Publications of the Ministry of Economic Affairs and Employment
Enterprises • 2022:49

The Fish Value Network and Business Ecosystem in Finland

Ministry of Economic Affairs
and Employment of Finland

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Anna Kortesoja, Niilo Salmela, Emma Kuusela-Opas, Susanna Sepponen, Pekka Pokela

Ministry of Economic Affairs and Employment of Finland Helsinki 2022

Julkaisujen jakelu
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arkivet Valto

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Ministry of Economic Affairs and Employment of Finland

ISBN pdf: 978-952-327-740-3
ISSN pdf: 1797-3562

Layout: Government Administration Department, Publications

Helsinki 2022 Finland

Description sheet
16 June 2022

The Fish Value Network and Business Ecosystem in Finland

Publications of the Ministry of Economic Affairs and Employment 2022:49		**Subject**	Enterprises
Publisher	Ministry of Economic Affairs and Employment of Finland		

Author(s)	Anna Kortesoja, Niilo Salmela, Emma Kuusela-Opas, Susanna Sepponen, Pekka Pokela		
Group author	Gaia Consulting Oy		

Language	English	**Pages**	52

Abstract

Finland's geography largely consists of coastline, seas and lakes, and fish has traditionally been a natural part of the local economy. A versatile ecosystem has developed around fish in Finland. Sustainable fishing, fish farming and fish processing and trade provide not only a climate friendly means of food production but also economic growth to various business actors. There is demand for innovative fish-based products.

Finland has global expertise in operating in cold climate conditions which makes Finnish industries and ecosystems natural partners in development cooperation aiming at adding the value of Arctic fish.

There are many aspects to raising the value-added of fish: developing fishing and fish handling processes, developing new user-friendly products for the customers and looking for new markets for fish as a raw material. This report maps the business and innovation ecosystem of fish in Finland and illustrates the opportunities linked with raising the value-added of fish.

Keywords enterprises, means of livelihood, value added, aquaculture, Arctic region, fishing, climate changes

ISBN PDF	978-952-327-740-3	**ISSN PDF**	1797-3562
URN address	https://urn.fi/URN:ISBN:978-952-327-740-3		

Kuvailulehti
16.6.2022

Kalan arvoverkosto ja liiketoimintaekosysteemi Suomessa

Työ- ja elinkeinoministeriön julkaisuja 2022:49		**Teema**	Yritykset
Julkaisija	Työ- ja elinkeinoministeriö		

Tekijä/t	Anna Kortesoja, Niilo Salmela, Emma Kuusela-Opas, Susanna Sepponen, Pekka Pokela		
Yhteisötekijä	Gaia Consulting Oy		

Kieli	englanti	**Sivumäärä**	52

Tiivistelmä

Vesistöjen osuus Suomen pinta-alasta on suuri, ja kala on perinteisesti ollut luonnollinen osa paikallista taloutta eri osissa maata. Kalan ympärille on kehittynyt Suomessa moninainen ekosysteemi, jossa kestävä kalastus, kalanviljely ja kalanjalostus sekä kauppa tarjoavat ilmastoystävällisen ruuantuotannon lisäksi talouskasvua monenlaisille toimijoille. Uusille innovatiivisille kalapohjaisille tuotteille on kysyntää.

Suomella on globaalia asiantuntijuutta kylmissä ilmasto-oloissa toimimisesta, mikä tekee suomalaisista elinkeinonharjoittajista luontevia kumppaneita arktisen kalan arvonlisän kehittämiseen.

Kalan arvolisän nostamiseen liittyy useita näkökohtia: kalastuksen ja kalankäsittelyprosessien kehittäminen, uusien helppokäyttöisten tuotteiden kehittäminen asiakkaille ja uusien markkinoiden etsiminen kalaraaka-aineelle. Tämä raportti kartoittaa Suomessa kalaan liittyvää elinkeino- ja innovaatioekosysteemiä ja kuvaa kalan arvolisän kasvattamiseen liittyviä uusia mahdollisuuksia.

Asiasanat	yritykset, elinkeinot, arvonlisä, kalanviljely, arktinen alue, kalastus, ilmastonmuutokset		
ISBN PDF	978-952-327-740-3	**ISSN PDF**	1797-3562
Julkaisun osoite	https://urn.fi/URN:ISBN:978-952-327-740-3		

Presentationsblad

16.6.2022

Värdenätverk och företagsekosystem i Finland för fiske

Arbets- och näringsministeriets publikationer 2022:49		**Tema**	Företag
Utgivare	Arbets- och näringsministeriet		
Författare	Anna Kortesoja, Niilo Salmela, Emma Kuusela-Opas, Susanna Sepponen, Pekka Pokela		
Utarbetad av	Gaia Consulting Oy		
Språk	engelska	**Sidantal**	52

Referat

Finlands geografi består till stor del av kust-, hav- och insjöområden. Därför har fisk traditionellt varit en naturlig del av den lokala ekonomin. Ett mångsidigt ekosystem har utvecklats kring fisk i Finland. Hållbart fiske, fiskodling och fiskförädling samt handel möjliggör inte enbart klimatvänlig livsmedelsproduktion utan också ekonomisk tillväxt för olika aktörer inom branschen.

Finland har global expertis inom verksamhet under kalla klimatförhållanden, vilket gör de finländska näringsidkarna och ekosystemen till naturliga partner inom fiskens värdeutveckling i arktiska områden.

Ökandet av fiskens mervärde omfattar många möjliga aspekter: utvecklingen av fiske- och fiskförädlingsprocesser, utvecklingen av nya förbrukarvänliga konsumentprodukter, och breddandet av potentiella nya marknader för fisk som råvara. Denna rapport kartlägger närings- och innovationsekosystemen för fisk i Finland och illustrerar nya möjligheter för ökandet av fiskens mervärde.

Nyckelord	företag, näringsgrenar, värdeökning, fiskodling, arktiska området, fiske, klimatförändringar		
ISBN PDF	978-952-327-740-3	**ISSN PDF**	1797-3562
URN-adress	https://urn.fi/URN:ISBN:978-952-327-740-3		

Table of contents

1 Introduction

Finland's geography largely consists of coastline, seas and lakes, and fish has traditionally been a natural part of the local economy in most parts of the country. Along with the other Nordic countries, Finland is generally doing well in achieving the global goals for sustainable development. It is, however, struggling with unsustainable production and consumption patterns, need for climate action and biodiversity conservation, and the state of the seas and waters[1]. As the climate footprint of fish is low in comparison to other animal-based food production, increased consumption of fish protein and products holds a potential for significant positive economic, environmental, and social impacts. Furthermore, a sustainable and competitive domestic fish industry has been defined as one of the current Finnish Government's strategic goals[2]. There are also market-based signs of a growing interest in the fish-related industries.

Fish industries across the whole Arctic region face some of the same opportunities and challenges related to sustainable production and climate change, affecting fishery and aquaculture areas. As neither regulation, industries or markets are restricted by national boundaries, there is a strong case for enhancing the understanding of both the framework and the value networks related to fish. This would help the Arctic countries to identify cooperation areas related to RDI development, business-to-business offering, funding and investment. Several initiatives are already in place that aim to fast-track innovation, product development and economic growth within the value network of fish and aquaculture.[3] This report aims to add to this knowledge base with a brief and illustrative overview of the current Finnish value network of fish: its strengths, challenges, and potential.

1 Report on the implementation of the 2030 Agenda for sustainable development. Voluntary national review 2020 Finland. Publication of the Prime Minister's Office 2020:8.

2 https://mmm.fi/kalat/strategiat-ja-ohjelmat/kotimaisen-kalan-edistamisohjelma (in Finnish)

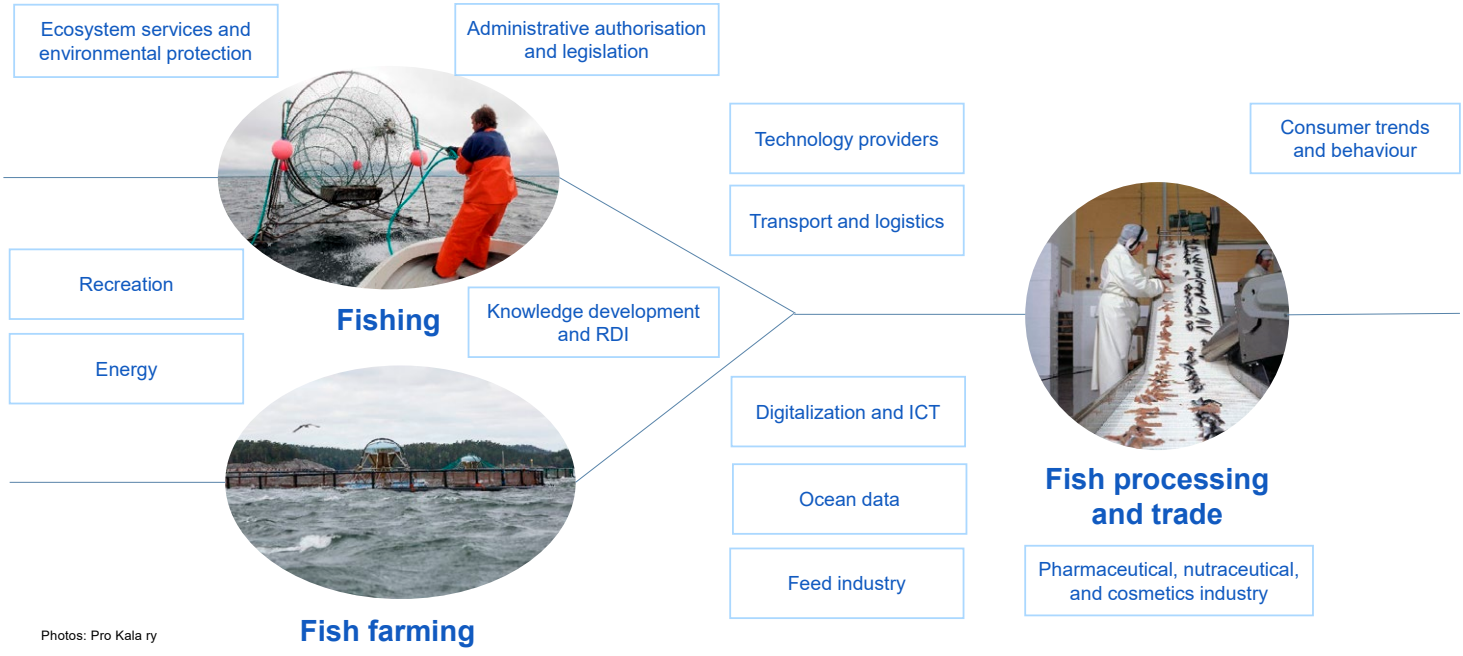
3 On Nordic ecosystems, see Sepponen et al. 2021. Sustainable Ocean Economy. Mapping of Nordic Strongholds. On Arctic development, see the Blue Economy working Group of the Arctic Economic Council, https://arcticeconomiccouncil.com/workinggroups/blue-economy-working-group

This report was compiled for Ministry of Economic Affairs and Employment of Finland by Gaia Consulting, a consultancy for sustainable business, in November–December 2021. The main method used was desk top study including analysis of publicly available material and Gaia's expert work utilising knowledge in the fish sector and arctic region, complemented by a few validating interviews.

