). The North-East, including Veneto's neighboring region Friuli Venezia-Giulia, is a national hub of freshwater aquaculture, where trout is the main species. This production is based mostly on rivers and streams, and in some cases on natural freshwater springs. Most farms are relatively small, with some notable exceptions. In spite of the small average firm size, as there are many

[11] https://www.cbc.ca/news/world/po-river-italy-shellfish-harvesting-industry-1.6767357

producers, in total, trout is Italy's second largest aquaculture output (Cai, Galli, and Zhou 2022). A large share of this production takes place in the North-East. In the North-East, there are multiple networks of knowledge exchange, as well as cooperatives such as ASTRO (Trento), and active interaction with the interest organisation Associazione Aquacultori Italiani (API), which has its main office in Verona (Veneto). While some farms still have on-site slaughtering facilities, in general fish slaughtering and processing has increasingly been consolidated at fewer and larger plants.

The major environmental and resource questions of trout farming in North-Eastern Italy are linked to water and feed. Where water comes from rivers, there can be competition for water with other water-intensive activities such as agriculture. However, compared to marine aquaculture, there is little evidence of water being polluted by trout-farming. Water is channelled into concrete basins, where the farmed fish lives separately from the river- and lake ecosystems. The water goes through a combination of mechanical and biological purification before being released again to the rivers.

No significant conflicts with local communities were reported or observed. However, some contrasting information was given regarding employees and recruitment. Some firms reported that it was easy to find employees among locals in their "original" communities, while others reported that there is low interest in working with aquaculture, and that they therefore mainly recruit their employees in immigrant communities located across Italy.

7.4.2 Case study 2 (IT_2), Sardinia

The second Italian case study (IT_2) explores Sardegna, or Sardinia, the second largest island in the Mediterranean, separated from the mainland of Italy by the Tyrrhenian Sea portion of the Mediterranean Sea. Sardinia encompasses an area of over 24,090km^2 of mostly hills and mountain regions surrounded by 1,849 kilometres of coastline (Circa BC, 2024). The total population of Sardinia is 1,561,339 with the capital city of Cagliari being the most populous (146,627) followed by Sassari (120,497 and Quartu Sant'Elena (68,108) (City Population, 2025). Sardinia's economy depends on tourism, agriculture, and livestock breeding, and it is considered one of Italy's poorest regions with a high unemployment rate and an ageing population due to emigration of its younger workforce (World of Info, 2025).

Shellfish makes up the majority of the aquaculture produced in Sardinia, mainly mussels, oysters and clams. In 2020, Sardinia aquaculture was valued at €66 million, which accounts of 15-20% of Italy's aquaculture production. Between 2016 and 2019, the number of farms increased from 31 to 51, and between 2014 and 2023, the number of aquaculture employees increased from 265 to 700. There is room for growth and development in aquaculture but that, according to their national Strategic Plan for Aquaculture and National Biodiversity Future Centre, protecting their biodiversity is essential due to the importance of tourism. There are challenges related to climate change, as well as bottlenecks related to stakeholder collaboration (Fish Site, 2023).

The case study focuses on innovations and particularly integrated multi-trophic aquaculture (IMTA) as a form of restorative aquaculture using native species, rather than a single species. The study compares IMTA with traditional aquaculture in the region in terms of the environmental and ecosystem aspects, and how these may build resilience into a geographical area that is experiencing warming seas and direct impacts of climate change. Also relevant is understanding the region's cultural and societal acceptance of innovations and the relationship

between stakeholders such as government entities, farmers and marine research and how this influences change and implementation of innovations.

7.4.3 Case study 3 (IT_3), Emilia Romagna

The third regional case-study in Italy is Emilia-Romagna, which is Italy's largest mussel producing region (Robert *et al.* 2013, European Commission 2022). Emilia-Romagna has a combination of different landscape types, with the Apennine mountain chain running along the southern regional border, river plains along the north, and smooth hills along most of the coastline, with the exception of the Po-delta, which consist of a unique wetland ecosystem. With its area of 22 446 km2, Emilia Romagna is a relatively large region. 4 425 366 inhabitants were counted in the 2021 census (Istat 2022). The highest population densities can be found in the plains, where the larger urban centres are located – most notably Bologna (390 945 inhabitants), Parma (195 717 i.) and Modena (185 693 i.). The coastline is also relatively densely populated, with a line of smaller urban centres along the coast. Since the 1970's, a lot of construction has taken place in the coastal areas, especially linked to tourism activities.

