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Green Aquaculture Intensification in Europe

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GLOSSARY OF ACRONYMS

Acronym	Definition
EU	European Union
EEA	European Economic Area
GAIN	Green Aquaculture Intensification in Europe
KI	Key Informant
LCA	Life Cycle Assessment
MT	Metric Tonne
PDNA	Porter Diamond National Advantage Framework
SWOT	Strengths, Weaknesses, Opportunities and Threats
T	Task
(G)VCA	(Global) Value Chain Analysis
DM	Dry Matter

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Contents

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1. Executive summary

The EU funded Green Aquaculture Intensification (GAIN) project seeks to optimise output of aquaculture in terms of product and value. In order to achieve this, it is essential to have a strong understanding of the value chains which underpin the industry. This means not only understanding the direct supply chains of production and processing but also the service industries, government, research and development actors which take an active part in driving the success of an industry. Deliverable 3.3 reports on the initial tasks which are underway as part of T3.3 and will feed into T4.2 over the coming months of the project.

The first part of the deliverable gives a basic literature-based overview of European aquaculture value chains, including brief descriptions of consumption and trade, the role of consumers, regulation, policy and certification and community interaction. We then provide a literature and expert based overview of the key EU species, which are the focus of the GAIN project and of tilapia and pangasius, as key traded species into the EU from Asia that can compete directly with EU culture species. A SWOT analysis is provided for each of the species. The analysis shows that there are good opportunities for most European aquaculture species to grow and add value. Salmon is growing in popularity world-wide, but is constrained by space in the major production areas and pathogen-related challenges, but better efficiencies, perhaps underpinned by precision aquaculture could boost production. Rainbow trout production has shrunk in the EU, but opportunities exist to differentiate product forms and to add value through better processing and marketing. Seabass and seabream are popular species but have challenges regarding high costs of production, particularly at the hatchery stage linked to required labour intensity and mortality. There are also challenges and opportunities related to imports of the two low cost white fish species from Asia. Potentially improved processing and value addition to by-products impacts positively on European actors through employment. However, this is affected by attitudes to consumption which are known to vary by country and context. Shellfish have less literature published regarding the specific opportunities and challenges and these are very different from country to country. For example, mussels are usually sold live in Scotland but processed in Spain, in contrast to finfish where northern Europeans tend to prefer processed fish compared to southern Europeans who like to buy it whole. These differences in processing and consumption patterns are complex and will become more apparent as the VCA is completed.

Section 4 of the deliverable provides a detailed methodology of the work that is currently underway as part of T3.3 and will continue over the coming months based on SWOT analysis, Porter Diamond National Advantage (PDNA) framework, Delphi process and the detailed in-country VCA work. SWOT analysis has been included based on literature as described above. This will be improved based on Key Informant (KI) interviews within the VCA. A Delphi process will engage a panel of experts drawn from KIs in an iterative process, which will highlight the most important areas for innovation within EU aquaculture sectors. This will be complemented by the PDNA analysis which will assess the competitiveness of companies/industries based on their ability to drive innovation, technologically, structurally, and related to legislation or policy.

To-date only Norwegian salmon has had the detailed VCA data collection completed. The list of the type of stakeholders approached for the work is provided (Table 26) along with the semi-structured survey and question checklist (Annex 1). In addition to the VCA country work, Key Informant interviews

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were performed at major seafood shows around the world to assess perceptions to trade and sustainable aquaculture from different perspectives, including EU trade to Asia and vice versa. A study of exhibitor sustainability messaging on the booths was also made by recording of all of the words related to sustainability and quality of products, along with certification logos and other key messaging. This has been undertaken at Boston, Brussels, Guangzhou and shortly to be completed, at Qingdao seafood shows. A comparison will be made between the sustainability image that EU and Asian producers and suppliers of seafood portray at the different shows around the world.

The different parts of the task are complementary in providing an industry driven consensus on the necessary improvements needed for the EU aquaculture industry and to highlight opportunities to add value responsibly and sustainably.

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2. Introduction

In order to understand the dynamics of any industry it is imperative to undertake a Value Chain Analysis (VCA), or mapping exercise. The value chain can be defined as the interconnected actors and stakeholders who provide resources, production capability, skills, innovation, and governance to an industry. In the modern world of international trade in goods and commodities, it is often referred to as the Global Value Chain (GVC). It is different to a supply chain, in that it includes indirectly affected stakeholders such as policy makers, academics, consumers who may affect or be affected by the activities within the chain and also seeks to understand the power relations between them. Moreover, understanding the impact of decisions and unforeseen implications along this chain, requires a comprehensive framework of sustainability indicators (Valenti *et al.,* 2018). Integrated Value Chain Analysis and Life Cycle Assessments (LCA) are an innovative approach to link social, economic and environmental impacts of international trade. The design of the work will be based on currently available literature, but supported where possible, with data drawn directly from stakeholders using a combination of structured and semi-structured surveys and Key Informant (KI) interviews. As such, the GAIN project is undertaking two VCA exercises to complement the LCA and sustainability indicator work in WP4. D3.3 reports on the initial activities in T3.3, containing the literature analysis of European value chains and an explanation of the methodological approach which will be used to underpin the stakeholder-based analysis which will be detailed in D4.2

In addition to the VCA of European aquaculture production, the purpose of T3.3 is to understand the strength of competitiveness of European production compared to cultured white fish imports, particularly of Asian products; Pangasius (*Pangasiadon hypophthalmus*), also known as *basa*, and tilapia (mainly *Oreochromis niloticus*). Global trade is increasingly centralised and dominated by brands, supermarkets and food service companies. These are also called 'lead' firms that control access and determine the terms of trade (Humphrey *et al.,* 2001).

Therefore, to understand European aquaculture Value Chains, the work contained within T3.3 of the project falls into four major parts:

(i) Develop a SWOT analysis of for each European major species/system context and for pangasius and tilapia for two Asian contexts based on market data and key informant interviews with value-chain members and industry observers;

(ii) Conduct a seafood value chain mapping exercises for each European major species/system context and for pangasius and tilapia for two Asian contexts from secondary data derived from previous and on going EU RTD projects (SEAT and Primefish), updated based on information derived using a DELPHI process with key value chain actors. Selected key informant interviews will be used to validate the findings in at least two international seafood exhibitions;

(iii) Develop competitiveness models for EU and Asian products using GVCA and PDNA frameworks based on data from (i) and (ii) together with in depth interviews with key informants and other industry sources;

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(iv) Assess impacts of agri-food standards on competitiveness and employment, based on a literature review and an internet survey of seafood businesses.

Due to the timing of D3.3 (M18) and D4.2 (M24) compared to the timetables for T3.3 (M13-24) and T4.2 (M13-36), some adjustment of the content related to D3.3 has been necessary as the work within the task related to in-country surveys and key informant interviews will not be completed until M30. The timings related to task and deliverables was raised as an issue within the inception meeting of project in Venice 2018.

The content within this deliverable relates to the literature review work carried out on European and Asian value chain mapping, including a SWOT analysis based on literature but not Key Informant interviews, as field work has only been partially conducted to-date. Methodology related to the continuing survey work is also presented within this deliverable.

3. Value Chain Mapping of European Aquaculture

3.1 Value Chain Analysis

Understanding the composition, structure and relationships within a value chain is vital for understanding how an industry innovates and grows. It characterises the industry in terms of its production and trends. More importantly it identifies, the challenges, bottlenecks, opportunities and strengths from a multi-stakeholder perspective and identifies who the key players are that are driving the industry forward or that are pivotal for its success. This is particularly the case for identifying competitive challenges, including those related to sustainability, and acting to overcome them, termed as “upgrading“

3.1.1 European seafood consumption and trade

Seafood consumption is covered in detail as part of D3.2. However, a short overview is given here to provide context to the VCA. European seafood demand has gradually increased from 20.7 kg capita^{-1} year^{-1} to 24.3 kg capita^{-1} year^{-1} from 2005 till 2016. However, demand cannot be met from domestic aquaculture and wild fisheries production combined. According to EUMOFA based on EUROSTAT, National sources, FEAP and FAO data, the EU self-sufficiency ratio, indicating the ratio of domestic production meeting demand, shows a decrease from 42.5% to 41.7% from 2015 to 2016, respectively. Consequently, increasing demand and stable or declining production leads to an increasing dependency on imports.

The European Union (EU-28) produced 6.3 million MT of seafood in 2016, equal to 3.1% of the total fish production globally, covering both aquaculture as well as fisheries. Wild capture fisheries produced 5 million MT, a relatively large share of 5.6%, while aquaculture accounted for almost 1.3 million metric tonnes, representing 1.2% of the global aquaculture production (EUMOFA, 2018; FAO, 2018a; EUROSTAT, 2019).

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Based on EUROSTAT and FAO data, the total fin-fish supply (live weight) increased from 13.8 to 14.2 MT from 2015 to 2016, respectively (EUMOFA, 2018). European fish production including fisheries and aquaculture accounts for 5.2 million tonnes, while 75% comes from capture fisheries. Additional fishery catches of 1.1 MT were destined for non-food use. The picture is complicated by global trade. Imports accounts for 9.1 MT, while export reached 1.8 MT in 2016. It is estimated that 12.4 MT of live weight equivalent is consumed within the European Union (EUMOFA, 2018). The red arrows in figure 1, below indicate a loss in the live weight balance through imports and exports, which if domestic production would improve (green) it could create self-sufficiency and meet the 12.4MT currently consumed in the EU and increase high value European export to other countries (Figure 1).

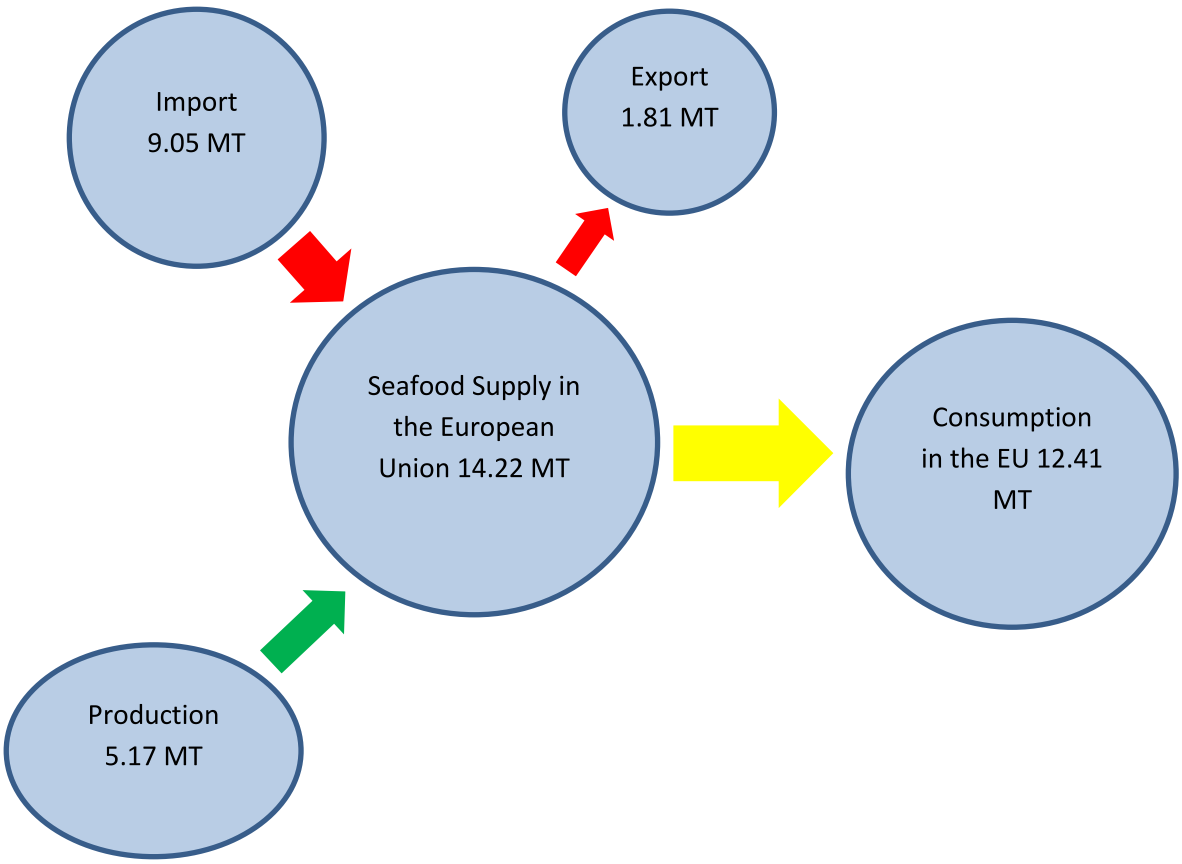

Figure 1: EU supply balance for fisheries and aquaculture products in 2016 (live weight equivalent). Replicate of Chart 5 (The EU Fish Market 2018 - (EUROSTAT, no date; EUMOFA, 2018; FAO, 2018a))

The majority of supply comes from imports, accounting for 63% to the seafood supply in the European Union. Fish has a valuable place, as they account for 18% of a total of EU143 billions of food products imported (EUMOFA, n.d.; European Commission, n.d. a). Fish imports are on the increase, with an average annual growth rate of 6% (EUMOFA, 2018). Most of the import is driven by Spain, mainly supplied by Morocco, China, Ecuador, Argentina, Peru and Chile. However, it must be noted that half of fish products traded within and outside the EU consists of intra-EU trade. This trade is on the increase, showing average annual growth of 3%, reaching 6.5 MT in 2017, with species, such as small

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pelagics (18%), salmonids (15%), groundfish (14%) and non-food use (11%) dominating the intra-trade market. Non-food use is dominated by fish oil (18%), fish waste (40%) and fishmeal (42%) volume representing EU833 million in in 2017, compared to 26.7 billion in 2017 represented by intra-EU exports (EUMOFA, 2018).