1.1 General description of the value networks and ecosystems

Finland is the biggest fishing state in the Baltic Sea area. The value of its fish economy value network is estimated to be about 1 billion euro a year[4]. The largest source of domestic fish are marine fisheries of wild fish populations[20].

Figure 1. Value Network of fish and business ecosystems in Finland.



4 Rahkonen, R. 2018. Publications of the Ministry of Agriculture and Forestry 6a/2018. pp 35. ISBN: 978-952-453-986-9

Fish processing was the most profitable fishery industry in 2019 with a net income of 7,6 million euros. The wholesale of fish generated a net income of 7,1 million euros while the retail trade specialized in fish made 6,3 million euros. The net income of fishing was 5,2 million euros. The only loss-making industry was fish farming which lost 3,1 million euros[5].

In this report, the value network of fish in Finland and business ecosystems within the network are summarized using examples of companies and other actors. With *business ecosystems* we refer to the naturally evolving cooperation within the industry, as well as with other related industries. With *innovation ecosystems* we refer to more systematically orchestrated ecosystems that usually have a joint RDI-agenda and financial support through national innovation programs[6].

This report describes fishing and fish farming as sources of Finnish fish, as well as the fish processing industry and fish trade. Services of several other industries are needed in order to these three main parts of the network to operate and cooperation with these other industries is part of the larger business ecosystems. These industries include transport and logistics, technology providers, the feed industry, digitalization and ICT, the pharmaceutical, nutraceutical and cosmetics industry, and the energy industry. In addition, the fish value network is connected to other activities, such as knowledge development and RDI, use of ocean data, and recreation. Furthermore, aquatic nature offers ecosystem services to protect the environment and waters from adverse effects. Although Consumer trends and behaviour have an impact on the fish market, new fish products impact consumer trends and behaviour as well.

The Finnish fish economy is part of a larger Nordic market that besides Finland and the Åland Islands encompasses Sweden, Norway, Denmark, including the Faroe Islands and Greenland, and Iceland as well as Estonia. Many of the larger companies within the fish industry have operations in several countries. Most of the fish imported to Finland comes from Norway with Sweden in second place. While Finland exports fish and fish products to e.g. France and Estonia, the imported volumes outsize the exports.

Many of the technologies recognized in this report can be used in several parts of the value network, especially those related to digitalization, automation, and energy solutions. Combining innovations and technologies from several fields and manufacturers across

5 Luke 2020f: https://stat.luke.fi/kalatalouden-kannattavuus (read 6.12.2021)

6 In Finland, the development of innovation ecosystems in the value network of fish have been supported by the national programs under the European Maritime and Fisheries Fund, but are still at an early stage.

different sectors within the value network can create added value by enabling more efficient utilization of available operations and resources.

1.2 Finnish business-led innovation ecosystems in industries linked to fish value network

For decades, Finnish companies have pioneered high-tech in the high seas. The competitive edge of Finnish maritime technology is its focus on safety and sustainability in demanding Arctic conditions. Finland is a global leader in icebreaker design and ice technology.[7]

Finland has a mechanism for building goal-oriented and systematic development of business-led innovation ecosystems. Such ecosystems can be publicly supported when a group of companies and other actors have identified a business spearhead with a global market potential that can be achieved in collaboration with others.[8] No such ecosystems exist in the fish industry as such, but in the following paragraphs we introduce some ecosystems that are directly or indirectly linked to the fish value network and may provide new solutions for actors within it.

Offshore wind farm and maritime traffic business ecosystems are being created in Finland with help of a growth engine model[9]. Team Renewable Arctic Finland (TRAF) is an ecosystem of businesses within a wide range of energy and maritime businesses that develop renewable energy solutions for offshore and maritime operations. The ecosystem specialises in arctic technologies[10]. There is an active push for making flexible business ecosystems to grow these sectors' company base and export potential.

One Sea is a business ecosystem combining autonomous systems and digitalization with maritime operations. One Sea attempts to develop digitalized solutions in port operations

7 Business Finland, Meri- ja offshore -teollisuus: https://www.businessfinland.fi/suomalaisille-asiakkaille/palvelut/ohjelmat/paattyneet-ohjelmat/arktinen-meri-ja-offshoreteollisuuden-ohjelma (read 21.12.2021)

8 Business Finland, growth engines: https://www.businessfinland.fi/en/for-finnish-customers/services/funding/growth-engines/funding-for-the-orchestration-of-growth-engines (read 22.12.2021)

9 Business Finland (2018): https://www.businessfinland.fi/ajankohtaista/uutiset/2018/meri-luo-uusia-kasvumoottoreita (read: 22.12.2021)

10 Gaia (2021): https://www.gaia.fi/news-archive/group-of-businesses-is-accelerating-finlands-offshore-wind-sector/ (read: 22.12.2021)

and logistics to make operations as efficient as possible. At the same time autonomous systems in maritime operations are developed for a wider range of applications. Many companies with expertise in maritime operations, automation and digitalization are a part of the ecosystem.[11] This provides a wide range of products and possibilities for novel innovations and new application of digital solutions specifically in marine areas.

To tackle the challenges for the energy sector caused by the climate change and over-use of fossil fuels, hydrogen-based energy solutions are being developed in Finland in collaboration with other countries in the Baltic Sea area. Hydrogen is a clean fuel that can provide an alternative to oil. Because hydrogen can be stored it can be used as an energy carrier. Hydrogen-based technologies are getting international attention as they can provide solutions for achieving carbon neutrality of energy production in many sectors including the maritime and fish industry[12]. BotH2nia is an example of a business ecosystem initiative for clean energy: they aim to create an integrated hydrogen, biogas, and wind energy-based economy around the Gulf of Finland. They want to create an ecosystem that can be implemented in other sea areas as well, and to create exportable solutions for green energy ecosystems[13].

Finally, Finland is also a rising star in space technology. Finnish companies are providing high-tech equipment internationally. Technologies for assessing operations on the Earth's surface, managing natural resources and making more accurate weather forecasts are developed and produced in the Finnish space-technology ecosystems. These technologies could be implemented in many sectors[14]. Predicting weather and ice conditions could help in fishing operations. Collecting spatial data can also help with more efficient fishery management.

11 One Sea (2018): https://www.oneseaecosystem.net/one-sea-sai-business-finlandilta-lisaa-rahoitusta-laivameklarit-mukaan-kehittamaan-digitaalista-merenkulkua/ (read: 22.12.2021)

12 Business Finland, Hydrogen (2021): https://www.businessfinland.fi/en/whats-new/news/cision-releases/2021/finnish-innovation-powers-hydrogen-economy (read: 22.12.2021)

13 BotH2nia: https://clicinnovation.fi/project/both2nia/

14 Business Finland, Space (2021): https://www.businessfinland.fi/en/whats-new/news/cision-releases/2021/new-space-economy-ready-to-lift-off-thanks-to-finnish-innovation (read: 22.12.2021)

2 Fishing

Fishing operations in the Finnish waters includes both coastal and freshwater species. Finland has a long coastline of 47 392 km in the Baltic Sea with extensive archipelago areas in the Southwestern part of the country[15]. At the same time, around 10 % of Finland's area consists of inland water bodies[16]. These geographical features have made fishing a natural part of the local economy in most parts of the country. The marine areas are economically more important than the inland water bodies as around 96 % of the catch comes from marine fisheries and around 4 % from freshwater fisheries[17].

The Finnish fisheries are divided into three areas: open seas, coastal and inland fisheries. However, generally the division is made between marine and inland fisheries[18]. These are capture fisheries which includes all activities to harvest fish resources. Fishing operators are divided into two categories according to the size of their operations: groups 1 and 2. Group 1 consists of operators whose revenue, including VAT, is over 10 000 euro while group 2 includes operators with revenue less than that[18].

This chapter describes the market and operators in Finnish fisheries as well as other industries linked to fishing using examples of companies. In addition, development needs, and research and innovation prospects are summarized.

15 Laurila, L. & Kalliola, R. 2019. Seurantatutkimus 'Suomen merenrannikon rakennetut ja rakentamattomat rannat'. Turun yliopisto, Maantieteen ja geologian laitos.

16 Ministry of Agriculture and Forestry of Finland 2020: https://mmm.fi/vesistot?p_p_id=com_liferay_journal_content_web_portlet_JournalContentPortlet_INSTANCE_d2bhGoJAzLUl&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&_com_liferay_journal_content_web_portlet_JournalContentPortlet_INSTANCE_d2bhGoJAzLUl_languageId=en_US (read: 2.12.2021)

17 Luke Statistics Database 2020: table on "Total fish production in Finland" (read 2.12.2021)

18 Pro Kala ry. 2018: Vedestä ruokapöytään, suomalainen elinkeinokalatalous.

2.1 Description of the market and operators

The total catch of Finnish fisheries was 117,3 million kg in 2020 and its total value was 46,4 million euro[19,21]. The amount of commercial fishermen in Finland in 2020 was 4128 of which 752 were categorized into group 1[20] (table 1).

Table 1. Table 1: Volume and value of commercial fisheries, and the number of registered fishermen in marine and inland areas in 2020.

In 2020	Total catch (million kg)	Value (million €)	Fishermen	Group 1	Group 2
Marine fisheries	112	31	2276	399	1877
Inland fisheries	5,3	15,4	1852	353	1499
Total	117,4	46,4	4128	752	3376

Commercial marine fishery caught 112 million kg of fish in 2020. In total, the value of the catch has been calculated to be 31 million euro. Highest catches come from Baltic herring (92,5 million kg) and sprat (12,5 million kg). As such, the Baltic herring is also the most important species economically. Other important species are salmon, European whitefish and pikeperch[19]. In 2020 there were 2276 registered fishers in the marine areas of which 399 were in group 1 and 1877 in group 2[20] (table 1). The fishing effort (calculated as number of days multiplied by the quantity of gear) has gradually been decreasing during the 2000s. The decrease from year 2000 to 2020 was 70 % for the total fishing effort20. On the other hand, the total catches from commercial fishing between years 2000 and 2019 show an increasing trend (figure 2).