The level of occupation is 70,6% for the entire regional population, which is almost 10% higher than the Italian national average (Regione Emilia Romagna 2024). The work participation rates are notably higher among men than among women. The average income in Emilia Romagna is 25.880 euros, which is the third highest among all Italian regions (Regione Emilia Romagna 2024). However, within the region the highest income levels are found in the major cities and their surrounding areas. The situation is a bit different along the coastline, where fisheries and marine aquaculture are located. Here the income levels range from the regional median and downwards.

Emilia Romagna has important specialisations in the secondary sector - most notably in machinery and vehicle production (especially packaging and automotive), ceramic products, textiles and food processing (Invest in Emilia Romagna n.d.). Furthermore, the region has developed to become a centre for big data in Italy and is thus developing its industrial base towards recent technologies. Emilia Romagna is also an important agricultural region, and, like much of Italy, tourism and service industries are important. Tourism is concentrated in the historic cities and along the coastline, which is a classical beach tourism destination, especially among domestic tourists.

The key aquaculture sectors in Emilia Romagna are mussel production and eel. While eel is a more specialised product, mussels are cultivated at a large scale along the coast. Mediterranean mussels are among Italy's main aquaculture outputs (Cai, Galli, and Zhou 2022). Mussel production take place in different parts of the coast, but with major concentration in Veneto, Emilia-Romagna, Marche, Apulia and Sardinia. Italian mussel production has decreased over several years, and the sector is reported to suffer from low profitability (European Commission 2022). Among other factors, this has been linked to low organisation among the producers, and a large share of the profit being left in other parts of the value chain. In Emilia Romagna and Veneto, mussel producers are organising towards vertical integration of the value chain – in particular with the aim to take control of purification and processing. Mussel producers in Emilia Romagna are organised through the Consorzio Miticoltori dell'Emilia-Romagna.

Organic production can be another approach to increasing the profitability of mussel aquaculture. Organic mussels have a price premium. Most of the organic mussel farms in Italy are located in Veneto or Emilia Romagna (Pulcini *et al.* 2020). The European Commission

(2022) reports that organic mussels are not valued in the Italian market – often being sold as "regular mussels - and that producers of organic mussels therefore focus on the French market. Yet, there were 9 organic mollusc farms in Emilia Romagna in 2015. Their production volumes were increasing, indicating that organic production may represent a viable business model.

Finally, where the natural conditions allow for it, clam production may be a more profitable alternative to mussel production. Therefore, different options within mollusc aquaculture may be investigated as part of the research on the Emilia Romagna aquaculture regional case-study.

Table 25: Summary of case studies – Italy

Name	Italy Case Study 1	Italy Case Study 2	Italy Case study 3
Code	**IT_1**	**IT_2**	**IT_3**
Region	**North-East: Veneto, Friuli-Venezia Giulia, Trentino-Alto Adige**	**Sardegna**	**Emilia Romagna**
Species	**Trout** (possibly mussels as secondary species)	**Integrated**	**Molluscs (Mussels)**
Scale of activities	655 finfish plants (can statistically expect at least half to be trout)	51 aquaculture farms in 2019	197 mollusc plants (Largest mussel producing region in Italy. Second largest according to others.)
Primary theme	Economic performance (viability & competitiveness)	Eco-production	Eco-production (including organic)
Secondary theme	Environmental quality	Ecosystem services and environmental quality	Social licence
Environmental Aspects		Native species and restorative aquaculture. Local interest and advocacy.	
Social Aspects		Cultural aspects and the level of acceptance, support and trust by farmers.	
Economic Aspects		Resilience and sustainability due to increased issues with climate change (e.g. mussels). Financial/state support to implement, train and experiment with scaling-up.	
Features	River-based flow-through systems. "Protected Geographical Indication" for parts of the hub. Local emissions and eutrophication have been an issue.	Integrated multitrophic aquaculture (IMTA). Link to 'Blueboost' SBEP project.[12]	Major mollusc producing region
Focus	Social vs. Environmental sustainability	Innovation (RAS, IMTA, River-based flow through etc.)	
Established?	Established	Established	Established