While food trade adds value to the resilience of the global food system from a food security perspective (Dolfing *et al.,* 2019), cultural attitudes towards socio-economic factors has implications for its acceptability. While production overseas (e.g. pangasius and shrimp) creates economic opportunities for developing countries, they have been criticised for negative social and environmental impacts. The development and transformation of aquaculture in these countries is the result of immanent (ongoing and undirected) and interventionist (intentional, externally inserted) processes. While delivering wider inclusive growth in Asia, the 'interventionist approach' often results in industrial scaled production, resulting in fewer local employment opportunities and centralised accumulation of capital (Belton and Little, 2011). Despite the possible conflicts, overall development of the aquaculture industry supports local production linked to integrated and circular economies with in excess 90% of farmed fish in the top aquaculture-producing countries consumed domestically (Belton *et al*., 2016; 2018).

Fisheries are still dominant within European seafood production, representing a share of 75% (EUMOFA, 2018), but with little prospect of an increase in production, as they are close to production limits (Bostock *et al.,* 2016). Despite this, the European fishery is a relatively small player, contributing to 5.6% of global wild capture fisheries (STECF, 2018) equal to 3.8 million MT. However, aquaculture and fisheries are interlinked, based on sharing of fish resources, common ecosystems and common markets (Soto *et al.,* 2012; Knapp, 2015). Outcomes of this interrelationship can lead to both conflict and opportunities.

Increased seafood supply must come from domestic or imported aquaculture product which currently suffer from negative quality and reputation perceptions but could be positively influenced by marketing campaigns and economic incentives (FAO, 2016a; European Commission, 2018). These factors could affect the growth of European aquaculture in the future. It is expected that an overall increase in production of 55% could be made by 2030. This growth supports the European goals of increased food security and economic development, but such expansion of production systems and feed demand may cause socio-economic and environmental implications in the EU and further afield (Lane *et al.,* 2014). However, there are many overlooked challenges regarding trade-offs from aquaculture and fisheries contribution to the food supply chain in the field of health medicine, human and fish welfare, safety and environment (Hall *et al.,* 2011; EFSA, 2015; Jennings *et al.,* 2016).

3.1.2 Consumers' role in GVCs

Sustainable supply chain management is increasingly driven by external factors, such as regulatory pressure, reputation and consumer preference (Saeed and Kersten, 2019). Consumers are influenced by other factors; primarily by food safety, taste and price but the hierarchy of preference is also is dependent upon variables such as location, social status, age, gender and if they have children. Ethical concerns such as social and environmental impact are becoming increasingly important but are

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generally lower down the list and evidence shows that consumers are generally not willing to pay substantially more for ethical considerations (Chambers et al., 2008; Prescott et al., 2002).

The rapid development of aquaculture and the appearance of more aquaculture products on shelves has been met with some suspicion among consumers fuelled by NGO criticism and protectionism from traditional seafood suppliers. Aquaculture is heavily criticised for a range of social and environmental impacts that have formed a long-term negative narrative amongst Western consumers. Nevertheless, globally, public attitudes towards aquaculture in general show a positive trend (Froehlich *et al.,* 2017). A majority of Europeans prefer wild over farmed products and they also show a preference for marine compared to freshwater fish (European Commission, 2018) However, mariculture is perceived more negatively by the public, especially in the USA. This is often based on misunderstandings of aquaculture systems and their associated (environmental) risks (Froehlich *et al.,* 2017). Attitudes are varied across Europe with countries with developed aquaculture industry and public awareness, such as Norway, show often a more positive attitudes toward fish farming. Where there is high-awareness consumers are often more optimistic about aquaculture and its various impacts (Hynes *et al.,* 2018, Thomas et al., 2018; Whitmarsh and Palmieri, 2011). Whereas some consumers claim a willingness to pay more for what they consider to be more responsibly produced food, this is sometimes not evidenced by sales. The attitudes of consumers and the perceptions that retailers as lead firms have about consumer attitudes have a considerable influence on how the aquaculture industry develops and the innovations that it pursues (Honkanen and Olsen, 2009). Further detail on seafood consumption trends and consumer attitudes are given in D3.2 and 3.4, respectively. However, a fundamental understanding of consumer perceptions is vital to understanding the drivers within aquaculture value chains.

3.1.3 The role of regulations and standards

EU regulations are some of the most robust in the world forming a broad framework of law by which EU producers and importers to the EU must abide, particularly on food safety regulation. The EU law may serve to drive or be a barrier to innovation in some circumstances, but is a considerable factor in the development of the aquaculture industry. This is playing a key role in the growth of sustainable aquaculture and considered a key factor for boosting sustainable/responsible production practices. Central to the EU's legislation is traceability with various schemes to allow full tracing of products back to their origins linked to the TRACES system and the Rapid Alert System for Food and Feed (RASFF) which notifies authorities of food safety alerts, particularly of traded goods with in and from without the EU. In addition to regulation, traceability is increasingly required by business through new technology, such as the distributed ledger technology (DLTs) (e.g.) blockchain which shows potential for supply chain management (Tijan *et al.,* 2019), and increase traceability in the agri- and food sector (Ge *et al.,* 2017; Kim and Laskowski, 2017; Kamath, 2018; Lin *et al.,* 2018). Intentional and unintentional mislabelling is a problem in the seafood industry (Smejkal and Kakumanu, 2018) with social, environmental and food safety consequences which could also be tackled through such technology in many circumstances. However, EU law falls short in some respects regarding imports from third countries, including environmental and social impacts. This not only raises questions about competitiveness of EU producers who do have to conform to stricter rules on employment or

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environmental impact when third country producers do not and where production costs are significantly lower. Where there is concern about such issues, consumers may turn to eco-labels and other certification to provide trust for responsible sourcing. Global private standards often use a top-down approach considering food safety and traceability , but may ignore the local complexity in producing countries, which could potential lead to socio-economic inequality among indigenous communities (Mialhe *et al.*, 2018). Consolidated industries with large vertically integrated companies are better positioned to obtain certification, compared to small scale farmers which operate through large complex value chains. Small scale farmers, when they do meet the technical requirements of certification may not benefit from being certified as they have little power in getting a premium for their certified product and cannot afford the audit fees. However, buyers, both retail and food service, often demand that the product is certified to give confidence. New innovations in the way eco-certification is currently used in the aquaculture industry and, in particular, to the non-vertically integrated value chains are required, often certifying collectives of small scale farmers (Bush, 2018). Additionally, the wide range of eco-certification and standards currently applied in fisheries and aquaculture creates confusion among consumers who may be given conflicting messages. While standards are developed to improve clarification about the sustainability of seafood labels, some standards use different criteria and compete each other, while some of them may offer cooperation and mutual recognition, adding to the confusion (Samerwong *et al.,* 2017). Although consumers could and should be aware of sustainability issues regarding their food, it is the buyer who can offer a trusted brand to their consumers which is bound by responsible, sustainable sourcing. Therefore, buyers tend to be key actors in terms of how and what type of certification standards are required of producers and processors alike.

3.1.4 Local community interaction

Perceptions towards aquaculture are often the results of community-based interactions with aquaculture activities. A strategy defined as social licence to operate (SLO) could be used to provide insights to the relationships between host communities and aquaculture and possibly improve it (Gehman *et al.,* 2017). However, ‘social licensing’ is often not clearly explained or quantified and future research is needed to find the most optimal strategy for its application (Kelly *et al.,* 2017). Insight into public perceptions often reveals different views of aquaculture across and within certain (sector) groups. These perceptions on aquaculture production correlates with the interpretation of its environmental impact (Rudell and Miller, 2012; Whitmarsh and Wattage, 2006). Other environmental disturbance in the area (not directly related to aquaculture) could have an effect on the perception towards aquaculture activities (Froehlich et al., 2017).

A stakeholder perception analysis in Catalonia, Spain, showed that participants were in general in favour of future marine fish farming development. Among these stakeholders 4 different perceptions were observed; (1) aquaculture as an important socio-economic benefit with low environmental costs, (2) importance to environmental concerns (eutrophication, chemicals and focussed on fish meal and fish oil substitution), (3) valuing both socio-economic as well as economic concerns and (4) focusing on economic aspects (Bacher et al., 2014).

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A case-study on the Mediterranean (Greece) (Perdikaris *et al.,* 2016), focussing on farmed seabass and seabream, revealed increasing awareness among consumers on demographics and socio-economic aspects, which function as key factors in the consumers' purchasing behaviour. This functions as a driver for key players in the aquaculture industry to adopt sustainable practices. The survey results indicated that environmental protection measures were applied by 82% of the marine and 60% of the freshwater farmers responders. Farmers were aware of organic farming, fishmeal and fish oil substitution and had different perceptions on the impact on the final product (Perdikaris *et al.,* 2016).

High quality community-producer relationships are essential to the growth of the industry. In Scotland, producers who wish to open a new site must participate in a community consultation period, where objections are heard (Peel and Lloyd, 2008). Many producers engage with local communities to improve their relationship and local image which may enhance the general perception of the company and the industry (Hishamunda *et al.,* 2014). Activities include sponsorship of local sports teams and events, investing in local infrastructure and local outreach in schools and other public establishments. However, the level of community engagement and the benefits that accrue are varied between countries and will become more apparent during the data collection period of the T3.3 and T4.2.

3.2 EU Aquaculture sector overview

The UK, France, Greece, Italy and Spain were responsible for 78% of direct value output from aquaculture in 2012, from which 50% of the value was produced in marine cages, but represented only 28% of the production volume (Bostock *et al.*, 2016). Bivalve shellfish made up a disproportionate 56% of EU aquaculture production (Ferreira and Bricker, 2015), compared with 21% worldwide (Cressey, 2009) in terms of harvested volume.

European finfish culture is mainly dominated by production of high value species such as Atlantic Salmon (*Salmo salar*), Rainbow Trout (*Oncorhynchus mykiss*), European Seabass (*Dicentrarchus labrax*) and Gilthead (Sea) Bream (*Sparus aurata*). Common Carp (*Cyprinus carpio*) remains an important niche species. While there are 70 aquaculture species cultured in the European Union (FAO, 2014), these 5 species make up 90% of all fish production by volume (Bostock *et al.*, 2016). Additionally, Turbot (*Scophthalmus maximus*) and Meagre (*Argyrosomus regius*) are upcoming species. The industry in the European Union employs currently approximately 80.000 people, from which a fourth is working in Spain, followed up by a high number of employees in Greece, Italy and Portugal (European Commission, n.d. h).

Shellfish aquaculture plays a dominant role within the EU context (Ferreira and Bricker, 2015) including; Mussels (*Mytilidae sp.*), Pacific Oyster (*Crassostrea gigas*), European Flat Oyster (*Ostrea edulis*), Manila Clam (*Ruditapes philippinarum*)in terms of a total harvested volume, which is close to 450.000 MT.

Production takes place in a variety of marine and freshwater systems. The most dominant are (1) marine supported and suspended culture (non-fed sedentary and attached animals followed up by (2) large scale systems – marine sites, using mechanized systems, and (3) intensive freshwater flow-through and partial recirculation systems (Lane *et al.*, 2014; Bostock *et al.*, 2016) (Table 1).