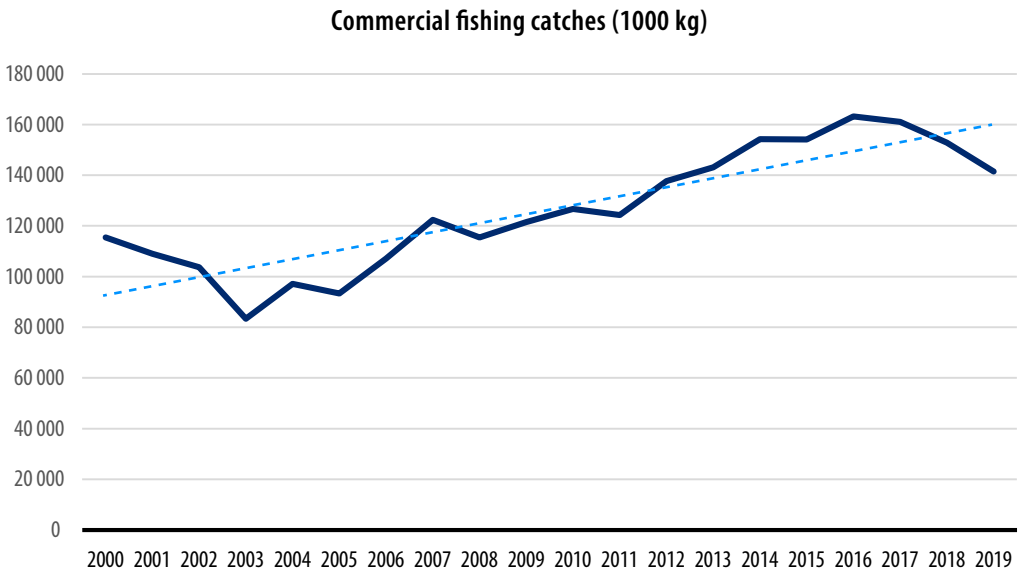
Commercial inland fisheries' total catch in 2020 was 5,3 million kg with a total value of 15,4 million euro (table 1). The most important species by volume was vendace which accounted for 40 % of the total catch with a value of 5,0 million euro. Economically, however, pikeperch was the most important species with a value of 5,7 million euro. Vendace and pikeperch account for three quarters of the total value of commercial inland fish catch. Other important species are European whitefish and crayfish (signal and noble

19 Luke 2020b: https://stat.luke.fi/en/commercial-marine-fishery-2020_en-0 (read: 2.12.2021)

20 Luke Statistics Database 2020: table on "Registered commercial marine fishermen" (read 2.12.2021)

crayfish). As a way to keep fishing areas in ecologically good status, roach, bream and smelt among others are removal-fished to fight eutrophication. The value of removal-fishing was 0,87 million euro[21]. There were 1852 registered commercial fishermen in inland waterbodies of which 353 were classified as group 1 fishermen. The catches in inland fisheries have been steadily increasing since 2000[20].

Figure 2. Total catches from commercial fishing from 2000 to 2019 in 1000 kg. Data includes both marine and inland fisheries combined (Luke Statistics Database).



Fishermen have several active interest groups that promote the fishing industry through media, technology, and research, as well as by guarding the fishermen's interests on a local and national level. Finnish Fishermen's Association, SAKL ry (Suomen ammattikalastajaliitto ry), is a national organization that guards the interests of its members and the fishery industry as a whole. Its purpose is to execute a strategy that has been approved by the industry. Additionally, its purpose is to develop the fishery industry, facilitate collaboration between stakeholders and take care of the internal and external communication of the industry.[22]

21 Luke 2020c: https://stat.luke.fi/en/commercial-inland-fishery (read:2.12.2021)

22 SAKL ry: http://www.sakl.fi/ (read: 2.12.2021)

Similarly, The Inland Professional Fishermen's Association of Finland, SSAK ry (Suomen sisävesiammattikalastajat ry), is an organization whose purpose is to create a beneficial operational environment for freshwater fishing. The organization's agenda is similar to SAKL ry's: to facilitate collaboration and take care of communication, but concentrating more on the inland commercial fisheries[23].

The Finnish commercial fishing companies are, in general, small family businesses. In 2020 there were 3352 registered fishing vessels in marine areas of which 94 % were less than 10 m in length[24]. Likewise, around 80 % of the registered fishermen have small-scale operations and fish seasonally; only a part of their income comes from fishing.[25] The trend is towards fishing companies decreasing in number and increasing in size[26].

One example of a typical larger fishing company in the marine areas is Oy Sonnfish Ab that mainly trawls for Baltic herring with a high seas trawler 32 m in length. The vessel has a fish sorting system onboard. A Fish Logistics Centre in the harbour of Kaskö for cold storage of the catch is also a part of the company. Oy Sonnfish Ab is a family-owned business with a turnover of 1,7 million euros and they permanently employ 10 people[27].

2.2 Other industries and activities linked to fishing

Ports and logistics

The Finnish coast, especially along the Bothnian Bay, has a dense network of fishing harbours. However, the harbors' ageing technology and limited capacity sometimes make them a bottle neck between fishing and the rest of the value network[28]. At the same time, Finnish companies, such Cargotec-owned companies MacGregor and Kalmar, provide modern technologies and cargo handling equipment that could provide solutions for the

23 SSAK ry: http://www.ssak.fi/ (read: 2.12.2021)

24 Luke Statistics Database 2020: table on "Registered marine fishing vessels" (read 8.12.2021)

25 Luke Statistics Database 2020: table on "Registered commercial marine fishermen" (read 25.12.2021)

26 EMKVR – Operational Programme for Finland 2021–2027 (Draft): https://merijakalatalous.fi/uusi-ohjelmakausi-2/ (read: 8.12.2021)

27 Oy Sonnfish Ab: https://sonnfish.fi/?lang=en

28 EMKVR – Operational Programme for Finland 2021–2027 (Draft): https://merijakalatalous.fi/uusi-ohjelmakausi-2/ (read: 8.12.2021)

ageing fish harbour infrastructure[29]. The possibility to share port services and logistical solutions between the fishing industry and other related industries could enhance the interest in developing modernised digitalised port infrastructures and services. With cross-sector technology, development of novel solutions to problems in the maritime industries could be launched. Companies Origin by Ocean and Avanto Venture organized an innovation competition for technology to gather blue-green algae from the sea and use the catch as a raw material in, for example, cosmetics[30]. The innovative use of technologies from several fields could be combined into new solutions: for example, blue green alga-harvesting fishing vessels or fishing vessels emptying harvesting facilities for blue-green alga. This way fisheries could get additional value from a new source of raw materials and remove excess nutrients from water while still performing fishing operations.

Fishing vessels for high seas trawling and purse seine fishing are manufactured by MacGregor International Ab. The vessels are equipped with their Triplex fish handling system to handle icy conditions by protecting the nets; the system includes cargo handling equipment such as a crane onboard. The company also manufactures spare parts and separate systems for fishing equipment. As the company manufactures polar research vessels, they have expertise in arctic conditions. MacGregor is a part of the Finnish Cargotec Corporation that specializes in cargo and load handling solutions and machinery.[31] Also Aker Arctic Technology Oy has specialized equipment for arctic and icy conditions. Additionally, Aker Arctic develops technology for autonomous ships and ship operations[32].

Technology providers

Electrification of the fish fleet presents major technological opportunities as the need to replace fossil fuels with more sustainable alternatives increases. Finland, along with many other European countries, is investing heavily in battery development as a future solution to the electrification of society and specifically the traffic and transport sector. However, batteries may not be a sufficient solution for the whole fishing fleet and other opportunities include e.g. biofuels, liquid natural gas and hydrogen.

29 MacGregor Ports: https://www.macgregor.com/Products/ports--terminals/ (read: 8.12.2021)

30 Origin by Ocean: https://originbyocean.com/2020/03/27/puhtaampi-itameri-mahdollista-sinilevan-teollinen-keraily-ja-hyotykaytto/ (read: 15.12.2021)

31 MacGregor: https://www.macgregor.com/Products/fishery-research-and-marine-resources/ (8.12.2021)

32 Aker Arctic: https://akerarctic.fi/en/solution/ (read: 15.12.2021)

Automation of the industry is another area of high interest that can mean many different things. Finland is in the international forefront in developing automated vessels, and this know-how could be further used also in the fishing industry. Automation of equipment and techniques used, utilizing digital solutions, is touched upon in the next section. Also, the monitoring of fishing can be more automated, increasing resource efficiency of both authorities and professionals.

Equipment used for fishing in Finland is developed taking into consideration the cold and harsh environments. The technology is, therefore, applicable to similar conditions in other Arctic countries. Finnish fishermen have knowledge of techniques for fishing during winter in inland and coastal areas where ice cover needs to be taken into account. Techniques and technology on how to fish with nets under the ice is a part of traditional Finnish fishing culture. With the right knowledge, fishing under ice can be easier than fishing in open waters.[33]

An issue related specifically to the Baltic Sea is the threat and damage to fishing in the coastal areas brought by seals that destroy equipment and prey on the fish close to fyke nets. This is one reason why net fishing has largely been replaced by fyke nets and fish traps. Seal deterrent devices decrease the amount of damage done by the animals[34]. The Finnish Natural Research Institute Luke has developed seal deterrent technology in collaboration with VireLabs Oy. The technology provides self-sustaining acoustic seal deterrents powered by solar and wind power. The deterrent uses 4G technology so that it's status can be controlled remotely and enables their effective usage in more remote areas[35]. The technology has been successfully piloted in bay areas and found to have potential to provide a solution to the seal problem. Seal deterrents have also been developed by Modul Plastic Oy and Arwell-Tekniikka Oy in collaboration with Luke and fishermen. The developed models are smaller and lighter to ease handling. It is also possible to change batteries in the field instead of taking the deterrents to onshore facilities for recharging.[36] The development projects are a part of an innovation programme "Partnership between research and fishermen" (Tutkimuksen ja kalastajien välinen kumppanuus) funded by the European Maritime and Fisheries Fund (EMFF).[37]

33 Kivikangas: https://www.kivikangas.fi/verkkokalastus---talvikalastusoppia-ammattilaisilta (read: 7.12.2021)

34 EMKVR – Operational Programme for Finland 2021–2027 (Draft): https://merijakalatalous.fi/uusi-ohjelmakausi-2/ (read: 8.12.2021)

35 Luke 2018: https://www.luke.fi/uutinen/uusi-hyljekarkotin-kokeilussa/ (read: 8.12.2021)

36 SAKL ry: http://sakl.fi/sv/hyljekarkotin-kehittyy-2/ (read: 15.12.2021)

37 EMKR: https://merijakalatalous.fi/innovaatio-ohjelmat/tutkijoiden-ja-kalastajien-valinen-kumppanuus/ (read: 15.12.2021)

Digitalization and ICT

Finland is highly competent in digitalization, and ICT and there is untapped potential for novel applications of relevance for the fisheries. Digitalization and ICT forms an important part of many business-led innovation ecosystems directly or indirectly related to the fishing industry and has the potential to develop efficient operations of the fishing fleet and harbours.

A couple of interesting examples already developed are the seal deterrent technology described above, which is dependent on digital technology, as well as the digital fish calculator developed by SAKL ry (Finnish Fishermen's Association) in collaboration with Aalto University. It automatically counts the number of fish that enters or leaves fyke nets. The fisherman remotely gets information about the amount and size of the fishes in the trap. This allows the fisherman to optimize the resources and time for travelling to and from the nets.[38]

Ocean data

The Finnish government provides extensive geographical information on its sea and land areas. The information is publicly available and can be used for supporting fishing operations. The provided data is extensive: it shows, among other things, ice predictions, maps for valuable biotopes and grades wind exposure on a surface. Increased use of data is seen as one of the keys for innovative renewal of the sector, one example being the utilisation of satellite images to locate and register fishing areas as spatial data.