[12] https://bluepartnership.eu/projects/project-title-culture-wide-range-low-trophic-species-boost-sustainable-production-blue ; https://www.blueboost.eu/

8 Investigating the 'triple-bottom-line of sustainability' across the case-studies

The 12 case studies will focus on the environmental, economic and societal pillars of sustainability, and specifically the following key themes either singularly or in combination to best investigate the sustainability of aquaculture in each regional case-study:

- **Eco-production (including organic)**
- **Environmental quality**
- **Social licence**
- **Economic performance (Energy, viability & competitiveness)**
- **Innovation (RAS, IMTA, Circular value chain, River-based flow through etc.)**
- **Animal welfare**
- **Regional embeddedness**
- **Nutrition & Well-being**

The interactions and combinations of these themes, as well as how they influence the balance of environmental, economic and societal concerns will become more defined and clearer during the semi-structured interviews, which constitute the next phase of this study in building a rich qualitative dataset. Following the baseline study, the case studies have been narrowed down to the primary and secondary themes in Table 26.

Table 26: Summary of regional case studies

Case study code	Region name	Species	Primary theme	Secondary theme
Nor_1	Vestland	Salmon	Animal welfare	Environmental quality
Nor_2	Trøndelag	Molluscs	Economic performance	Eco-production
Nor_3	Nordland	Cod	Economic performance	Social licence
Den_1	Limfjorden	Blue Mussel	Regional embeddedness	Eco-production
Den_2	Northern Jutland	Salmon/king fish	Innovation	Eco-production
Den_3	Vejle	Rainbow Trout	Eco-production	Economic performance
Ire_1	County Cork & Kerry	Mussels	Eco-production	Economic performance
Ire_2	County Galway & Mayo	Salmon	Social licence	Eco-production
Ire_3	County Donegal	Oysters	Regional embeddedness	Economic performance
IT_1	North-East: Veneto	Trout	Economic performance	Environmental quality
IT_2	Sardinia	Integrated	Environmental quality	Eco-production
IT_3	Emilia Romagna	Mussels	Eco-production	Social licence

In the Norwegian case studies, there are environmental quality and environmental welfare issues related to salmon farming in the Vestland region. Case study 1 (Nor_1) will also look into social embeddedness and environmental sustainability related to salmon. For case study 2 (Nor_2), the Trøndelag region is the biggest producer of mussels in Norway, and so mollusc production and its economic performance as well as eco-production methods will be investigated. For Case study 3 (Nor_3), in the Nordland, Lofoten/Vesterålen regions, there are issues between wild caught fisheries and farmed cod fisheries, and so the biological and economic conflicts will be investigated. There are social licence challenges to be investigated as well as economic performance and environmental challenges.

In the Danish case studies, Blue Mussel production will be investigated in terms of eco-production and regional embeddedness of production in the regional inlets and fjords for case

study 1 Den_1). The second case study (Den_2) will look at the innovation and eco-production methods of salmon and king fish in RAS facilities as three of the five largest RAS facilities are in the Limfjorden region of Denmark. In the Vejle case study (Den_3), the economic performance and the eco-production of rainbow trout in traditional land-based facilities will be investigated, as this region has the largest organic production facility in Denmark.