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Table 1: EU aquaculture species categorized by production volume, system and country (GAIN Consortium, 2017)

EU Species	Production (t) (2015)	Dominant Production System / (fresh/salt)	Main EU Production Countries/Regions
Atlantic Salmon (*Salmo salar*)	1,492,300	Intensive seafarming (saltwater)	Norway/Scotland
Rainbow Trout (*Oncorhynchus mykiss*)	290,652	(semi)-Intensive farming (freshwater)	Italy, France, Denmark, Spain, Germany
European Seabass (*Dicentrarchus labrax*)	100,292	Extensive and semi-intensive farming (saltwater cage and pond systems)	Germany and the Mediterranean
Gilthead (Sea)Bream (*Sparus aurata*)	78,963	(semi)-Intensive farming (saltwater)	Mediterranean
Common Carp (*Cyprinus carpio*)	59,865	Extensive and intensive (freshwater)	East-Europe
Turbot (*Scophthalmus maximus*)	9,773	Extensive and semi-intensive (on-shore tanks and cages)	Portugal, Spain, France, Germany, United Kingdom and Denmark
Meagre (*Argyrosomus regius*)	5,063	Semi-intensive (saltwater cage)	France, Spain, Portugal, Italy
Mussels (*Mytilidae sp.*)	324,770	Extensive (saltwater)	Spain, France, Germany, Denmark, Norway, Netherlands, UK, Ireland
Pacific Oyster (*Crassostrea gigas*)	83,414	Extensive (saltwater)	Norway, Germany, Ireland, UK, France, Spain,
European Flat Oyster (*Ostrea edulis*)	3,083	Extensive (saltwater)	Croatia, Bosnia, Greece, Netherlands, Norway, France, Spain, UK, Ireland
Manila Clam (*Ruditapes philippinarum*)	35,036	Extensive (saltwater)	(Ireland, France, UK, Italy, Spain)

The selection of species within the GAIN Project is based on socio-economic relevance of these species in terms of global demand and niche markets (local and organic) from a range of production sites and methods. Additional species show potential for marine aquaculture, while climate resilient species are being researched for expansion or introduction, but are not included in this analysis. The species being researched under the 'H2020 DIVERSIFY' project include meagre (*Argyrosomus regius*), greater amberjack (*Seriola dumerili*) for warm-water marine cage culture, wreckfish (*Polyprion americanus*) for warm- and cool-water marine cage culture. Additionally, the Atlantic halibut (*Hippoglossus hippoglossus*) is suitable for marine cold-water culture, while the grey mullet (*Mugil cephalus*), a euryhaline herbivore, thrives better in pond/extensive culture, and pikeperch (*Sander lucioperca*) are suitable for freshwater intensive culture using recirculating systems (Diversify, 2013). Additional projects, such as ClimeFish, are also assessing strategies to ensure sustainable growth under climate change scenarios (ClimeFish, 2016). Resilience against

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climate change could be achieved by diversification of species and distribution of production (FAO, 2016b).

3.2.1 Atlantic Salmon (Salmo salar)

The majority of the salmon production takes place in Norway, which is the most developed aquaculture value chain in Europe (EU and EEA) (Asche et al., 2018), producing approximately 1.3 million MT in 2016 (FAO, n.d. g). The production increased with over 1 million MT since the year 2000 (Figure 2) (FAO, no date b). Grow out production is exclusively in net pens in relatively sheltered fjords, lochs and bays, relying on environmental services to disperse wastes and provide clean water. The main recent innovation in production/ management practices is the introduction of Recirculating Aquaculture Systems (RAS) for smolt production. Whereas historically, smolts were predominantly produced freshwater cages and flow through systems, they did not offer the same amount of control as RAS. Temperature, water quality, light regimes can be used to grow smolts to much larger sizes, in closely controlled disease-free environments, before they go to sea. The advantage is that the smolts are more robust when they go to the marine environment and mortality is much reduced from challenges such as the shock of movement, and exposure to sea lice and environmental stresses.

The Norwegian aquaculture production is covered by approximately 20 large companies, producing approximately 1.3 million MT in 2016 (salmonbusiness, 2019; Aas *et al.,* 2019), from which the majority of the production is dominated by only a few companies. Feed production takes place in 4 large companies (Biomar, Cargill (Ewos), MOWI and Skretting), from which some have a global presence. It must be noted that a trend of vertical integration is observed, where some fish production companies are producing their own feed (Asche *et al.,* 2013). In 2016, 1.62 million metric tonnes of feed were used to support production. The composition of feed changed significantly since 2012 and includes an increasing share (% in DM) of terrestrial plant ingredients, such as soy protein concentrate (19%), which has become a major source of protein. Additionally, included are wheat gluten (9%), corn gluten (3.6%), faba beans (3.4%), sunflower meal (1.1%), pea protein concentrate (1.3%), sunflower protein (0.5%), other vegetable protein (2.3%). Plants oil used are mainly rapeseed and camelina oil (19.8%), and to a much more limited extent linseed oil (0.3%). Carbohydrates are included in the form of wheat (8.9%), pea starch (0.8%) and others (1%). Marine ingredients converted into fishmeal make up 14.5% of the feed, of which 2.8% of feed inclusion originated from trimmings. Marine oils originate currently almost entirely from forage fish, and constitute around 7.8% of the feed, while trimmings make up 2.6% of the feed inclusion. It must be noted that the majority of the marine ingredients fed are imported and certified under IFFOrs, while plant ingredients, also mostly imported, show a lower proportion of certification. Finally, micro ingredients, such as crystalline amino acids, phosphorus sources and astaxanthin cover 4% of the total inclusion of salmon feeds in 2016 (Aas *et al.,* 2019).

Slaughtering and primary processing (gutting) takes place in approximately 60 plants. This sector is considered fragmentated, as approximately only half of the total revenue generated by 5 large companies (EY, 2017). New development, such as processing boats shows potential and this might

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become more relevant in the future, as it shows several advantages in terms of lower mortalities, lower contamination risk and improved fish welfare.

Norwagian salmon production is export driven and makes up 53% of global salmon production (FAO, 2018). Demand for salmon products (e.g. frozen fillets) in the European Union (EU28) and the USA is stabilizing, while the demand for other salmon products, such as fresh salmon is increasing in the European Union. Additionally, exports towards South-East Asian and Latin American markets show potential (FAO, 2019b).

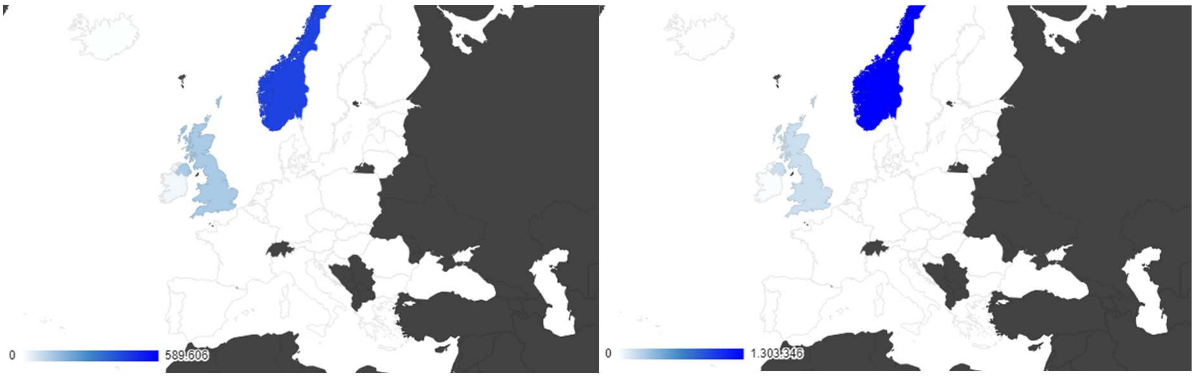

Figure 2: Geographical distribution of Salmon farming production (MT) between 2000 (left), and 2015 (right). Figure made by Wesley Malcorps, based on (FAOSTAT, 2019)

Sea lice remains the biggest cause of mortality and is a source of criticism of the industry for welfare reasons as well as disease transfer to vulnerable wild stocks. Physical and biological control/ management of sealice is being developed in preference to chemical treatment that dominated until recently.

Despite significant challenges, substantial growth has been achieved with suitable environment for marine aquaculture supported by increasingly vertically integrated value chains (Figure 3). The production volume increased over the last decades, during a period of consolidation reducing production costs and improving efficiency. In 2017 a total of approximately 1600 companies involved in salmon and trout farming employed 7400 employees (Eurofish, n.d.). It must be noted that an enormous shift from unskilled labour to academic qualified employees took place (FAO, no date b). Additional factors contributing to the increase in production are 'economics of scale' resulting in relative cost saving as result of increasing production. Additionally, the innovation model in Norway is well established, consisting of industry, R&D and National and local authorities (FAO, no date b; SINTEF, 2015).

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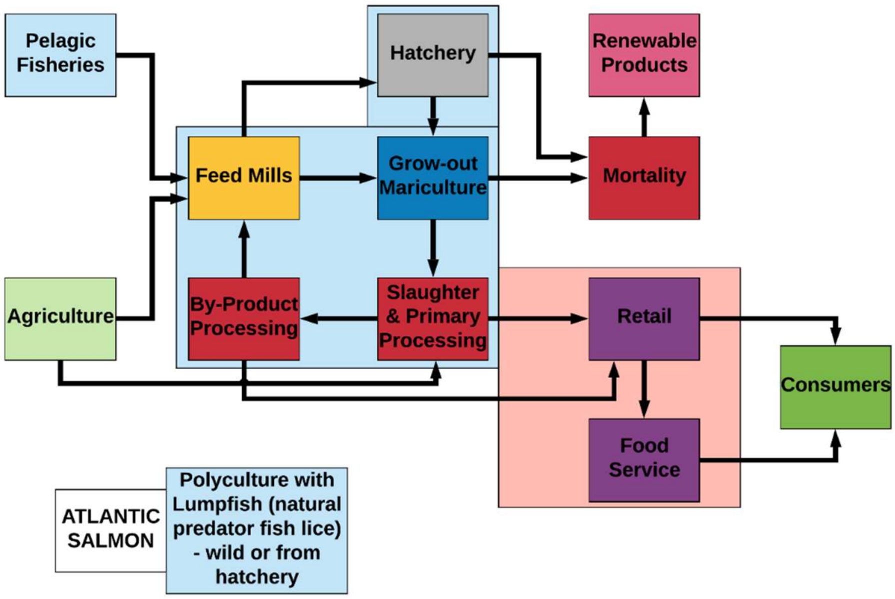

Figure 3: Flow diagram Salmon.

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Table 2: SWOT Analysis of Atlantic Salmon Production in the EU

Strengths	Weaknesses
• High production • Production countries have a history of production and experience • Established quality • Technology driven • Marketing • Tasty and versatile fish (multiple product forms, smoked etc) • Healthy (omega-3 content) • Establishing value addition opportunities	• Quality perception (wild vs farmed) • Negative media attention and public perception; environment and welfare • High dependency on marine ingredients • Control of sea lice remains a challenge
Opportunities	**Threats**
• Increasing export opportunities, especially China • Higher outputs as a result of technology • New technologies create USP (traceability, salmon face recognition) • Pioneers of precision aquaculture	• Open systems and therefore less resilient (pollution, diseases etc.) • Climate change • Chinese and other increasing external competition • Competition for feed ingredients (marine) • Lack of space for expansion

3.2.2 Rainbow Trout (Oncorhynchus mykiss)

The total production of rainbow trout decreased from approximately 290,000MT to 250,000MT between 2000 and 2015, respectively. The European Union represented 31% of global production in 2007, but this decreased to 23% in 2016 covered by Italy, Denmark, France, Spain, Poland, United Kingdom, Finland (EUMOFA, n.d. b). Norway is the largest producer, as part of the European Union (EU) and the European Economic Area (EEA) and represent a production volume of 75.000 tonnes in 2012, based on FAO and FEAP data (Janssen *et al.,* 2015). Total production in intensive freshwater flow-through was approximately 150.000MT-160.000MT (Bostock *et al.*, 2016), while saltwater production accounted for 91.000MT in 2015 (FAOSTAT, 2019). (Figure 3). Based on FAOSTAT, marine culture showed a relative increase from 21% towards 37%, while freshwater showed a decrease from 75% till 59%, from 2000 till 2015, respectively (Figure 4). The reduction could be explained by environmental legislation, as well as increased competition with the salmon industry (Bostock *et al.*, 2016) and trout producers outside of the European Union, such as in Turkey (Undercurrentnews, 2014)

Rainbow trout in Europe is produced by approximately 15 breeding companies (Janssen et al., 2015). Production takes place in raceways and ponds with flow through from rivers systems (Figure 5). However, they can also be produced in cages and recirculation systems (FAO, n.d. c). They are begin

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fed with a range of feed ingredients from marine and terrestrial resources, namely fishmeal, fish oil, soybean meal, wheat gluten soy oil and canola oil, wheat and corn starch. Additionally, ingredients such as krill meal and animal by-products can be found in trout feed (FAO, n.d. d). A significant proportion of rainbow trout is smoked in the European Union in countries, such as Poland, United Kingdom, Germany, France (EUMOFA, n.d. b). It must be noted that trout shows a self-sufficiency rate in the EU of 89%, as a result of the increased farmed production. In other words, European consumption demand is met with the current production rates.