Knowledge development and RDI

Finnish professional fishers have an effective system of educating new operators in the industry. Apprenticeship contracts enable the flow of practical information from the experienced fishermen to the next generation either interested in starting their own fishing business or continuing the fishing operations of their ageing teacher. Additionally, educational institutions, such as vocational schools Livia[39] and Salpaus[40], can provide a more formal education.

38 SAKL ry: https://t.co/LwL7T2gJAZ

39 Ammattiopisto Livia: https://www.livia.fi/koulutustarjonta/kalatalouden-perustutkinto-paivakoulutus (read: 8.12.2021)

40 Further Education Salpaus: https://www.salpaus.fi/koulutusesittely/kalastaja/ (read: 8.12.2021)

The RDI (Research, Development and Innovation) development is largely driven by companies in cooperation with the strong research teams at the Natural Resources Institute Luke, and technology-focused Aalto University, and also the government owned company Finnish Technical Research Centre (VTT). The Finnish know-how is recognized specifically in the areas of cold chain development. This includes research on more efficient and less stressful ways to transport live and dead fish from the nets at sea to the harbour; many of the caught fish are still alive when they are transported[41]. Techniques to keep the fish fresh and minimize the stress are an important part of modern fishing. The Blue Products innovation programme attempts to find solutions through both product development and technical innovation. Within the framework of the program, VTT in collaboration with Turku University and the Nature Resource Institute have been researching ways to better keep the fish fresh during transport in an ethical way. Transportation in freezing water in combination with salt significantly decreases the microbial activity in fish while attempting to keep the fish stress levels at a minimum[42].

Innovation in the fish sector has in Finland been mainly supported by national programmes under the European Maritime and Fisheries Fund[43]. Among the innovation programmes that have risen during the past few years is a collaboration on new fishing practices and technologies. Main collaborators are SAKL ry and Luke, with partners from SSAK ry, the universities of Jyväskylä and Eastern Finland, as well as the Finnish Institute of Health and Welfare, and Finnish Environment Institute. Through sharing knowledge and a wide array of professional competences, the programme has worked towards finding solutions to critical problems in fishing practises[44].

41 Blue Products 2021: https://merijakalatalous.fi/wp-content/uploads/Alakomi_Innovaatiopaivat_2021.pdf (read: 17.12.2021)

42 Blue Products 2021: https://merijakalatalous.fi/wp-content/uploads/Alakomi_Innovaatiopaivat_2021.pdf (read: 17.12.2021)

43 forthcoming Eruopean Maritime, Fisheries and Aquaculture Fund

44 EMKR: https://merijakalatalous.fi/innovaatio-ohjelmat/tutkijoiden-ja-kalastajien-valinen-kumppanuus/ (read: 9.12.2021

2.3 Development needs and opportunities

A challenge in the Finnish fishing industry is the ageing of fishermen; many operators have been in the branch for a long time and few new people are vying to replace them[45]. There are not many young professional fishermen. It is important to inspire younger people to start in the fishing occupation and learn from the older professionals[46].

Secondly, it has been recognized that some of the fish resources are under-utilized. As an example, consumers do not know how to use small Baltic herring in their daily lives. Populations of some species, such as roach and bream, are not extensively fished for consumer use. Bycatches of small fish and under-utilized populations can be included in the fish value network by new fish processing techniques and product development, products and marketing that can turn these resources into more desirable products.[47] This is further explored in the chapter of fish processing and trade.

Research and innovation prospects

Future potential can be found especially in combining fishing with other productive operations. There are potential in electrification and automation of fishing vessels and equipment. Combining different technologies from different industries could help with decarbonisation by sector coupling, and with the efficiency of fishing and port operations. Combined with technology for automation, fish net handling and fish hauling from other companies, such as Aker Arctic or MacGregor, could make efficient green fishing and shore operations with arctic specialization realized.

Other research and innovation prospects that hold future potential are for example:

- Further digitalisation and automation of fishing technologies and processes, where Finland has strong business interests and RDI environments

45 The Federation of Finnish Fisheries Associations: https://ahven.net/kaupallinen-kalastus/ (read 9.12.2021)

46 Salpaus Further Education: https://www.salpaus.fi/koulutusesittely/kalastaja/ (read: 9.12.2021)

47 Valve, H., Lukkarinen, J., Beliskij, A., Kara, P., Kolehmainen, L., Klap, A., Leskinen, R., Lähteenoja, S., Marttila, T., Oikarinen, M. & Pitzen ,S. 2019. Lisäarvoa kalasta ja maatalouden sivuvirroista Varsinais-Suomessa – Sinisen biotalouden murrosareenan tulokset. BlueAdapt. ISBN 978-952-5844-43-6

- The electrification of fishing vessels, an issue of increasing importance in the years to come, as Finland is aiming at reaching its carbon goals. Finding more sustainable solutions will especially affect the future of energy-intensive fishing methods. Technologies for more energy efficient shipping and fishing would help with achieving a greener fishing industry. Gas-operated, hybrid or fully electric vessels are researched and manufactured, for example, by Wärtsilä Oyj Abp. In high seas vessels another approach to minimize fuel consumption and emissions is to use Rotor Sail technology that uses wind power which would cut fuel consumption by up to 30 %. The company also provides onshore energy solutions where vessels can use land-based energy while in a port or a port area. At the same time the vessels can charge their batteries. Wärtsilä also provides an automated EcoControl system that optimizes ships' energy use[48]. Biological waste from fishing and fish processing could be used to make biogas and could then be utilized in energy production on shore or as fuel for fishing vessels[49].
- Developing novel and increased use for fish species that traditionally have not been captured and utilised to a great extent

48 Wärtsilä 2020a: https://www.wartsila.com/marine/decarbonisation/our-offering-at-a-glance (read:16.12.2021)

49 Wärtsliä 2020b: https://www.wartsila.com/marine/products/gas-solutions/biogas-solutions (read: 16.12.2021)

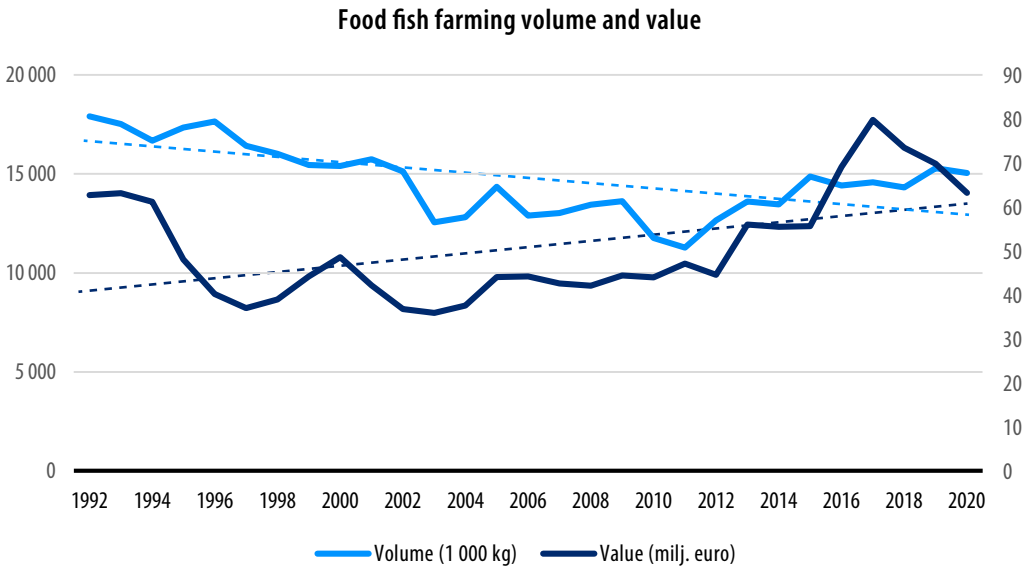
3 Fish farming

This chapter describes the market and operators in Finnish fish farming. Fish farming is one line of more general term aquaculture, which refers also to farming of e.g. mussels and algae. In Finland aquaculture consists currently mainly of fish farming operations. Additionally, in this chapter, other industries linked to fish farming are described using examples of companies as well as development needs, and research and innovation prospects are summarized.

3.1 Description of the market and operators

In 2020 the total amount of fish from farm production was 15,1 million kg. There has been a general declining trend in production volume and value since 1990s. However, both the value and volume has seen a slight increase since 2000s. In the last 20 years the overall trend has been rather stable[20] (figure 3).

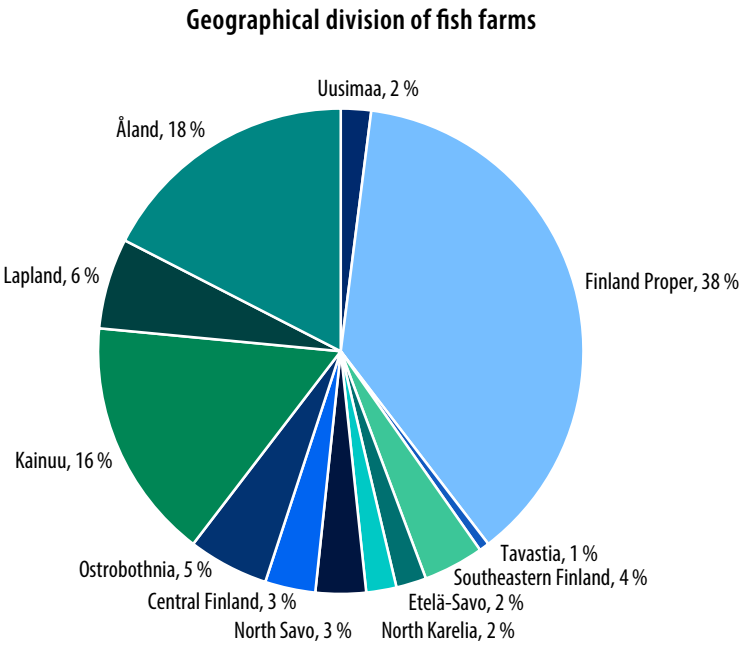
Figure 3. Volume (left y axis) and value (right y axis) of farmed food fish (including roe) between 1992 and 2020 (Luke statistics database 2020).



Marine fish farming constituted 73 % and inland farming 27 % of the production in 2020. The most productive fish farming area is the Archipelago Sea in the Southwest of Finland where 40 % of the marine farmed fish are produced. The most commonly farmed species is rainbow trout (ca 14,3 million kg) which constitutes almost 95 % of the farmed volume. The second most farmed species is European whitefish (0,58 million kg). Furthermore, smaller amounts of trout, Arctic char, pikeperch and sturgeon are produced. The Natural Resources Institute of Finland (Luke) also researches possibilities for new species for farming, such as nelma (*Stenodus nelma*) a freshwater whitefish[50].

In 2020 there were 403 registered fish farms and 246 fish farming companies in Finland. The areas with the most farms are Finland Proper (23 %), Kainuu (17 %) Central Finland (14 %), Southern Savonia, and Åland (7 %). The rest of the areas constitute 39 % of the total number with a range from 6 % to 2 % (figure 4). Of the mentioned areas, Finland Proper and Åland are both mainly sea areas whereas Kainuu, Central Finland, and Southern Savonia are inland areas. Individual farms in marine areas tend to have larger production volume than the inland farms.