In the Irish case studies, Blue Mussel production will be investigated for case study 1 (Ire_1) in the Cork and Kerry counties, with a comparison between Kenmare Bay (Kerry) and Bantry Bay (Cork) in terms of the economic performance and eco-production methods. Also considered is the scale of production and the differing methods and materials used. Ireland's second case study (Ire_2) will investigate salmon production in Galway and Mayo Counties. There is local community and national conflict in terms of open case production methods, the claim that organic production still uses chemical, and in terms of disease, animal welfare and impacts on natural ecosystems. Social licence and eco-production will, thus, be investigated. For case study 3 (Ire_3) in the Donegal region, oysters and the regional embeddedness as well as economic performance will be investigated. There are societal and environmental issues related to the production of invasive species the *Gigas*, pacific oyster versus the farming of native species of oysters.

For the Italian case studies, the Veneto region (IT_1) will investigate trout production in terms of economic performance and its viability and connectiveness. Also considered will be the impacts on environmental quality and the river-based flow-through systems. There are 'protected geographical indications' in this region, and eutrophication and local emissions are an issue. For the Sardinia case study (IT_2), integrated multi-trophic aquaculture (IMTS) research into farming native species is showing promise in terms of restorative aquaculture, and so innovation as well as ecosystem services and environmental quality will be investigated. Also considered is the potential of uptake by local farmers. The third case study, (IT_3) will investigate Mussel production and the eco-production methods as well as social licence in the Emilia Romagna region.

It was important to narrow down the focus into the key themes that have been identified as an issue or unique activity within each case study region. By identifying the challenges, successes or bottlenecks to growth or sustainability in aquaculture for that particular species being farmed, it will help facilitate the in-depth understanding of the nuances of these barriers. These can also help identify and fill in gaps in knowledge to other regions.

9 Conclusions

Completion of this Deliverable 1 of Work Package 1 provides a strong foundation upon which to build the work for the ensuing deliverables.

9.1 Main results

The main results based on the baseline studies of aquaculture in Norway, Denmark, Ireland and Italy and their regional hubs, is the determination of the 12 regional case studies, and the species and themes to be investigated. In conducting the desktop research into the political and topographical geography, trends, governance, policies and objectives in aquaculture in Europe and the consortium countries has informed the mapping and delineating of the three regional case-studies in each country. The Atlantic northeastern aquaculture will be

investigated in the Norway and Irish coasts, its North Sea region will be investigated in Denmark, and the Mediterranean Sea aquaculture will be investigated by understanding production in Italian waters. The assessment and characterisation narrowed the focus to 12 regional case studies, and these will each explore a primary and secondary theme and how they relate to the sustainability of aquaculture in the region in terms of the balance of environmental, economic and societal objectives. Based on this study, the prevalence of the type of aquaculture in each case study region is highlighted, for example, the differing methods, materials, products produced, objectives, innovations, drivers, barriers and weaknesses, and how these relate to the objectives of a balance in environmental, economic and societal sustainability.

9.2 Limitations

Study limitations of deliverable 1 include the differing regional case-study sizes, climates, cultures, geographies and locations, and so some data may not be comparable. The differing languages may have limited the comparability of the findings in relation to the data compiled, although this is not a limitation in terms of the handling of the data.

9.3 Next Steps

This baseline study mapping the regional aquaculture cases-studies provides the foundation upon which to develop Deliverable 2 of this study, that is the qualitative research of the case studies, developed from extensive local stakeholder engagement. The further work will focus on obtaining an in-depth qualitative understanding of the aquaculture in each of the twelve individual regional case studies. Six to eight interviews at each of these case studies will constitute the rich qualitative primary data of Deliverable 2, the next phase of this Work Package. The semi-structured interviews with diverse stakeholders both online and in-person, will explore the experiences, objectives, interests, perspectives, actions, tensions, conflicts, barriers and work of diverse stakeholders with involvement in aquaculture and how these may influence the sustainability of aquaculture in the region. Each case study will focus on the themes and species as determined by the characterisations in this study, although this is subject to change following the insights discovered during the interview process. Some stakeholder interviews have commenced, and already observed is a complex web of conflicting objectives and perspectives on the sustainability of aquaculture.

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Annex 1: The Consortium

Western Norway University of Applied Sciences

NCE Seafood Innovation

Università degli Studi di Verona

Mary Immaculate College

University of Copenhagen