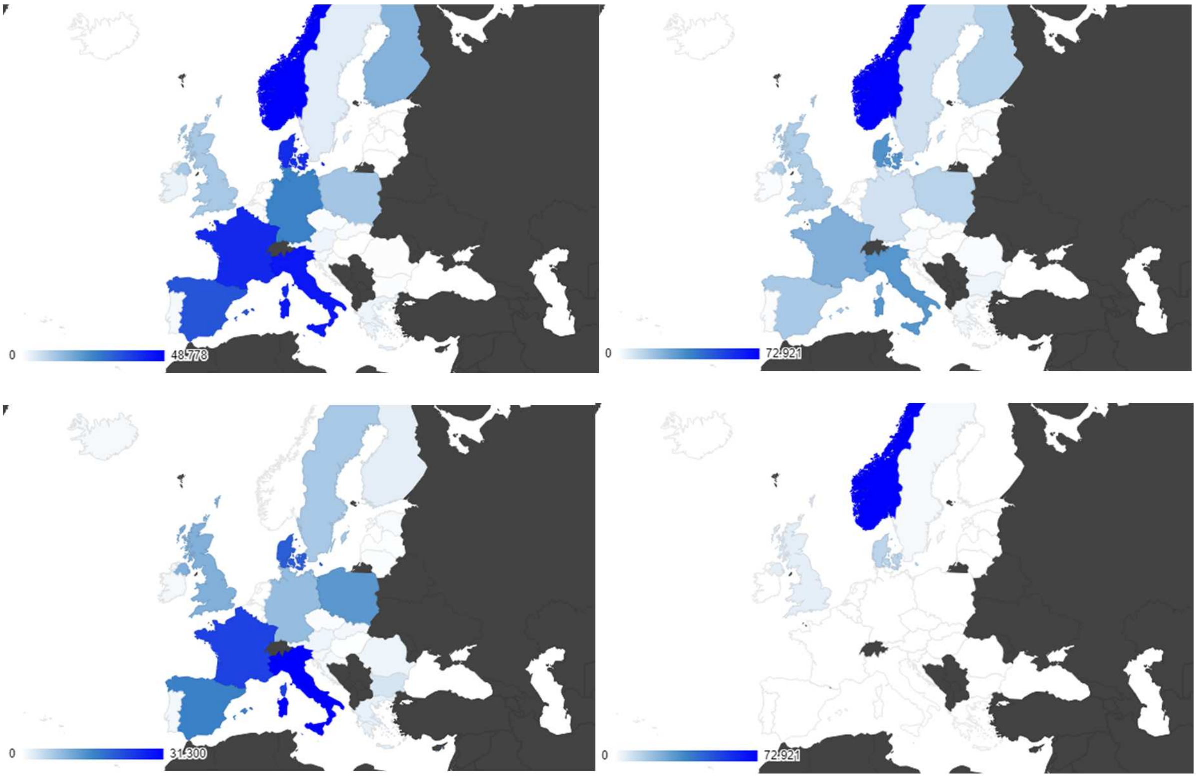

Figure 4: Geographical distribution of rainbow trout farming production (MT) between 2000 (upper-left), and 2015 (upper-right) and freshwater (lower-left) and marine (lower-right) production systems. Figure made by Wesley Malcorps, based on (FAOSTAT, 2019).

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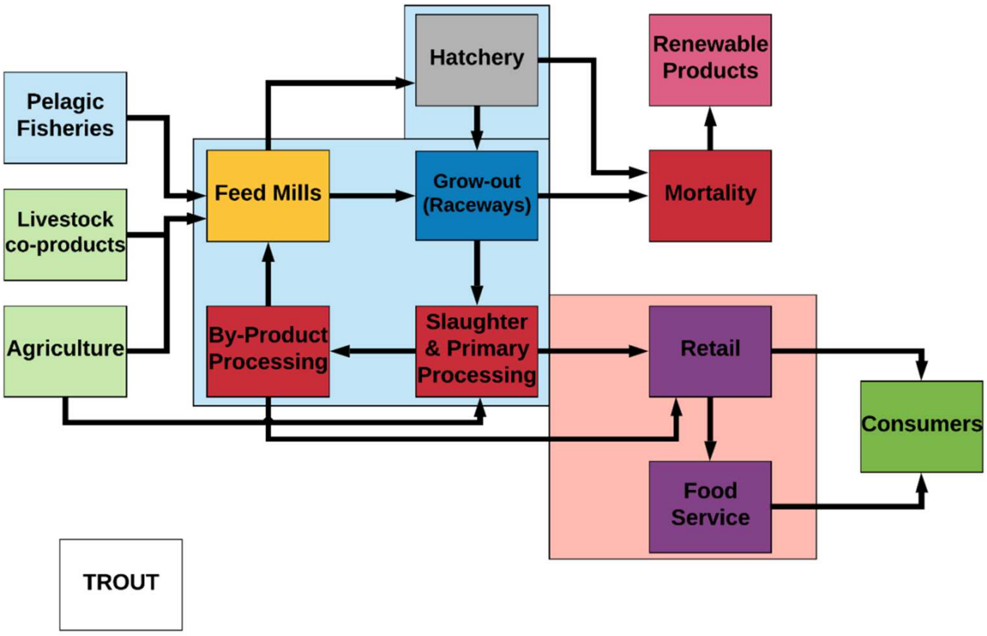

Figure 5: Flow diagram Rainbow Trout.

Table 3: SWOT Analysis of Rainbow Trout Production in the EU

Strengths	**Weaknesses**
• Lower inclusion of marine ingredients than salmon • Production in marine and freshwater • Production in different systems • Well established species • Can be produced in variety of sizes for different markets (pan size or larger) • Is also produced for large restocking and sport fishing market (diversification) • Not susceptible to sea lice in freshwater • Potentially more sites available • Favourable taste and health perception	• Quality perception (wild vs farmed) • Less well developed than salmon • Product competes with salmon • Less established export markets than salmon • Shrinking domestic production • Dependence on wide range of broodstock (spawning seasonal)
Opportunities	**Threats**
• Product diversification into domestic and export markets • Space for growth, especially in inland waters • Better processing and use of by-products	• Open systems and therefore less resilient (pollution, diseases etc.) • Climate change • Growing non-EU production (competition) • Lower production costs in Turkey

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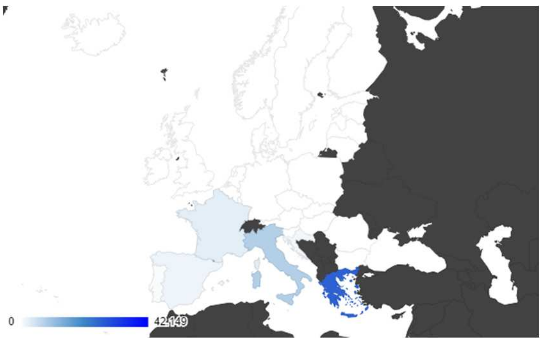
3.2.3 European Seabass (Dicentrarchus labrax) and Gilthead (Sea)Bream (Sparus aurata)

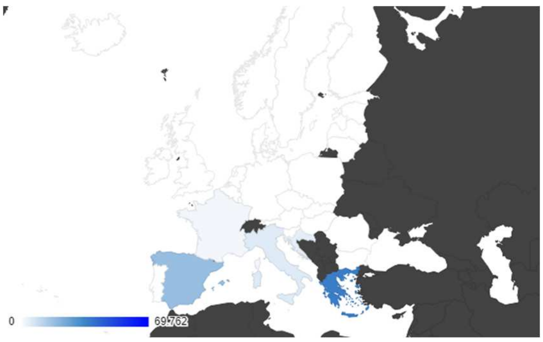
Seabass and seabream farming share the same geographical distribution, as they require similar environmental conditions and are sometimes produced in 'alternate culture'. Due to the grazing nature of seabream on algae, it is common to have a cycle of sea bream after a cycle of seabass culture within the same facilities. The seabream effectively de-foul the cages ready for the next cycle of seabass.

The seed supply for both seabream as well as seabass is sophisticated and required skilled staff in the hatcheries. Once the larvae are hatched the nutrients are provided by the sac for the first few days. This is followed up by a diet of microscopic algae and zooplankton. The next diets consist of artemia and a high-protein diet (European Commission, n.d. b; European Commission, n.d. c). The grow-out phase of the production is dominated by sea cage farming systems, while some are farmed in seawater ponds and lagoons (Figure 7 and 8). The production increased from approximately 42.000 MT in 2000 to approximately 70.000 MT in 2015, according to (FAOSTAT, 2019). On the other hand, gilthead seabream production increased from 60.000MT to 83.000MT from 2000 till 2015, based on (FAOSTAT, 2019) (Figure 6). The majority of the production takes place in on-growing sea cages, which is considered the most profitable due to low energy costs.

Seabass and seabream are fed a mixture of marine and terrestrial ingredients and over the last decades the inclusion of fishmeal in the diets decreased significantly. Major ingredient components consist of fishmeal, krill meal, corn (gluten meal), wheat (gluten), pea, faba beans, lupins. Additionally, oilseeds such as rapeseed meal, sunflower meal, full fat soybean, soybean meal and soy protein concentrate are included in the diets. Most of these ingredients are imported from outside Europe.

Seabass is often marketed as whole or fresh and only a minority of the production undergoes processing or value addition. This is also applicable for most of the produced seabream in the main European markets, such as Italy (EUMOFA, 2014; European Commission, n.d.). This is mainly because of consumer preferences in southern Europe (The Fish Site, 2010). Seabass and seabream exports are being dominated by intra-EU trade, and exports outside the European Union are very low (European Commission, n.d. b; European Commission, n.d. c).





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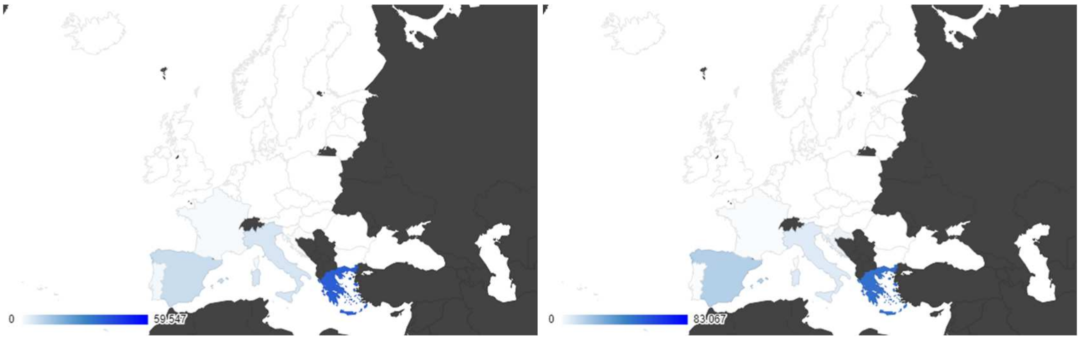

Figure 6: Geographical distribution of seabass farming production (MT) in 2000 (upper-left), and 2015 (upper-right) and gilthead seabream farming in 2000 (lower-left) and 2015 (lower-right). Figure made by Wesley Malcorps, based on (FAOSTAT, 2019).