Figure 4. Proportions of fish farms in different geographical areas of Finland in percentages (Luke statistics database 2020).



50 Luke 2020e: https://stat.luke.fi/vesiviljely (read: 2.12.2021)

Of the 403 fish farms, 45 % are natural food pond farms, 33 % are food fish farms and 22 % are fry farms[51]. Natural food fish farms are an inland farming type where the fish eat food naturally provided by the pond ecosystem. Fish from natural food farms are usually used for fish transplanting[52]. Food fish farms produce fish from fish fry for consumers or for further processing by providing the fish with feed[53]. Most food fish farms are located in coastal areas in Finland Proper and Åland. There are, however, many food fish farms in Kainuu (ca 16 %) as well. Similarly, most of the fry fish production is located in Finland Proper and Kainuu. In contrast, Åland has only one registered fry farm20 (table 2); most fry fishes are brought from mainland Finland. Fish fry farms are mostly land based facilities from where the fry are later taken to the actual food fish farms[54].

Table 2. Numbers of food fish farms, fry farms and natural food pond farms in different regions as well as numbers of active companies in 2020 (Luke statistics database 2020).

In 2020	Food fish farms	Fry farms	Natural food ponds farmers	Total
Uusimaa	3	2	4	9
Finland Proper	56	25	10	91
Tavastia	1	7	10	18
Southeastern Finland	6	2	13	21
Southern Savonia	3	8	28	39
North Karelia	3	3	3	9
Northern Savonia	5	5	16	26
Central Finland	5	13	39	57
Ostrobothnia	8	2	6	16
Kainuu	24	22	22	68
Lapland	9	8	5	22
Åland	26	1	0	27
Total	149	98	156	403
Companies	71	53	149	246

51 Luke Statistics Database 2020: table on "Fish farms" (read 2.12.2021)

52 Ruskeala, J. 2014. Luonnonravintolammikon perustaminen ja ylläpito – Maatalouden sivuelinkeino. Opinnäytetyö. Hämeen ammattikorkeakoulu.

53 Suomen Kalankasvattajaliitto ry: https://www.kalankasvatus.fi/kalanviljely/kalanviljely-elinkeinona/ (read: 22.12.2021)

54 Suomen Kalankasvattajaliitto ry: https://www.kalankasvatus.fi/kalanviljely/viljeltavat-kalalajit/ (read: 2.12.2021)

Efficiency and profitability of food fish farming is actively improved by selective breeding. The Finnish Natural Resources Institute (Luke) maintains and develops breeding programmes for farmable fish species. The selective breeding programmes produce fish fry and broodstock for the farming industry and also provide training and education for fish farmers.[55]

Finnish Fish Farmers Association, (Suomen Kalankasvattajaliitto ry) is an institution of operators in the fish farming industry. Its purpose is to guard the interests of its members and the industry as a whole by attempting to influence the legislation, administration and market development in fish farming. Additionally, Kalankasvattajaliitto provides education, and research and development for the industry. Another task of the union is to provide information and to promote fish farming as a whole.[56]

An important operator in the Finnish fish industry, that has specialized in fish farming, is Nordic Trout Oy. Nordic Trout is a part of the Kalaneuvos Group which is a major player in fish processing and wholesale, and exports and imports of fish and fish products. The company also does research and development in production techniques as well as in selective breeding of the fish stocks[57]. Nordic Trout Oy is the largest fish farming company in Finland and Sweden with annual production off around 10 million kg[58].

Another major player in fish farming industry is Heimon Kala Oy which is owned by an Estonian company Vettel Oü. The company has farms in Finland, Sweden and Estonia. They also have production facilities for fish products in several countries: Finland, Estonia and Scotland. Likewise, the sales markets are also in Finland, Estonia and Scotland, while imports of fresh fish come from Norway, Denmark and Sweden[59].

Most of the operators in fish farming are smaller players in comparison to Nordic Trout and Heimon kala. Many of these smaller operators are planning on expanding their operations and production capacity. Examples of fish farmers are Laitakarin kala, Salmonfarm, Brändö Lax and a family business Lännenpuolen Lohi.

55 Luke: Aquaculture and water economy: https://www.luke.fi/en/services/expertise-areas/aquaculture-and-water-economy#further-information (read 2.6.2022)

56 Kalankasvattajaliitto ry: https://www.kalankasvatus.fi/kalankasvattajaliitto/ (read: 8.12.2021)

57 Kalaneuvos: https://kalaneuvos.fi/yritys/kalaneuvos-oy/ (read: 7.12.2021)

58 Nordic Trout: https://nordictrout.com/en/company/history/ (read: 7.12.2021)

59 Heimon kala: https://www.heimonkala.fi/eng/about-us/heimon-kala (read: 7.12.2021)

Finnforel is a Finnish borne technology start-up with a focus on sustainable development in the aquaculture food chain (started 2015). In November 2021, Finnforel announced a 45M€ investment programme[60] for 1st phase scaling up of the company's technology and concept, with a range of institutional and international investors joining, and with support from e.g. the European Investment Bank. The core of the investment aims at scaling the pilot factory in Varkaus into a full-scale Giga factory for the whole value network. In their farming operations Finnforel employs indoors RAS techniques where the company can control the outer factors (such as temperature) for the fish. At the same time the nutrients from possible excess feed and fishes' own metabolism can be filtered from the water and then used elsewhere. Their facilities operational value chain is short: the fish are grown, filleted and packed at the same site. Finnforels concept also includes the minimization of food waste: they attempt to use all parts of the fish[61].

3.2 Other industries and activities linked to fish farming

Offshore solutions

Finland has a lot to offer in expertise in the offshore solutions and innovations for Arctic maritime conditions. The industry is being developed especially within the Team Renewable Arctic Ecosystem. Although no direct links to fish farming have been developed, yet, it is recognised that a future untapped potential lies in more efficient and combined use of offshore technologies and sites.

Fish farming is constantly seeking solutions on how to move farms further offshore. Offshore fish farming is attractive since the eutrophication effects of excess nutrients are smaller in the open sea and the options for good spaces for fish farming are growing slimmer close to the shore. However, the demanding offshore conditions require special expertise and equipment. Finland has competencies in offshore solutions and Finnish offshore fish farming could benefit from innovative cooperation between offshore companies operating primarily outside of fish value chain and fish business companies.

One such company is Enersense Offshore. This Finnish engineering, project management and fabrication company operates in Mäntyluoto, Pori. They have a long experience in the offshore industry and they can offer tailor-made project execution and solutions to both domestic and international customers.[62]

60 Press release and recorded press meeting on Finnforels web site: https://live.esf.fi/FFPress09112021

61 Finnforel: https://www.finnforel.com (21.2.2022)

62 Enersense, About us: https://www.porioc.com/company/ (read 15.12.2021)

Transport and Logistics

Technology for transporting live fish in marine areas is an important step in the fish farming process. Transporting of live fish is needed in different phases of fish farming i.e. when the fishlings need to be moved to bigger growing pouches or when the fish are moved to a more weather stable location during winter time. Specialized vessels with proper systems that keep the live fish in good condition and enable easy loading are needed for successful transportation. A company that produces live fish carriers and fish pumps is MacGregor. The vessels have life-support technology to keep the fish alive during transportation. MacGregor also manufactures specialized service boats for fish farm maintenance specifically with exposed locations with demanding conditions in mind. The service boats have equipment for fish welfare and for inspecting the condition of the fishes and farming facilities[63].

Technology providers

Technology for RAS-farms (Recirculating Aquaculture Systems) is developed and sold in the Finnish markets. It is still too expensive to farm fish other than fry fish and more valuable species in closed systems. However, as the technology progresses it is becoming more viable to expand closed system farming to encompass more species in an economically profitable way[64]. One example of a company that offers pieces of equipment as well as turnkey products for closed system farms is Clewer Aquaculture Oy[65]. One of their more innovative products is a patented RBBR bioreactor (Rotating Bed Biofilm Reactor) for water treatment systems ranging from aquaculture, municipal and industrial wastewater treatment. There are also others doing research and development in closed loop fish farming. Sybimar Oy, a part of Meriaura Group, has developed a system that combines fish farming and greenhouse vegetable farming with bioenergy. By-products from fish farming are used in vegetable production and vice versa. Emission from the farming operations are used to produce green energy for the needs of the whole operation[66].

63 MacGregor Live fish carriers: https://www.macgregor.com/Products/fishery-research-and-marine-resources/live-fish-carriers/

64 Kalankasvattajaliitto ry: https://www.kalankasvatus.fi/kalanviljely/ (read: 8.12.2021)

65 Clewer Aquaculture: https://cleweraquaculture.com/ (read: 8.12.2021)

66 Motiva 2020: https://www.motiva.fi/ratkaisut/uusiutuva_energia/palvelut/greenenergycases/sybimar_oy_suljetun_kierron_konsepti.13.html (read: 9.12.2021)

Digitalization and ICT

Digitalization and automation are crucial parts of smart and sustainable fish farming. Digital technologies include the possibility to monitor fish development and health, optimize feeding, at the same time as data is gathered and processed through machine learning to enable automated solutions. Digitalization and better use of data is key to developing functional offshore fish farms that utilize automated services, an area of development for Finland. Data and digitalization, and the development of machine learning and AI solutions for fish farming is the theme of several RDI projects, in which Finnish companies and research institutes participate. For example, the Finnish environmental institute in collaboration with Meattavita Oy has been developing an AI system for monitoring the fish in fish farms. The AI would use cameras for observing the fish and their behaviour then calculate the amount, size and the biomass of the fish as well as their condition[67].

The Growth Sonar technology by Raisioaqua Oy is another example of digitalization. Growth Sonar combines computer and smartphone technology with fish farming. This technology allows a farmer to digitally follow the growth of the fish biomass in the farms and in combination with environmental data from sensors at the site, adjust the amount of feed. In this way, the farmer gets the most growth out of the feed. The information from the biomass and growth data is also saved in a computer or smart phone which gives good information on the production of the farming operation.[68] Other examples include the Finnish Natural Resources institute Luke being involved in RDI projects with partners from Norway[69] and the start-up Finnforel announcing data and digitalization as the cornerstone for its new investment programme.

Knowledge development and RDI

RDI development is largely driven by companies in cooperation with the strong research teams at the Natural Resources Institute Luke, and technology-focused Aalto University, but also the Finnish Fish Farmers Association with its members. The Finnish know-how is recognized especially in the areas of ecological feed for fish farming, e.g. the Baltic Blend by Raisioaqua that minimizes the input of land-based nutrients[70].

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67 https://www.kalankasvatus.fi/wp-content/uploads/2020/08/Kirjolohi_hahmontunnistus_antti-R.pdf (21.2.2022)

68 Raisioaqua: https://www.raisioaqua.com/en_GB/growth-sonar (read: 9.12.2021)

69 NordForsk: https://www.nordforsk.org/projects/intelligent-farming-and-health-control-landbased-recirculating-aquaculture-systems (read: 21.2.2022)

70 Raisioaqua: https://www.raisioaqua.com/en_GB/web/raisioaqua/environment (read 16.12.2021)

Innovation in the fish sector has in Finland mainly been supported by the national programmes under the European Maritime and Fisheries Fund. This fund is managed by the Ministry of Agriculture and Forestry of Finland. Among the innovation programs that have developed during the past few years is a programme on innovation in fish farming (Vesiviljelyn innovaatio-ohjelma). The innovation programme is a collaboration between governmental institutions (Luke, SYKE, Metsähallitus, Evira, Finnish Meteorological Institute), the Finnish Fish Farmers Association and educational institutes (Universities of Oulu and Jyväskylä, and vocational school Livia). The main theme in the innovation programme is promoting fish farming in closed loop systems and open sea areas. Combining closed loop farming with wood processing has given promising results[71].

Luke has 25 years of research in fish genomics (JALO breeding programme since 1992) that is used in a public-private partnership with fish farmers. In the programme, Luke aims to breed fish phenotypes to maximize productivity while minimizing the ecological footprint[72]. Luke collaborates with the private sector to fulfil the needs of farmers by providing suitable phenotypes for different farming methods. Luke and Finnforel Oy are developing a fish strain suitable for RAS farming[73].

3.3 Development needs and opportunities

The self-sufficiency rate of Finnish fish is very low and most of the fish consumed in Finland is imported. At the same time, according to a survey conducted by Kalaneuvos Oy in 2020, more than 80% of Finnish people would like to eat more domestic fish and encourage an increase in domestic fish farming. In order to promote domestic fish farming, the companies Raisioaqua Oy, Kalaneuvos Oy and Nordic Trout Ab have started a project called "Aalloilta ateriaksi" – translated as "From waves to meals". The companies have identified the main obstacle on the way to increase Finnish fish farming to be the low number of issued fish farming permits and reductions on the quantity of fish allowed to be farmed per fish farming location. Therefore, a part of the project aims to promote an increase in issued fish farming permits. The number of permits could be increased since fish farming accounts for less than 2–3 % of the total nutrient input in the Archipelago

71 EMKR: https://merijakalatalous.fi/innovaatio-ohjelmat/vesiviljelyn-innovaatio-ohjelma/ (read: 16.2021)

72 Luke 2020g: https://www.luke.fi/en/natural-resources/fish-and-the-fishing-industry/aquaculture/selective-breeding-of-farmed-fish/ (read: 16.12.2021)

73 Luke 2021a: https://www.luke.fi/en/news/luke-and-finnforel-co-operate-to-develop-selective-breeding-of-rainbow-trout/

Sea[74]. Additionally, with modern fish feed, it is even possible to reduce the phosphorus and nitrogen load in the Baltic Sea.[75]

With the sustainability of fish farms being one of the key challenges, solutions are being developed to strengthen the aquatic ecosystem services. Mussel farming can be used to remove excess nutrients from water areas. Due to the low salinity in the Finnish marine areas, the mussels do not grow big enough to serve as a commercially feasible food source for people. However, there are techniques for separating the meat from the shells and processing them into powder and feed for poultry and farmed fish. The remaining shells can be used as fertilizer[76].

Farming seaweed and algae in combination with fish farms is also being explored as a way to strengthen the ecosystem services and compensate for the environmental burden of the fish farm. Development of technologies and processes for combined use of aquatic sites is an area of interest for Finland, where there is already knowhow and learning potential. Origin by Ocean Oy is a Finnish start-up specialised in seaweed and algae farming that is interested in upscaling production in connection with existing fish farms[77].

Another development related both to resource efficiency and fish health, is developing genetic selection, based on Luke's extensive research on fish genomics. The opportunity was recently announced by Finnforel in cooperation with Luke, as a means for upscaling efficient and sustainable rainbow trout farming.

Research and innovation prospects

Future potential can be found especially in open seas and closed loop fish farming with related technologies. Research and innovation prospects include for example:

- Finding more economically viable ways for closed loop and RAS-fish farming by new technologies. By combining different operations, such as bioenergy and greenhouses, more value might be extracted from farming. Examples of this would be Clewer Aquaculture's solutions.

74 Kipina-Salokannel, S & Mäkinen, M. 2021. Varsinais-Suomen ja Satakunnan vesienhoidon toimenpideohjelma vuosille 2022–2027. Raportteja 44. ISBN 978-952-314-951-9

75 Kalaneuvos, Kalaneuvos mukana käynnistämässä Aalloilta ateriaksi -hanketta: https://kalaneuvos.fi/aalloilta-ateriaksi-hanke/ (read 13.12.2021)

76 Hyvärinen, H., Usva, K., Saarenketo, P., Juhanoja, S. & Tuhkanen E-M. 2017. Uutta liiketoimintaa vesistöjen ravinteista. Luke, Luonnovara- ja biotalouden tutkimus 39/2017.

77 https://originbyocean.com/

- More efficient extraction of by-products such as dead fish and fish storage fluid for fertilizers or energy production (one example being Wärtsilä's biogas extraction solutions).
- Combining algae and mussel farming with fish farms. More research is needed on how algae and mussels could be utilized in addition to minimizing eutrophication effects near farms by nutrient capture. Mussel farming in combination with fish farms mitigates eutrophication as the mussels filtrate the water for nutrients. There is also evidence that mussel farms keep the seabed in better condition and make the water clearer which benefits local macroalgae and water plants. Mussels can have great potential in increasing the state of the Baltic Sea[78]

78 SUBMARINER Network Mussels Working Group, 2019. Mussel farming in the Baltic Sea as an environmental measure. Berlin, Germany.

4 Fish processing and trade in the value chain of fish

The amount of fish processed by Finnish companies in 2019 was 76 million kilos[79], making fish processing the most profitable industry within the value chain of fish, with a net income of 7,6 million euros. The wholesale of fish generated a net income of 7,1 million euros while the retail trade specialized in fish made 6,3 million euros.[80] Fish processing companies were also the biggest employers in fishery business, providing 813 man-years of work.[81] This amounts to 35% of the employment provided by the whole Finnish fishery value chain.[82]

This chapter describes the market and operators in Finnish fish processing and trade as well as other industries linked to them using examples of companies. In addition, development needs and research and innovation prospects are summarized.

4.1 Description of the market and operators

Fish processing

In 2019, there were 124 companies in Finland engaged in fish processing. Over 94% of all processed fish was done by 19 companies which all processed over half a million kilos of fish yearly.[83] Fish processing companies are scattered all over Finland with the Southern and Southwestern coastline and the big Eastern lake areas accumulating most of the companies.[84] Many primary producers have their own small-scale processing of fish, for example smoking equipment. Some of the biggest operators in the fish processing and trade in Finland include the following companies:

79 Luke 2020g: https://stat.luke.fi/kalajalosteiden-tuotanto (read 3.12.2021)

80 Luke 2020g: https://stat.luke.fi/kalatalouden-kannattavuus (read 6.12.2021)

81 Luke 2021b: https://portal.mtt.fi/portal/page/portal/taloustohtori/kalanjalostus_ja_kalakauppa/aikasarja/kalanjalostus_tunnusluvut/ (read 6.12.2021)

82 Luke 2021b: https://stat.luke.fi/kalatalouden-kannattavuus (read 6.12.2021)

83 Luke 2020g: https://stat.luke.fi/kalajalosteiden-tuotanto (read 3.12.2021)

84 Fonecta.fi, Kalanjalostus: https://www.fonecta.fi/haku/kalanjalostus (read 8.12.2021)

- Kalaneuvos Oy, which is part of Kalaneuvos Group based both in Finland and Sweden, is specialized in fish farming, fish processing, wholesale, import and export of Nordic fish. Their head office and production facilities are located in Sastamala. Annually the Group processes a total combined volume of over 20 000 tons of fish products.[85]

- Martin Kala Oy is part of the Kalaneuvos Group and processes annually around 3,5 million kilos of fish. Their production facilities are located in Turku and Kaskinen. The company is the most important manufacturer of Baltic herring fillet in Finland. In addition to Baltic herring, they process other natural fish, as well as farmed European whitefish, rainbow trout, and salmon.[86]

- DISAS Fish Oy, DISAS Caviar Oy LTD and Kuusisen Kala Oy operate under DISAS Companies in fish processing and retail. In their production facility in Tesjoki, Loviisa, Kuusisen Kala Oy makes a variety of fish products and specializes in in the manufacture of various roe. The company is one of the leading manufacturers in the world in the production of rainbow trout roe. Disas Caviar Oy Ltd operates as a wholesale company for Disas. The company has retail stores in Hamina, Imatra, Lappeenranta's Mustola, and Nuijamaa.[87]

- Hätälä Oy is a four-generation-old fish company that manufactures and markets different fish products to retailers, professional kitchens, and wholesalers. The company processes yearly around 18 million kilos of fish and employs 220 people permanently. During the high season, the number of employees can rise up to 350 people. Additionally, Hätälä Oy acquires fish for its production from 400 Finnish professional fishers with whom the company has long standing partnerships.[88]

Around 60% of the processed fish in 2019 - 45 million kilos –was domestic fish and the rest – 31 million kilos – was imported fish. The volume of fish processing has declined slightly with 3 million kilos from 2017 being the last time the industry was monitored statistically.[89] More than 15 million kilos of Finnish fish and nearly 22 million kilos of imported fish from abroad were processed into frozen and fresh produce in 2019. 14 million kilos of fish were used for more processed products, of which 40% were domestic. Baltic herring, salmon,

85 Kalaneuvos Oy: https://kalaneuvos.fi/yritys/kalaneuvos-oy/ (read 8.12.2021)

86 Martin Kala Oy: https://kalaneuvos.fi/yritys/martin-kala/ (read 8.12.2021)

87 DISAS and Kuusisen Kala Oy: https://www.disas.fi/kuusisen-kala-oy/ (read 13.12.2021)

88 Hätälä Oy: https://hatala.fi/hatala-oy/ and https://hatala.fi/pohjoisen-rehtia-kalaa/kotimaiset-kalastajat/ (read 13.12.2021)

89 Luke 2020g: https://stat.luke.fi/kalajalosteiden-tuotanto (read 3.12.2021)

rainbow trout and European whitefish were used most in the fish processing industry. These four species accounted for 95% of all fish raw materials.[90]

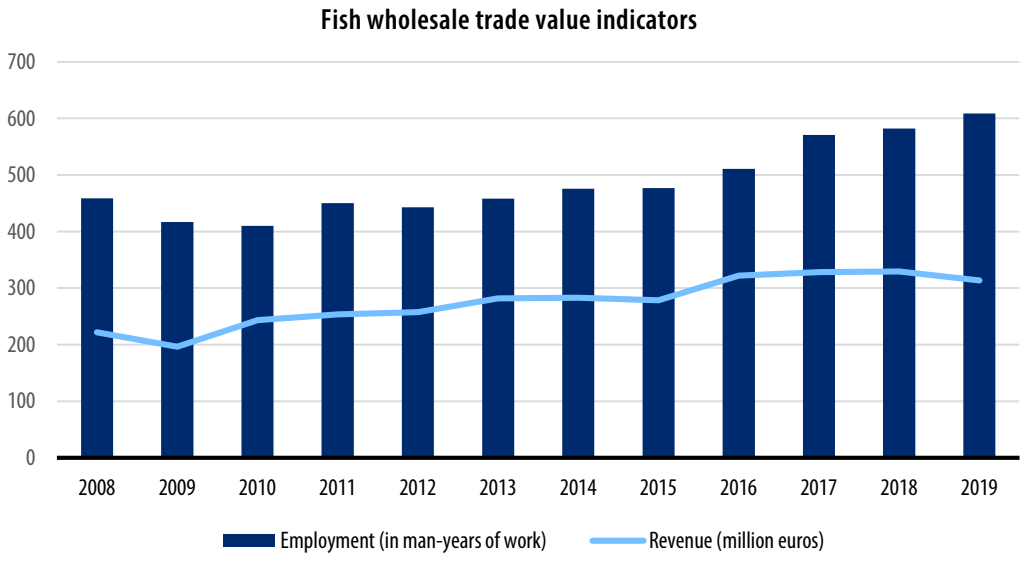
Fish trade

Table 3. Number of companies in fish trade in Finland (Luke taloustohtori -statistics database 2022)

Number of companies in fish trade in Finland	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Fish wholesale trade	64	70	64	64	62	58	60	56	52	54
Fish retail	125	119	119	118	125	121	114	110	93	93

There were 54 companies engaged in the wholesale trade of fish in 2019. They employed people with 609 man-years of work and generated total income of 313,5 million euros. The trend of revenue in wholesale trade of fish has been quite steadily increasing for the past 10 years reaching 313,5 million euros in 2019.[91]

Figure 5. Value indicators for Finnish companies in wholesale trade of fish (Luke statistics database 2022).