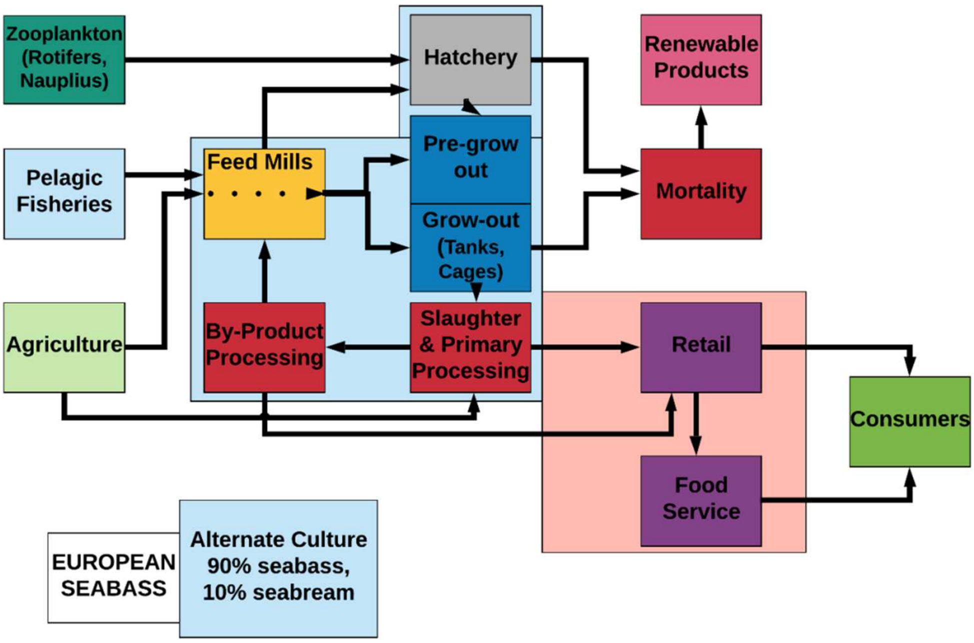

Figure 7: Flow diagram European Seabass (Spain)

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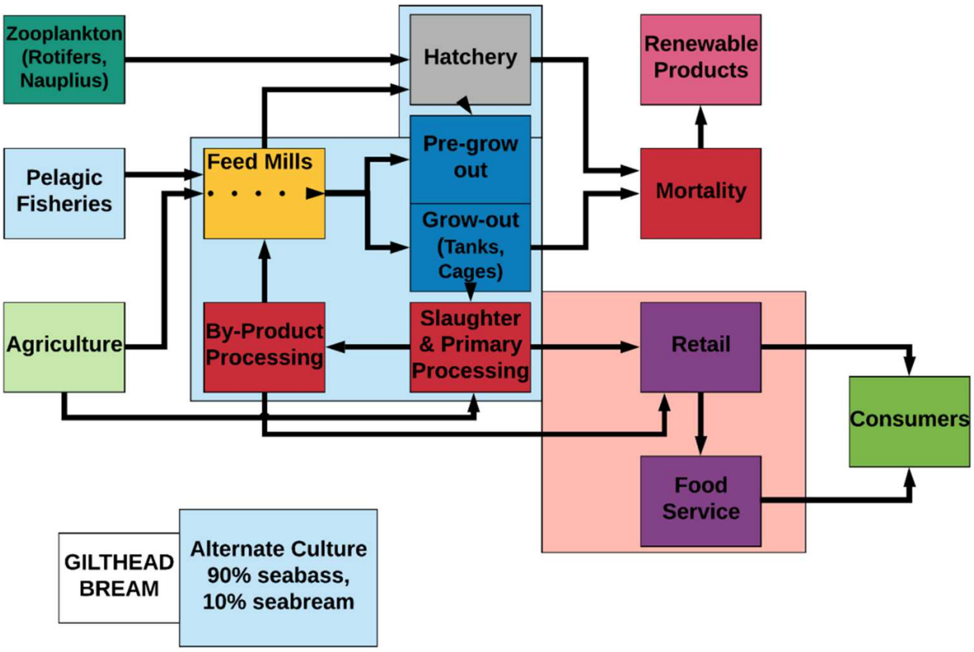

Figure 8: Flow diagram Gilthead Seabream (Spain)

Table 4: SWOT Analysis of European Seabass Production in the EU

Strengths	**Weaknesses**
• Tolerant to changing environments (5-28°C) and fluctuating salinities • Well established product throughout the EU • Favourable taste and health perceptions	• Quality perception (wild vs farmed) • One breeding season per year • High mortality at hatchery • Need for live feeds • High labour and production costs (marine hatchery RAS) • High price of product • Feed ingredients imported • Largely unprocessed
Opportunities	**Threats**
• Better processing • Value addition and diversification • Market access	• Open systems and therefore less resilient (pollution, diseases etc.) • Aquaculture expansion in Turkey • Competing with other market segments, such as white fish species; pangasius, tilapia and Asian sea bass

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Table 5: SWOT Analysis of European Seabream Production in the EU

Strengths	**Weaknesses**
• High Volume, decreasing price • Established markets • Production integrated with seabass (also a weakness)	• Quality perception (wild vs farmed) • Marine hatchery technology and skills • Live feed • Largely unprocessed
Opportunities	**Threats**
• Processing and value addition	• Open systems and therefore less resilient (pollution, diseases etc.) • Aquaculture expansion in Turkey • Competing white fish imports

3.2.4 Turbot (Scophthalmus maximus) Spain and Portugal

Turbot production increased from approximately 5,000 MT to 10,000 MT between 2000 and 2015, respectively (FAOSTAT, 2019) and Spain is the major producer (European Commission, n.d. e) (Figure 9). Value chain flow charts show the most important nodes (Figure 10).

The seed supply for turbot is sophisticated and requires skilled hatchery staff. Larvae are fed zooplankton and artemia for the first 2 months (Figure 10), which is followed up by an artificial diet (European Commission, n.d. d). The management of this stage of production is crucial to increase larval survival rates, and lower total production costs (FAO, n.d. d). Reproduction takes place in a strict and controlled environment where broodstock is kept at low densities. Broodstock is fed with specialized pellets and under specific temperature and light conditions to stimulate egg production.

Note the importance of onshore tanks in the land based production. These square or circular tanks are often outdoor and are connected to an open-circuit of pumped seawater (European Commission, n.d. d). Only a small percentage of turbot is being produced in recirculation systems. Turbot is being fed a range of (imported) marine and terrestrial ingredients, such as fishmeal, fish oil, soybeans, wheat grains, blood meal, pea protein, rape meal and soya oil.

Turbot is sold whole in Spain and other Mediterranean countries, while filleting is applied to turbot being exported to the north of Europe to satisfy consumer demand (FAO, n.d. d). However, most turbot is being sold whole to local food services (European Commission, n.d. d).

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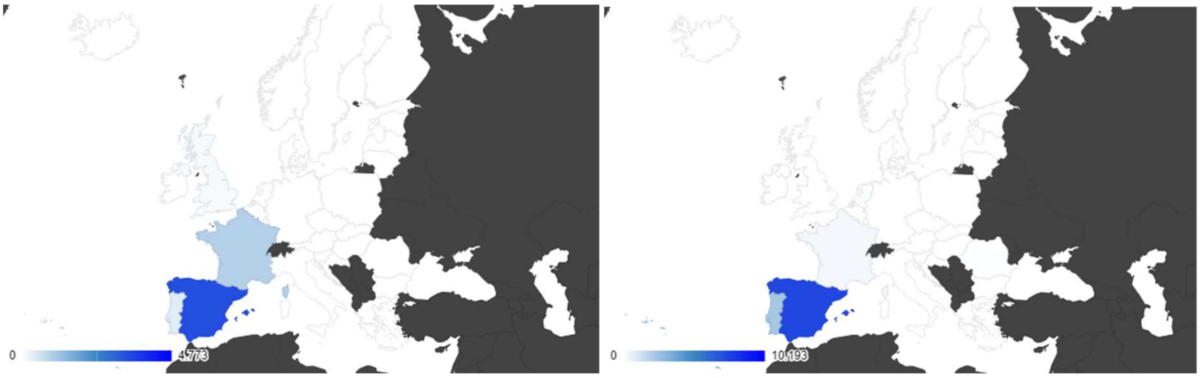

Figure 9: Geographical distribution of turbot farming production (MT) between 2000 (left), and 2015 (right). Figure made by Wesley Malcorps, based on (FAOSTAT, 2019)

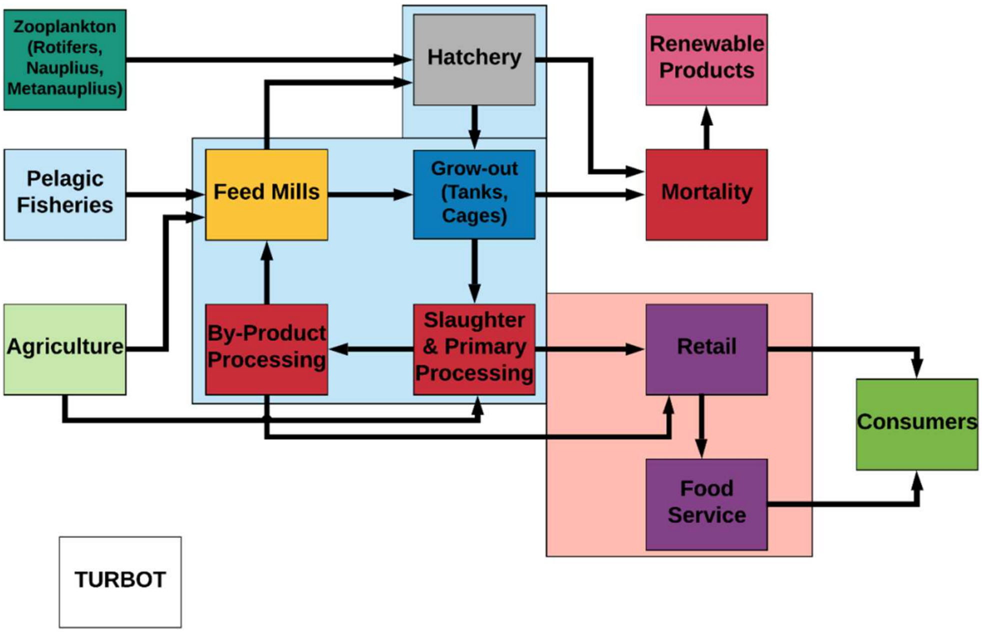

Figure 10: Flow diagram Turbot.

Table 6: SWOT Analysis of Turbot Production in the EU

Strengths	**Weaknesses**
• Exclusive/high price • Established species through fisheries	• Quality perception (wild vs farmed) • Often exported as whole • Marine hatcheries, high cost, high expertise, high mortality • Small and exclusive markets

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Opportunities	Threats
• Processing and value addition • Emerging species	• Open systems and therefore less resilient (pollution, diseases etc.) • Low market opportunities

3.2.5 Common Carp (Cyprinus carpio) (Poland).

Carp aquaculture is ancient and well-established having been introduced from Asia during the Middle Ages. Traditionally the fish was grown in low densities with little or no feeding. Carp production is often classified as organic aquaculture because of the extensive nature of production but represents only 4.7% of the total EU aquaculture production. This production approach is characterised by farm management that combines best environmental practices, high level of biodiversity, and preservation of natural resource with high animal welfare standards and supporting rural development (Guiseppe and Mente, 2019).

Common carp production slightly decreased from approximately 74.2MT to 71.4 MT between 2000 and 2015, respectively (FAOSTAT, 2019) (Figure 11). This production takes mainly place in farmed extensive systems in the rural areas the Czech Republic, Poland, Hungary and Germany.

Carp feeds mainly on natural organisms from pond fertilization, however, feed is sometimes applied (Figure 12). Periodic grading takes place in order to sustain significant growth. At the start of the winter carp is being transferred to a special tank, in which they reduce their activity and feed intake. The spring of the third year is the time where the carp is moved to large ponds, where their natural feed is supplemented with pellets. These pellets include ingredients, such as fishmeal, fish oil, plant ingredients and vitamin and mineral supplements (European Commission, n.d. d). Harvest time is December for the traditional Christmas market, typically 1.5 kg per specimen, sold live. However, a change in consumer perspective has been observed, with increasing processing in fillets. Nevertheless, live sales still dominate marketing of the species.