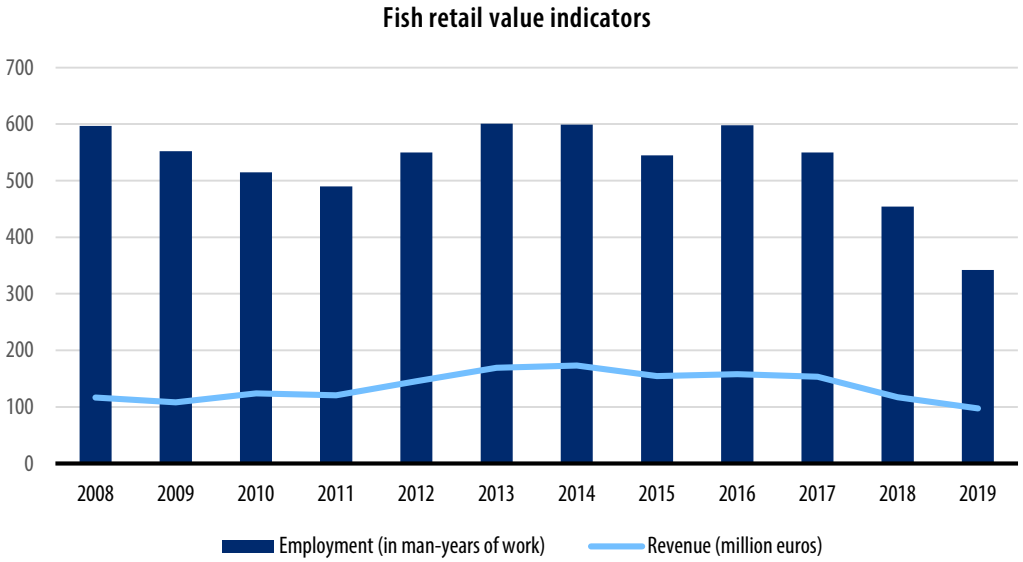


90 Luke 2020g: https://stat.luke.fi/kalajalosteiden-tuotanto (read 3.12.2021)

91 Luke Kalanjalostus- ja kalakauppa-aineisto. Kalan tukkukauppa, tunnusluvut: https://portal.mtt.fi/portal/page/portal/taloustohtori/kalanjalostus_ja_kalakauppa/aikasarja/kalan_tukkukauppa_tunnusluvut/ (read 6.12.2021)

In retail sale of fish in 2019, there were 93 companies employing people with a total of 342 man-years of work. Companies in fish retail made 97,6 million euros of revenue in 2019. For the past 5 years, the revenue has been declining. In 2015 fish retail generated 154,8 million euros and in 2018 retail was only 117,3 million euros.[92] The revenue of fish processing companies has, on the other hand, been steadily growing so that in 2019 it amounted to 403,6 million euros. In 2015, the revenue of fish processing had been 301,8 million euros.[93]

Figure 6. Value indicators for Finnish companies in fish retail (Luke statistics database 2022).



Suomen Kalakauppiasliitto ry (SKKL)[94] has been advocating for Finnish companies engaged in fish processing, wholesale, and retail trade of fish since 1941. The Association cooperates with all domestic fishery related organisations, managing and supervisory authorities, and similar Nordic fishery related organisations. It also receives up-to-date information from the EU level organisations in the field of fisheries.[95]

92 Luke Kalanjalostus- ja kalakauppa-aineisto. Kalan vähittäiskauppa, tunnusluvut: https://portal.mtt.fi/portal/page/portal/taloustohtori/kalanjalostus_ja_kalakauppa/aikasarja/kalan_vahittaiskauppa_tunnusluvut/ (read 6.12.2021)

93 Luke Kalanjalostus- ja kalakauppa-aineisto. Kalanjalostus, tunnusluvut: https://portal.mtt.fi/portal/page/portal/taloustohtori/kalanjalostus_ja_kalakauppa/aikasarja/kalanjalostus_tunnusluvut/ (6.12.2021)

94 Translated as the Finnish Fishmongers Association.

95 Suomen Kalakauppiasliitto ry: https://kalakauppiasliitto.fi/skkl/ (read 6.12.2021)

Kalakauppiasliitto was one of the founding members of Pro Kala ry in 1994 and continues to work in cooperation with the association. Pro Kala ry is a non-profit association whose members represents the entire chain of fish food including professional fishermen, fish farmers, fish processers and traders, and organisations of the fish economy.[96] Pro Kala ry provides useful information about classifications and standards of fish products such as practical information on product classification of rainbow trout[97].

4.2 Other industries and activities linked to fish processing and trade

Logistics

Transporting fish while keeping it fresh is a major concern for the whole fish industry. Keeping the cold chain intact is important for health and safety reasons. Traditionally, fresh fish has been transported in Styrofoam boxes that are disposed of after use. A Finnish paper industry company Stora Enso has developed a waterproof cardboard box (EcoFishBox[tm]) for transporting cold goods. The empty boxes can be stacked flat before being assembled. The assembling can be done by hand or automated. Since the assembled boxes take less room than the Styrofoam boxes, more fish can be transported at one time. The used boxes can be recycled as material for new ones.[98]

Finnair Cargo plays a special role in linking Nordic fish business with the Asian market. Under the "'Fresh Fish Every Day'" concept co-developed by Lerøy Seafood Group, Norway's top seafood exporter, and Finnair Cargo, 200 tonnes of salmon are flown weekly on Finnair's direct passenger flights to Japan. The salmon is farmed in the cold fjords of Norway and trucked to Helsinki iced in Styrofoam boxes. Finnish logistics service has enabled the availability of the high quality salmon from Norway to the demanding sushi and sashimi segment of the Far East already for a decade.[99] The high-speed transit times and efficient transport by Finnair Cargo between Norway and the Far East also make it possible to carry live king crabs by Finnair to Asia, especially to the

96 Pro Kala ry: https://prokala.fi/ (read 6.12.2021)

97 https://prokala.fi/wp-content/uploads/2021/07/kirjolohen-tuoteluokitus.pdf

98 Stora Enso: https://www.storaenso.com/en/products/corrugated-packaging-solutions/ecofishbox (read:8.12.2021)

99 Finnair Cargo, The air cargo journey of the Aurora salmon produced in Norway: https://cargo.finnair.com/en/cargo-news/leroy-seafood-group-aurora-salmon-asia (read 10.12.2021)

fish market of South Korea.[100] In order to keep the sea food fresh and at the correct low temperatures, in 2018 Finnair opened the COOL Nordic cargo hub in the Helsinki airport which brings international top-of-the-line temperature-controlled logistics to Finland.[101] This investment has further supported Finland's role as a critical bridge between Nordic seafood producers and the Asian seafood market.

Technology providers

Automation of equipment and techniques is a constantly growing trend in fish processing facilities. Investments in automation provide different companies a major competitive edge and play an important role in increasing the value of fish with the possibility of making different new products.

New machinery and technology are especially in demand in the processing of small fish, like vendace, roach and perch to reduce their processing time. In Finland, technical solutions for small fish processing are being developed especially by smaller companies. A company called Future missions Oy has developed a gutting machine with automatic feed for small fish. The gutting machine can even be equipped with a filleting function.[102] Another type of small-fish-gutting machine has been developed by Kittek Ky. The machine guts vendace and collects the roe from it.[103]

Digitalization and ICT

Digitalization is a key in automated services related to fish processing, where new technologies can enhance resource efficiency by e.g. fish sorting and processing by size.

The availability of data on the origin of the fish is especially important in fish products, and the potential to gather data from the whole chain from fish to table is being developed. VTT Technical Research Centre of Finland is coordinating a project called "The Smart Tag" in consortium with research partners, food industry and technology developers all over Europe. The project aims to develop smart tags for food products which are visible,

100 Finnair Cargo, Norwegian king crabs flying Helsinki to Seoul: https://cargo.finnair.com/en/cargo-news/king-crabs-norway-helsinki-south-korea (read 10.12.2021).

101 Finnair Cargo, Norwegian seafood and Finnair Cargo: a match made in the Nordics: https://cargo.finnair.com/en/cargo-news/norwegian-seafood-salmon-stories (10.12.2021).

102 Suomen Ammattikalastajaliitto ry, Kalatalouden 2020 Innovaatiopäivät 5.-6.11. Vantaalla: perjantai 6.11. http://sakl.fi/kalatalouden-2020-innovaatiopaivat-5-6-11-vantaalla-perjantai-6-11/ (read 17.12.2021)

103 Yle, Uusi kone perkaa pikkumuikun sekunnissa: https://yle.fi/uutiset/3-5307087 (read 17.12.2021)

electronic markers with environmental sensing functions. These environmental sensing functions are carried out by combining software intelligence with for example functional ink, sensors and indicators. They track changes in the environment of the product, such as temperature or humidity, and can be scanned by the consumer to convey more detailed information about the product such as origin of the ingredients, the product's sustainability, transportation methods, shelf life, and how recyclable the packaging is. The Smart Tag project is running throughout 2021 and is supported by EIT Food, a body of the European Union.[104]

Knowledge development and RDI

Innovation in the fish sector has in Finland mainly been supported by the national programmes under the European Maritime and Fisheries Fund. Among the innovation programs that have developed during the past few years is the Blue Products programme concentrating on novel fish products[105], as well as actions to enhance the consumer awareness of domestic fish[106]. Many of the innovative fish products described in the following sections have been developed with support from this fund.