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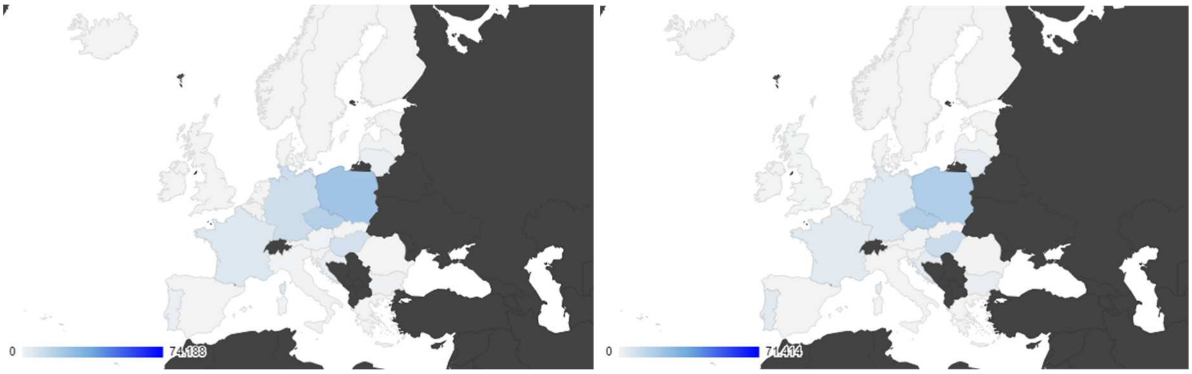

Figure 11: Geographical distribution of turbot farming production (MT) between 2000 (left), and 2015 (right). Figure made by Wesley Malcorps, based on (FAOSTAT, 2019)

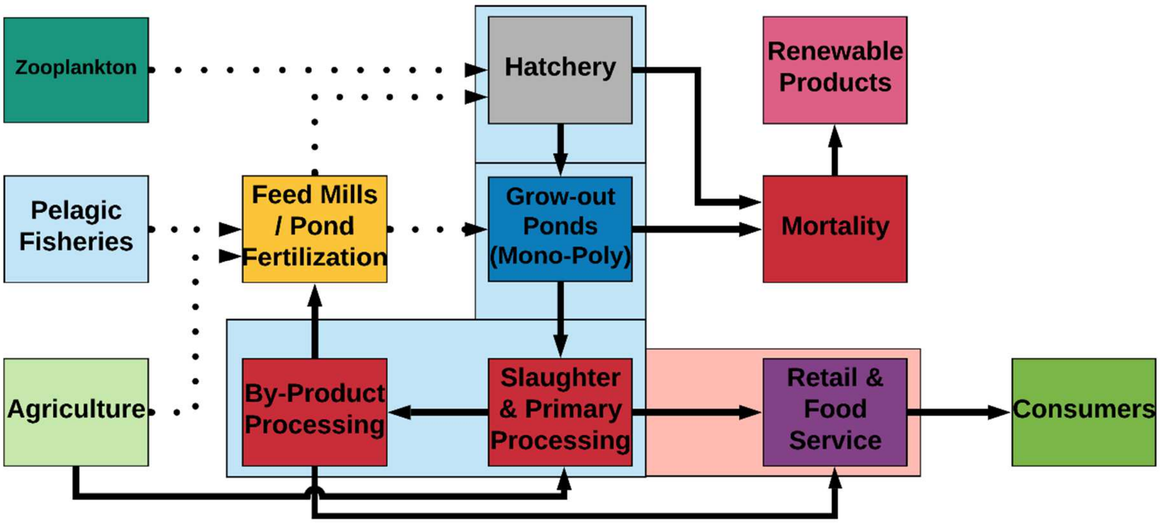

Figure 12: Flow Diagram Carp

Table 7: SWOT Analysis of Common Carp Production in the EU

Strengths	**Weaknesses**
• Well established traditional markets throughout Eastern Europe • Easy to culture and resilient • Easy to grow "organically" • Wide range of habitats • Wide range of feeding • Quick growth • Low marine ingredient demand	• Only popular at Christmas time • Dropping popularity • Quality issues (muddy/ off-flavour)
Opportunities	**Threats**
• Processing and value addition • Increasing demand for organic products	• Trend towards consumption of species from higher trophic level

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	• Competing species

3.2.6 European Blue Mussel (Mytillus edulis)

European blue mussel farming was the first organised shellfish farming in Europe. The major producers in the European Union produce approximately 470,000MT, from which Italy produces 67,000, France 57,000, and the Netherlands approximately 54,000. It represents one third of all aquaculture production in the European Union (European Commission, n.d. f; FAO, n.d. f; SeafoodSource, 2019) and mussel farming in Europe produces 34% of the global mussel production (EUMOFA, n.d. c).

Mussels are often sold alive, but are also found canned, marinated or mixed with sauce. The main processor of mussels is Spain, who produce almost 14.000 MT of canned mussels in 2016, according to ANFACO. Most of the trade in mussels is intra-EU (EUMOFA, n.d. c). Where processing does occur, it has often been a problem to dispose of the shells because there are few market opportunities, but include making into building materials.

Table 8: SWOT Analysis of Mussel Production in the EU

Strengths	**Weaknesses**
• Native • No feed inputs • Regarded as environmentally benign • Established species • High omega-3, healthy. • Multiple systems • Potential in IMTA	• Filter feeders vulnerable to pollution/ bioaccumulation • Depuration can have high energy costs and carbon footprint • Low value by-products • Mixed reputation among consumers
Opportunities	**Threats**
• Low impact food becoming more popular	• Open systems and therefore less resilient (pollution, diseases, predation, etc)

3.2.7 Oysters; Pacific cup oyster (Crassostrea gigas) and European flat oyster (Ostrea edulis)

The pacific cupped oyster is an exotic species, originally originating from Japan and was introduced into the UK in 1965 (Wolff and Reise, 2002). The European Union had the fourth highest production level wordwilde of 142.000 MT, with France being the dominant producer. On the other hand, the European flat oyster is the native species, but shows a significantly lower production of 3000 MT (GAIN consortium, 2017). Additionally, it must be noted that the wild populations of European oyster are

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highly endangered, as a result of overexploitation, habitat loss, pollution and disease. Currently there is much effort to restore the native populations in Europe, which will create natural reefs beneficial for local fish species. However, this is challenging due its slow growth rate and sensitivity for diseases (NORA, n.d.).

The production of the Pacific cup oysters starts with the collection of the oyster larvae at strategic locations in the wild, which are placed in tanks and fed algae. The oysters are then attached to a substrate, which can be mesh bags (off-bottom), directly on the intertidal ground (bottom culture), container culture at depths of 10 meters, or on ropes (suspended culture) and feed themselves with plankton (European Commission, n.d. g). This process is relatively similar for the European flat oyster, but this species is more sensitive to diseases. This has resulted in a demand for hatcheries trying to develop a disease resistant strain (The Fish Site, 2010a). Until now, hatchery development has focussed mainly on the pacific cup oyster, rather than the European oyster, due to it difficulties in this production phase (FAO, n.d. f).

The main market for the pacific cup oyster is France where they are sold and consumed live (European Commission, n.d. g). Most of the oysters are shipped to local markets and restaurants and consumed half on the shell (FAO, n.d. f).

Table 9: SWOT Analysis of Pacific Oyster Production in the EU

Strengths	**Weaknesses**
• Fast growth • Luxury, high value species • Established with good provenance • Healthy, omega-3, micro nutrients • Unfed and regarded as environmentally benign	• Open systems and therefore less resilient (pollution etc.) • non-native • Filter feeder susceptible to pollution and bioaccumulation
Opportunities	**Threats**
• Precision aquaculture and monitoring systems	• Open systems and therefore less resilient (pollution, diseases etc.)

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Table 10: SWOT Analysis of Flat Oyster Production in the EU

Strengths	**Weaknesses**
• Native oyster species High value species • Unfed/ environmentally benign • Healthy, high in omega-3	• Slow growth • May not be price competitive with Pacific oysters • Susceptible to pollution and bioaccumulation • Susceptible to disease
Opportunities	**Threats**
• Hatchery technology development	• Open systems and therefore less resilient (pollution, diseases etc.)

3.2.8 Striped Catfish (Pangasianodon hypophthalmus)

The striped catfish is more commonly known as *basa* by retailers or pangasius among scientific circles. It is a white fish regarded as an overwhelming success story of intensification, with production volumes of only a few tens of thousands of tonnes in 2000 rising to well over a million tonnes by 2012, since when production stagnated for several reasons. Production of pangasius is dominated by Vietnam (Figure 13) who pioneered the technology to close the cycle of successful large-scale reproduction in hatcheries. Since 2000, a highly sophisticated, modern value chain has developed supported by government and private initiatives. Production is almost exclusively in the Mekong Delta which means highly concentrated production can be transported quickly to processors with highly efficient economies of scale.

The fast growth of the industry brought a number of problems and criticisms. Western NGOs and consumer groups criticised the industry as being dirty and exploitative while producing an unsafe product. However, much of this was unfounded and based on protectionism as it competed with higher cost domestically produced white fish from fisheries and aquaculture (Little *et al.,* 2012). Nevertheless, the negative press, along with disease issues and stagnating farm-gate prices led to small scale farmers, struggling to make profits and a period of consolidation ensued, which arguably, continues today. Imports into the EU remain significantly lower than at their peak in 2009(CBI, 2018), but show recovery in the beginning of 2019 with an increase in export of 30% compared to the beginning of 2018 (Comayimexco, 2019).

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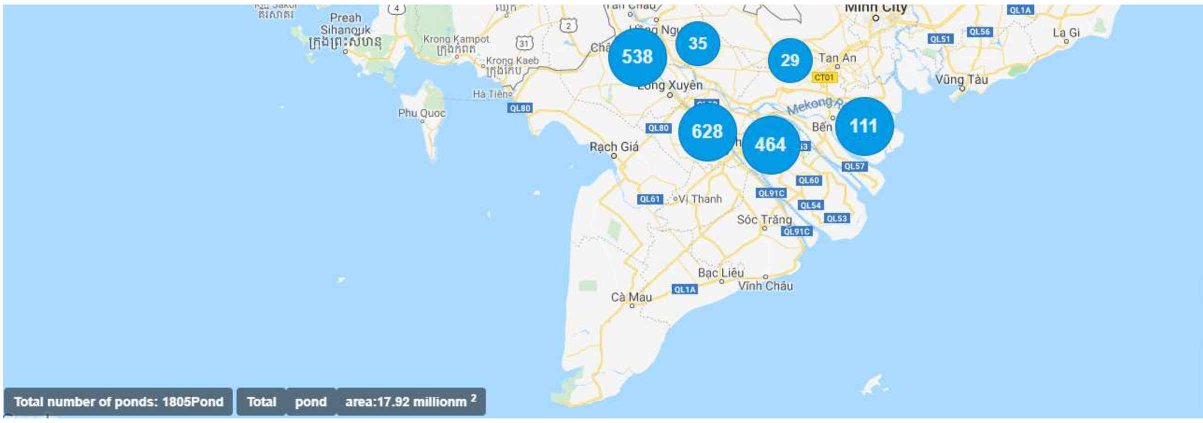

Figure 13: Pangasius production in the Mekong Delta of Vietnam 2019, thousands of tonnes (Vietnam Pangasius Association, 2019)

Since the high volatility of the market in the years following the price stagnation, Vietnamese production has stabilised but with government targets to produce 2million MT. Vietnam is a communist country, where the government has a very powerful influence over the industrial strategies of the nation, including investment, land ownership and designation. However, private companies also have a large influence and the two are not mutually exclusive with company owners having influential roles within the Communist Party that control policy.

Production is almost universally in earth ponds, but they are much deeper than traditional fish ponds at up to 4 meters. The intensive nature of production can mean rapid water degradation, which the deep ponds mitigate against, where the uneaten feed and faeces sink to the bottom and form an anoxic sludge. The fish populate the top layers of the pond and are facultative air breathers so they can supplement their oxygen when water quality becomes poor. The minimal water exchange, and sludge management remains a challenge (Phan, 2014).

Strict protocols need to be operated to achieve third party certification such as ASC, which EU buyers are becoming more insistent on to give them confidence over the quality and responsible production of the product where consumer confidence is low and legislation is thought to be weak and poorly enforced.

The product is processed into skinless fillets and mostly exported all over the world, with popular markets in the EU, USA, China, Middle East, CIS and Australia. The consolidated and universal nature of the product has provided a good market for the processing by-products (Newton *et al.,* 2014), which are collected and processed into "marine ingredients" and mostly used for pig feeds. Lead firms such as Vinh Hoan, which is one of the largest integrated producers and processors is pioneering better utilisation of by-products by separation and further processing, especially fish collagen from skins.

Although Vietnam is the largest producer by far, other countries are now starting to produce pangasius, such as Bangladesh which produces solely for its domestic market. However, they are regarded as a competitor by the Vietnamese and may seek to find export markets in the future.

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Table 11: SWOT Analysis of Asian Pangasius Production

Strengths	Weaknesses
• Fast growing species • Resilient and easy to culture • Well established global markets • Cheap and competes with other white fish • Consolidated, modern supply chains and processing sector • Established by-product industry	• Low fillet yields • Poor consumer perceptions in some markets • Difficult for small scale producers to get certification • Effluent and sludge disposal problems • High mortality at hatchery/ nursery stage • Weak domestic market
Opportunities	**Threats**
• Growing markets world-wide • Improving technology • Improving efficiencies • Growing by-product market opportunities	• Open systems and therefore less resilient (pollution, diseases etc.) • Volatile markets and production costs • Growing international competition

3.2.9 Tilapia (mostly Oreochromis Niloticus)

Tilapias are a sub-tropical warm-water finfish that has been cultured for thousands of years, pioneered by the ancient Egyptians. It is omnivorous and able to filter-feed in highly productive systems. Although many species are cultured worldwide, as well as hybrids, the most popular is the Nile tilapia, *Oreochromis niloticus*. It is cultured in the Americas, Africa, Asia and Oceania. This species is also most popular amongst Asian producers who predominantly export to EU markets.

Tilapia have been grown in Asia in traditional earth pond systems, often as polycultures along with other finfish, shrimp or other crustacea, or sometimes in integrated systems with aquatic fowl or with rice and combinations of these approaches (Little, 2000). These systems were traditionally unfed, relying only on fertilisation with organic and inorganic manure, including the excreta of the fowl in order to boost primary productivity within the pond (Tran et al., 2019). In many cases, these are still the dominant production practices, such as on the Indian sub-continent. However, elsewhere, the advent of intensification and the opening of export markets led to serial improvements in some countries, particularly in Thailand and China (Ponte et al., 2014). The introduction of Genetically Improved Farmed Tilapia (GIFT) strains improved the performance along with techniques to produce all male progeny (monosex). This led to uniform growth rates, reduced aggression and prevention of self-recruitment within the production systems (Dey and Gupta, 2000). There have also been huge improvements in nutrition, health management and breeding programmes to improve fillet yields, which can be as low as 37% (compared to salmon at around 58%). Intensification has led to more monoculture production which may occur in either ponds or in freshwater cage systems.

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As for pangasius, in most countries there are a huge number of small independent tilapia producers that sell to whole sale markets before they are sold to processors (Bush and Belton, 2012). The trading network and number of middlemen steps before the product reaches the processor varies with the most complex network of traders in Bangladesh and other countries in the Indian subcontinent, but these routes tend to be for domestic consumption only. There are also highly integrated companies that export tilapia worldwide. Tilapia is also a white fish but the situation regarding competition is different because tilapia is so widely produced compared to pangasius. In Thailand, Charoen Pokphand (CP) is Thailand's largest private company, employing 300,000 people (Wikipedia, accessed 24/10/2019). It is a conglomerate of companies that operate mainly in agrofood businesses, including tilapia but many other aquatic and terrestrial species production, feeds, processing, retail etc, in Thailand and throughout SE Asia and beyond. In addition to CP, Grobest is an integrated, producer and processor, predominantly of aquatic animals feeds and animal health products operating mainly in Asia. Both companies are at the forefront of utilising by-product fractions, with an effort to maximise the edible yield such as producing snacks from trimmings and recycling other by-products into feed ingredients in their feed industries. However, China has the largest tilapia production in the world and exports to many countries, increasingly outcompeting the domestic markets of African and other Asian producers. China's aquaculture industry has been impressive, dominated by carps, but with more valuable species becoming increasingly important. The growth in production, particularly in shrimp and marine species, but also the sheer volumes of carps and tilapias has put pressure on global marine ingredients supplies. China has devastated its own fisheries over decades of mismanagement (Zhang *et al.,* 2019) fishing further down the food web as more valuable species have become depleted. The marine ingredients industry in China has provided an opportunity for fisheries to stay viable parallel to aquaculture growth. The unsustainable depletion of domestic fisheries has led to Chinese signing deals with other countries to allow them to exploit those waters too, particularly in Africa, leading to fears over food security in those countries.

Table 12: SWOT Analysis of Asian Tilapia Production

Strengths	**Weaknesses**
• Well established global species • Strong domestic and international markets • Omnivorous and versatile species • Well regarded, tasty fish	• Low fillet yield • Poor quality seed in some locations
Opportunities	**Threats**
• Improving technology • Breeding programmes for disease and fillet yield • Expanding by-product opportunities	• Open systems and therefore less resilient (pollution, diseases etc.) • High levels of competition leading to volatility in many countries • New disease threats (Lake virus)

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4. Value Chain Analysis data collection methodology

The methodology for the value chain analysis falls into two main sections. The first section is a survey of major global seafood shows to assess business to business seafood sustainability messaging and Key Informant interviews to assess aspects of international trade and sustainability. The major section is a full value chain assessment conducted in country involving semi-structured surveys and interviews with major aquaculture industry stakeholders in European production centres.

4.1 Seafood show sustainability surveys and Key Informant interviews

Seafood shows are a hotspot for traders and buyers from all over the world with different preferences and perceptions towards seafood. Additionally, attitudes towards trade, environment, messaging and other food cultures differ significantly round the World. Surveys will be conducted at the major seafood shows in Boston, Brussels, Guangzhou and Qingdao in order to understand global seafood trade, sustainability messaging attitudes and the potential of European aquaculture in the global context of seafood trading. At first a survey regarding sustainability messaging was developed in order to gain understanding about the different strategies to sell seafood. Secondly, a key informant survey was developed in order to gain insight into global market aspects through a SWOT-analysis with a focus on 'adding value strategies' and the use of by-products.

4.1.1 Survey sustainability messaging

Global seafood markets differ significantly in their production volumes. Global seafood trade is complex and consumers' preferences and perceptions differ significantly across the globe. This influences the way that people market and promote their seafood. However, these differences are relatively unknown. This led to a research framework developed in collaboration with researchers and partners within GAIN and beyond to assess 'sustainability' messaging at global seafood shows in Asia, Europe and the United States in 2019 (Table 13). Dates were selected based on the relationships between the largest producers and largest seafood markets in the world, Asia, United States and Europe, respectively.

Table 13: Details of seafood shows visited during T3.3

Seafood show	Location	Organizer	Date (2019)
Seafood Expo North America	Boston	Seafood Expo Global	March 17
Seafood Expo Global	Brussel	Seafood Expo Global	May 7-9
Fishes Guangzhou	Guangzhou	FISHEX	August 23-25
China Fisheries & Seafood Expo	Qingdao	China Seafood Expo	October 30 – November 1

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The research involved visiting seafood company booths at the shows and collecting information on the sustainability messaging that they were using to sell their product. Data was collected based on observation of booths and company details were recorded. More specifically, words or logos on the booth in relation to nutrition, health, environment and social aspects, such as fresh, sustainable, high in omega-3, no Genetically Modified Organisms (GMOs) or ingredients, traditional, healthy, organic etc. All the words were recorded for later categorisation and analysis, determined by the type of company, product and nationality. In addition, extra information regarding sustainability communication given on product packaging was collected, if available, relevant and time allowing. The details of the proposed survey are displayed in Table 14. Data has been collected from three of the four shows at the time of the writing of this deliverable. Data will be analysed to compare what the sustainability priorities of seafood companies are selling from and to different locations around the world.

Sample frames for the data collection were established based on the number of seafood sellers present. Typically, international seafood shows have a range of exhibitors, dominated by seafood sellers but also including machinery sellers, ingredients and feed companies, other industry service and support companies, logistics and press, which were not involved in this research. The population can be stratified by, e.g. country, then using probability proportion to size (PPS) or by simple random sampling or systematic sampling as follows. The number of booths sampled is dependent on the population size, confidence level and confidence interval. For the purposes of this study, the confidence level is set at 95% with a confidence interval of 5%. The population size differs between shows but generally the sample size is between 250 and 350 booths per show. The sampling starts by selecting an element from the list at random and then every *Kth* element in the frame is selected, where k, is the sampling interval: this is calculated as:

$$K=N/n$$

where n is the sample size, and N is the population size.

Table 14: Sustainability messaging survey

Company Details	**Booth details**	**Product details**
Company name?	Logo on the booth?	Booth Displays products? (yes/no)
Country?	Sustainability Words on the Booth? (yes/no). If yes, which one?	Relevant Product Packaging Messaging?
Continent/area?	Certification logo on the Booth? (yes/no). If yes, which one?	Sustainability Words on Package? (yes/no). If yes, which one?
Main activity?	Health words on the booth (yes/no)? If yes, which one?	Certification on the package? (yes/no). If yes, which one?
	Relevant for Booth presentation (colours,	Health Words on Package? (yes/no). If yes, which one?

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Company Details	Booth details	Product details
	pictures, videos, flyers, leaflets)?	
Email?	Relevant for Booth presentation (colours, pictures, videos, flyers, leaflets)?	1. Nutritional Composition on Package? 2. Moisture/Water Content on Package? 3. Place of Production on Package? 4. Origin of Raw Materials on Package? 5. Is Product Traceable for Consumers Through e.g. Scan-Code + App?
Contact details?	How many different products are displayed in the booth?	

4.1.2 Key informant interviews

The expansion of European aquaculture could create opportunities for exports. However, global trade is driven by numerous factors and understanding the driving forces of the markets is crucial if certain criteria want to be met. Therefore, a survey is created with in-depth questions regarding the strength, weaknesses, opportunities and threats (SWOT) of European aquaculture derived from Key Informant interviews which were conducted to gather more contextual information regarding sustainability perceptions and priorities of stakeholders. The interviews were semi-structured involving discussions around key themes, led by the interviewer who asks questions around the themes of sustainability, value addition to by-products and EU trade (Table 15). Key informant interviews are conducted at seafood shows and during field visits to partner countries as part of the Value Chain Analysis.

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Table 15: Key informant interview questions asked to seafood producers and traders at international seafood shows and during VCA

Company/ respondent details	Question checklist for sustainability and trade
Booth number? Company Name? Country? Number of full-time employees? Employee Name? Position in the company? How many years of experience in the company? How many years of experience in the field? Email address? Phone number? Main company activity? What is the range of products you develop?	• What are sustainability terms used by seafood exhibitors? • What is the definition/meaning of these terms to them? • What do they do in their business to achieve these goals/terms? • Are they members of any certification schemes? • For exhibitors who are not using any of sustainability terms/any certification scheme, why they don't? • Do you add value to the products? • If yes, what do you do? • Which products have the most added value? • What is the range of scale/value of these products? • What do you do with the by-products? • Do you import/export by-products? • How do you see the future of the fish by-product industry (coming 5-10 years)? • What is the source of your import portfolio in terms of farmed vs wild fisheries (ratio)? • How do you see the future (5-10 years) in terms of imports (wild vs farmed)? • How do you see the future (5-10 years) in terms of imports (species)? • Do you import from the EU? • What is the ratio between EU imports of fisheries and aquaculture products? • What is the ratio between EU imports of • fisheries and aquaculture products? • Do you export to the EU? • If yes, what is the incentive? • What is the share of products (volume and/or value) of exports to the EU compared to other countries?

These questions are a guide and starting points around which discussions are allowed to develop, allowing more open answers and perceptions to be gathered, compared to structured survey tools. The questions are neither imperative or exhaustive, with the goal being to lead a discussion towards gathering relevant information. The answers given will give insights into the different barriers and opportunities for traders of different fisheries and aquaculture products being traded internationally, their perceptions about what sustainability challenges will be important for them and the industry as a whole into the future. Key Informants are chosen according to their engagement level, knowledge,

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and representativeness of their business their experience in the industry and companies actively in imports (European and American) of Asian seafood and vice versa.

4.1.3 SWOT analysis and Delphi process

SWOT analysis is an established technique used to characterise the current standing of a business or industry and its capacity to meet future challenges. SWOT i.e. Strengths, Weaknesses, Opportunities and Threats, where strengths and weaknesses refer to the company/industry itself and opportunities and threats refer to the business environment in which they operate. The SWOT analysis is conducted through a combination of survey work and literature. The results from the Key Informant interviews, value chain analysis and literature review will be used to inform the SWOT analysis presented in D4.2. In this deliverable a basic SWOT analysis of GAIN species, tilapia and pangasius has been presented based purely on literature data. The results of the analysis are presented in Section 6.

The Delphi method was originally developed for consensus building, where expert’s opinions were used for business forecasting. The method was later used for decision making in a variety of domains, such as technology industry, engineering and social science (Hirschhorn, 2018). Within GAIN it is applied to complements SWOT as a business/ industry forecasting methodology relying on a panel of independent, anonymous experts. Essentially it is an iterative process by which the experts comment on a selection of business scenarios/ forecasts/ innovations and are then invited to revise their opinions based on the feedback from previous rounds as the iterations progress. The methodology is particularly useful for gauging the timeline for implementing technology, the likelihood of certain business developments and the policy required to allow for such changes within the industry. In this case, the panel of experts will be drawn from Key Informants from seafood shows and the VCA with their opinions from the interviews used within the process, but made available to the rest of the panel anonymously. The University of Stirling will act as a facilitator whereby complementing and conflicting opinions are compiled before returning the results to the panel for reassessment. The process is then repeated towards finding a consensus between the different actors. The Delphi process will begin on completion of the Key Informant interviews from the Seafood shows and VCA fieldwork up to month 30.

4.1.4 Porter Diamond of National Advantage (PDNA frameworks)

The Porter Diamond model or Theory of National Competitive Advantage of Industries, here referred to as the Porter Diamond National Advantage (PDNA) framework, is used to explain why certain industries or individual companies are more competitive internationally than others within a nation. The SWOT analysis and Delphi results will be integrated in a PDNA framework in order to understand the competitive advantages of European aquaculture and its international competitive advantage compared to other producers around the globe. Missing gaps will be completed with the help of a literature review. The 4 factors in this framework, namely: factor conditions; demand conditions; strategy, structure and rivalry; and related supporting industry, will provide an overview of key drivers and competitive advantages of European aquaculture to fulfil domestic demand. The model predicts that if the four factors are favourable, then the industry/sector/company will be able to effectively

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innovate, "upgrade" and meet challenges, enabling it to compete on the international stage. Factor conditions relate to the resources available within a country and available to the industry, including natural and human capital. Demand conditions relate to the domestic demand for products which may help an industry to innovate and prepare for international opportunities and challenges. Strategy, structure and rivalry refers to how much domestic competition there is which drive innovation and thus make companies more competitive on a world stage. Related supporting industry generally refers to how strong the supply/ value chain is in helping companies to perform, giving them access to good quality materials and resources, but can also refer to how much collaboration there is between similar companies, enabling them to overcome mutual challenges and innovate. In addition to the four main pillars of the diamond, the role of government and chance is also incorporated into the analysis. Government plays a key role in influencing the demand and factor conditions by stimulating demand and by helping to provide especially human resources. Chance is often incorporated into the model as factors outside of the control of stakeholders but may influence the competitiveness of the industry. These chance factors are often subjective and difficult to predict. The PDNA framework will be applied when the results from the KI derived SWOT analysis has been completed.

4.2 European aquaculture value chain analysis surveys

Understanding the value chain, material-flows and stakeholders involved is crucial in order to assess the suitability of innovations being developed within GAIN and other projects and cannot be understood from literature alone. KI interviews at seafood shows give a good overview of trade and industry trajectories but cannot represent the sustainability issues that are facing all of the stakeholders within a value chain and cannot provide necessary resolution of the interrelationships that exist. In order to GAIN insight into the power relationships within the industry, the effect of innovation, the individual sustainability concerns and need for innovation, a full Value Chain Analysis is necessary. This involves a series of structured and semi-structured surveys of a representative cross-section of the stakeholders within the industry, including those directly involved in producing and trading the product, as well as service providers, researchers, government, regulators etc.

4.2.1 Semi-structured value chain survey

Value chain surveys will be conducted for the main species in the EU and EEA, namely salmon (Norway), carp (Poland), seabass, seabream and turbot (Spain and Portugal). After a preliminary scoping meeting with Gildeskål Research Station (GIFAS), a total of 29 stakeholder groups were selected for the stakeholder analysis in Norway. A similar scoping exercise will be carried out for field work in Poland and Iberia. The stakeholder groups that were interviewed for the work can be seen in Table 16 and a copy of the survey is given in Annex 1. Stakeholders were contacted through phone or by email using the networks of project partners where possible to increase engagement in the project. In some cases, VCA surveys were combined with LCA/ sustainability index surveys to optimise data collection.

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Table 16: EU and EEA aquaculture value chain stakeholders contacted for the VCA of the Norwegian salmon industry

Broodstock/egg producers	**Integrated companies**	**Recreational (Guide) Tour**
Hatchery (RAS)	Cleaner fish producers	Research and innovation company (R&D)
Smolt production (RAS)	Exporting and trading company	Trainer institution
Smolt production (Flow-through)	Retail company	Equipment producers, maintenance and recycling
Grow-out Farm	Well boat/transport	Government and representative authorities
Feed companies	Transport and site maintenance boats (people and cargo)	Certifying body/organization
Slaughter house and primary processing	Vet/health management company	NGO/Representative organization
Secondary processing	Ingredient producers (fish oil, hydrolysates/meals etc).	Consumer group/associations
Value addition processing	End users	Other supporting industry (chemicals, ice)
By-product processor	Education	

4.2.1.2 Stakeholders and their function in the value chain (power and interest relationships)

Stakeholders along the value chain fulfil different functions and innovate in order to stay competitive. Assessing the suitability of certain innovations requires an understanding of the power and interest of stakeholders (table 1.1, Annex 1) to make industry changes and the effect of changes or innovation on stakeholders (interest), which could influence the perspective towards these innovations. As stakeholders generally cannot objectively determine their own power or interest within an industry, stakeholders were asked to score the power (1 = barely any influence, 10 = highly influential) and interest of other stakeholders within the chain, which will then be combined to provide an average score. In addition, stakeholders were asked to provide information on collaborations and partnerships, the number and length of relationships regarding association members, workshop attendance, R&D with academia/NGO, R&D with commercial and government programs. Stakeholders are asked to highlight the stakeholders whom they have most contact with, by providing detailed information on the type of relations, amount of meetings and years of relationship. All of the information given provides a picture of the power relationships and structure of the industry.

4.2.1.3 Assessing knowledge, attitudes and perceptions regarding sustainability

A survey for the listed stakeholders (table 16) is developed to understand the knowledge, attitudes and perceptions towards sustainability issues facing them as stakeholders and the innovations being developed in GAIN. This will provide a better understanding of the suitability of the innovations and the potential drivers and barriers for implementation. At first the stakeholders will be asked questions in relation to sustainable intensification and the availability of information regarding this topic to the

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public (table 17). Then stakeholders are asked to score the most important sustainability issues facing them and the industry which could be positive, negative or uncertain e.g. they might say sea lice is an extremely negative factor which they score as -5. They also say that new feed ingredients are being introduced which will have a positive influence on them which they score as +3. They also say that there is new regulation coming in which they are uncertain of how it is going to affect them (see Annex1).

Table 17: Survey regarding sustainable intensification and sustainability issues

How do you see sustainable intensification in aquaculture (positives/negatives/impacts)?
Does your company have a vision/plan for sustainable intensification?
What are the current topics / processes on sustainability that you are currently working on?

The GAIN innovations (Table 18) show potential to support the sustainable growth of the industry. However, some innovations might be more suitable then others depending on active stakeholder awareness towards these innovations. Stakeholders will be asked if they have any knowledge, company interest or industry interest in these innovations. Their answers (yes/no/uncertain) will be scored accordingly in order to gain quantitative insight in the awareness and potential of these innovations. Stakeholders are also asked to comment more generally on the innovations.

Table 18: GAIN innovations and stakeholder perspectives.

Micro algae	*Macro algae*	*Hydrolysed fish proteins*	*Single cell proteins*	*Insect proteins*
Sludge for fertiliser	*Sludge for biogas*	*Mortalities for biogas*	*Processing by-products for feed*	*By-products for cosmetics/nutraceuticals*
Shells for biofilters	*Shells for packaging*	*Shells for cement/filler*	*Use of big data management support*	*Use of big data for fish welfare*

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5. Conclusions

Optimizing aquaculture output in terms of production volume and economic output requires an understanding of the value chain in terms of production and processing and its related context, especially services and broader such as governance. This requires a comprehensive approach, including a literature review on trade, consumption, production, and processing and sustainability issues. This will be combined with a VCA during fieldwork in Norway, Poland, Spain and Portugal focussing on trade flows, stakeholder positions and sustainability perceptions.

Additionally, in terms of seafood trade, key informants will be interviewed and data will be organized and analysed in SWOTs in combination with a Porter Diamond National Advantage (PDNA) framework and Delphi process. This provides insights into global trade, seafood marketing and opportunities to differentiate European aquaculture products in the global market. It will also provide understanding of current drivers and barriers of European aquaculture in relation to competitive producers in e.g. Asia.

These analysis and insights altogether will contribute to a better understanding of the aquaculture value chain in the EU and EEA and the potential of innovations to increase aquaculture output sustainably.

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7. Table of Contents for Figures and Tables

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8. Annex 1 Value Chain Analysis Key Informant structured questions and checklist (as used in Norway July – September 2019)

Introduction and verbal consent

My name is …………… and I am working for ………..

We have a research project "GAIN – Green Aquaculture INtensification in Europe" to support the ecological intensification of aquaculture in EU and the EEA. The objectives are to increase production and competitiveness of the industry while ensuring sustainability and compliance with EU regulations on food safety and environment.

Part of this project is to assess the consumers and stakeholders' acceptance of eco-intensification measures for which we are conducting a survey for the key players along the value chain.

Would you be happy to participate in this survey and discuss your opinions/vision and your business plan regarding aquaculture intensification, it will take approximately 30 minutes? Yes/No

Company/business and interview details

What is the main activity of this company, which sector this company can be classified (farming, processing, feed ……)?

What is your position/responsibility in this company?

How many years are you working in aquaculture?

How many years are you working for this company?

Value chain information

Total industry production (MT - feed, grow out, smolts etc)

Type of products or activities (Producer, R&d, education etc depending on stakeholder)

Comparison to other companies

Number of companies in Norway

Company production as % of total

Main markets of total industry (domestic, international)

Transportation methods (% air/sea/land of total industry).

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What are the main trends in the industry (growth, markets, practices, innovation, structural, managerial, consolidation, integration, new players, diversification, value addition)?

What are the main changes in your part of the industry?

What are the main changes in your company?

1.1 Can you rate the power and interest of the following stakeholders in terms of their power to make industry changes/innovate and how it could affect them? Score 1 (barely any influence) to 10 (highly influential)

Stakeholder	Power	Interest
Broodstock/egg producers		
Hatcheries (RAS)		
Smolt production (RAS)		
Smolt production (flow-through)		
Grow-out farms		
Independent slaughter house and primary processors		
Independent secondary processors		
Value addition processors/smokeries etc.		
Integrated companies		
By-product processors		
Cleaner fish producers		
Exporters/trading companies		
Retail		
Well boat/transport		

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Stakeholder	Power	Interest
Vet/health management companies		
Feed companies		
Ingredient producers (fish oil, hydrolysates/meals etc)		
End users (pet food)		
Education groups		
Research innovation companies		
Trainers		
Equipment producers		
Government authorities		
Certifiers		
NGOs		
Consumer groups/associations		
Other support industries/suppliers (ice, chemicals, consumable products etc)		

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1.2 Do you participate in the following?

	No.	Length relation	Description
Association membership			
Workshop attendance			
R & D with academia/NGO			
R & D with commercial			
Government programme			
Other …..			

1.3 What stakeholders do you have most interaction with?

Name	Type (NGO, feedmill,..)	Relationship (customer,…)	Number meetings/yr	Years of relationship

Knowledge, attitudes and perceptions regarding aquaculture intensification and sustainability

By intensification, we mean producing more with fewer resources at all stages along the VC

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How do you see intensification in aquaculture (positives/negatives/impacts)?

Does your company have a vision/plan for sustainable intensification?

What are the current topics / processes on sustainability that you are currently working on?

What factors do you foresee that could positively or negatively affect your farms performance over the next 5 years? Score 1 (negatively) to 5 (positively) or rank.

	Sustainability Factor	**Overall Rank/score**	**Response**
Negative			
Positive			
Uncertain			

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Within GAIN project we are proposing the following eco-intensification measures, for each of these measures we would like to know your opinion and acceptance and if your company already applying or willing to adopt in the future. Please remember the following QS may not be applicable to all the measures bellow.

For each measure please ask the following QS:

Have you heard about this measure?

Do you have any example of it being applied?

Production and Environment

Measure	Micro algae	Macro algae	Hydrolysed fish proteins	Single cell proteins	Insect protein
Knowledge					
Company interest					
Industry interest					
Comment					

Enhancement of secondary outputs - finfish

Measure	Sludge for fertiliser	Sludge for biogas	Mortalities for biogas	Processing by-products for feed	By-products for cosmetics/nutraceuticals
Knowledge					
Company interest					
Industry interest					
Comment					

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Enhancement of secondary outputs - shellfish

Measure	Shells for biofilters	Shells for packaging	Shells for cement/filler	Use of big data management support	Use of big data for welfare
Knowledge					
Company interest					
Industry interest					
Comment					

Do you think there is enough information available for the awareness of sustainable aquaculture intensifications?

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