4.3 Development needs and opportunities

The main challenge in the Finnish value chain of fish processing is the low level of processing. Most of Finnish fish exports are low-value raw materials. In the Research and competence building agenda on the blue bioeconomy[107], The Ministry of Agriculture and Forestry identified measures that improve the key conditions that would boost the achievement of the United Nations (UN) Sustainable Development Goal on sustainable food production. For the Finnish business ecosystems in the value chain of fish, one of the biggest challenges is the availability of domestic fish and the low processing level of products. For the fish processing industry, the research paper named increasing

104 VTT Technical Research Centre of Finland, Novel Smart Tags solutions to increase value chain transparency of food products: https://www.vttresearch.com/en/news-and-ideas/novel-smart-tags-solutions-increase-value-chain-transparency-food-products (read 13.12.2021)

105 The web portal for the Finnish operational program of European maritime and fisheries fund, Kalastuksen innovaatio-ohjelma Blue Products: https://merijakalatalous.fi/innovaatio-ohjelmat/kalastuksen-innovaatio-ohjelma/ (read 17.12.2021)

106 The web portal for the Finnish operational program of European maritime and fisheries fund, Markkinoinnin innovaatio-ohjelma: https://merijakalatalous.fi/innovaatio-ohjelmat/markkinoinnin-innovaatio-ohjelma/ (read 17.12.2021)

107 Out of the Blue Sinisen biotalouden tutkimus- ja osaamisagenda. Chapter 3.1. Kestävä ruuantuotanto. http://urn.fi/URN:ISBN:978-952-453-986-9

the product processing level and branding and productization as short-term priorities for development. Long-term goals included improving production efficiency with technological innovations and also managing food, energy and industrial production in combinations, i.e. business symbiosis.

The Finnish innovation ecosystems within the value chain of fish have during the past few years worked especially on developing new higher-value products from domestic fish. Among novel product developments is the so-called pulled Baltic herring which could be used like minced meat as a protein source in cooking. Pulled Baltic herring – which as a pilot product isn't yet available in retail sale – has been developed by the VTT Technical Research Centre of Finland as part of Blue Products innovation program which VTT manages in cooperation with the University of Turku and Natural Resources Institute Finland. The aim of the program is to find new uses for Baltic herring and other underutilized fish, both as food and, even as a raw material for other industries, like the cosmetics industry.[108]

Research and innovation prospects

Future potential can be found especially in product development and technological innovations in production and logistics. Research and innovation prospects include for example:

- Developing novel products of fish, especially products of higher value and of different underutilized wild domestic fish
- Increasing exports of Finnish fish products and utilizing Finland's already efficient international logistics solutions
- Investing in the development of automated processing technology and machinery that can process especially small fish

108 Ministry of Agriculture and Forestry, Kala on ilmastoystävällinen valinta ja nyhtösilakka uusin trendituote kalasta: https://mmm.fi/-/kala-on-ilmastoystavallinen-valinta-ja-nyhtosilakka-uusin-trendituote-kalasta (read 13.12.2021)

5 Other industries and activities linked to fish business ecosystems

This chapter describes other industries, activities and perspectives that are linked to fishing, fish farming, and fish processing and trade. These include other industries utilizing fish and by-products of fish (feed, pharmaceuticals, nutraceuticals, cosmetics, textile and energy), recreation, ecosystem services and environmental protection, administrative authorisation and legislation, and consumer trends and behaviour. These perspectives are summarized using examples of companies.

5.1 Other industries utilizing fish and by-products of fish

The value of Finnish fish is small since they are mainly used as feed for fur animals or in production of fish feed. Only about half of fish grown and fished in Finland end up in human consumption. Additionally, fishing and fish farming accumulate a large amount of fish gutting and filleting residues, such as internal organs, stalks, leather and scales which leads to having approximately 20 million kilos of fish side streams unused annually.[109] Only about 4% of all the fished Baltic herring and sprat are used domestically for human consumption. The value of fish catches and their side streams needs to be multiplied by creating more high-value products.[110] A study of Natural Resources Institute Finland (2021) mapping fish establishments producing significant and very significant side-volumes, estimated on the basis of production quality and turnover, that lost side streams of fish could be utilized all over Finland.[111]

Next, we will look into other industries than the fish processing for human food and what type of high-value products they could make utilizing side streams of fish.

109 Yle, Kalan perkuujätteessä piilee miljoonabisnes: Silakkajalosteen kilohinta nousee satoihin euroihin: https://yle.fi/uutiset/3-11088388 (read 17.12.2021)

110 Kallasvuo, M., Kärkkäinen, K., Mäkinen, S., Nieminen, K., Suuronen, P. & Vielma, J. (toim.). 2021. Sininen biotalous: Tutkimusohjelman loppuraportti. Luonnonvara- ja biotalouden tutkimus 22. Luonnonvarakeskus. Page 29.

111 Luonnonvara- ja biotalouden tutkimus 68/2021, Elintarviketuotannon sivujakeiden hyödyntäminen. Liha-, kala- ja kasvistuotannon sivujakeet, page 22.

Feed industry

There is an increasing demand in the fish feed industry for domestic supply of feed and some Finnish fish companies have answered to this demand with innovative products. Since 2016 Salmonfarm Oy has produced fish meal and oil from Baltic herring and sprat in cooperation with a Finnish fish feed manufacturer, Raisioaqua. By using Baltic herring and sprat as raw material, Raisioaqua's fish feed removes and recycles phosphorus and nitrogen from the Baltic Sea. This innovative fish feed is registered with Baltic Blend® trademark. Using Baltic fish for domestic fish feed production supports sustainable development and also improves Finland's food security.[112]

Fish meal and oil are the main ingredients of fish feed, and their demand is higher than the supply. Therefore, new alternative raw materials for the production of feed are in demand. Another fish feed innovation is by the company eniferBio who has developed a new mycoprotein feed for aquaculture. Their PEKILO® P65 high-protein ingredient is made using renewable raw materials and aims especially to reduce the amount of soy protein concentrate used in common fish feed. The use of soy protein links fish feed to the unsustainable practices of soy farming and PEKILO® offers a sustainable alternative to the current industry standard.[113]

Side streams of fish and even entire fish catches are also important raw material for many different animal feeds. Baltic herring is Finland's most important commercial fish species and also one of the most underutilized fishes. More than half of Baltic herring and sprat catches are used as fur animal feed.[114] The added value of fish as animal feed is very low and it would be better to channel these side streams and fish catches to be processed as other high-value products. When Baltic herring ends up as feed it is sold approximately with the price of 16-18 cents per kilo. If Baltic herring would be processed as bioactive peptides and used in the nutraceutical and cosmetics industries, the price per kilo would rise to hundreds of euros.[115]

The regulation on feed industry laid down in European Union legislation and supplemented by national legislation is very strict. The by-product legislation aims to protect human and animal health and the safety of the food and feed chain from

112 Raisioaqua, Feeds: https://www.raisioaqua.com/en_GB/feeds (read 8.12.2021). AB Salmonfarm Oy, Kalajauhon- ja öljyn valmistus: https://salmonfarm.fi/yritys#kalankasvatus-jalostus (read 8.12.2021)

113 eniferBio, Who we are: https://www.eniferbio.fi/ (read 17.12.2021)

114 Luke, Total fish production 2019: https://www.luke.fi/en/statistics/total-fish-production/total-fish-production-2019 (read 17.12.2021)

115 Yle, Kalan perkuujätteessä piilee miljoonabisnes: Silakkajalosteen kilohinta nousee satoihin euroihin: https://yle.fi/uutiset/3-11088388 (read 17.12.2021)

pathogens that may be present in by-products.[116] Planning any new innovations or development in the feed industry means always taking into account the requirements of the by-product legislation. The Finnish Food Authority is the highest authority looking after the hygiene and legality standards of fish by-products supply for the feed industry.

Pharmaceutical, nutraceutical and cosmetics industry

The use of by-products of fish in pharmaceutical, nutraceutical and cosmetic industry offers big potential for making added value products for fish. However, in most cases such production is indeed still only on a research level and the commercial scaling of these innovations is still waiting to happen.

The Natural Resources Institute of Finland has studied the use of fish peptides produced from Baltic herring and edging side streams and estimated them to have high commercial potential in different dietary supplements, as well as pharmaceutical and cosmetic applications. Fish peptides could be added to food products in order to promote blood glucose control, to support diabetes medication and to be used as an antimicrobial agent against the bacteria that cause food poisoning and food spoiling microbes. The main challenges in commercialising fish peptides are ensuring sensory quality and verifying health claims.[117]

Another topic under study for the Natural Resources Institute Finland is fish gelatine. Their studies have shown that gelatine from Finnish fish is particularly suitable for frozen products or cold-stored products due to its low melting point. Fish gelatine could also be used in manufacturing of biodegradable films. What makes fish gelatine an interesting product for the public is that it presents a substitute for gelatine from other animals (e.g. pigs) for those with dietary restrictions due to religious or environmental reasons. In addition to gelatin, collagen is a sought-after product in the pharmaceutical, nutraceutical and cosmetics industry that can also be produced from domestic fish.[118]

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116 Eläimistä saatavien sivutuotteiden käsittely ja valvonta elintarvikealan laitoksissa. Ruokaviraston ohje 1746/04.02.00.01/2020/6. https://www.ruokavirasto.fi/globalassets/tietoa-meista/asiointi/oppaat-ja-lomakkeet/yritykset/elintarvikeala/elintarvikehuoneistot/ohje_elaimista_saatavien_sivutuotteiden_kasittely_ja_valvonta_elintarvikealan_laitoksissa.pdf. Page 5.

117 Kallasvuo, M., Kärkkäinen, K., Mäkinen, S., Nieminen, K., Suuronen, P. & Vielma, J. (toim.). 2021. Sininen biotalous: Tutkimusohjelman loppuraportti. Luonnonvara- ja biotalouden tutkimus 22. Luonnonvarakeskus. Page 29.

118 Kallasvuo, M., Kärkkäinen, K., Mäkinen, S., Nieminen, K., Suuronen, P. & Vielma, J. (toim.). 2021. Sininen biotalous: Tutkimusohjelman loppuraportti. Luonnonvara- ja biotalouden tutkimus 22. Luonnonvarakeskus. Page 30.

Fish bones and scales are good sources of minerals such as calcium and phosphorus. There are already calcium supplements made of fish scales on the market for humans and pets, like dogs or horses. By treating fish bones at high temperatures, they produce hydroxyapatite, which can be used as a bone transplant material in medical and dental applications.[119]

Textile industry

Fish skin is not a new material in textile industry but it is still quite unknown to the general public and relatively little used. In order to better productize fish skin in the textile industry, creativity, courage and also the right kind of marketing is needed. In Finland, the most popular fish species for making fish skin are pike, different Salmonidae (for example salmon, trout and chars), European whitefish, eel and perch. Practically all types of fish skins are suitable for tanning. Factors that affect which fish are chosen to be prepared as fish skin are size, availability, appearance and workload that the specific fish requires in order to make the fish skin. Fish skin can nowadays also be manufactured using factory-like methods.[120]

In Finland, fish skin and products made out of it are made by small companies or artisans. Examples of companies and hand workers are Galateia, Kalaparkki, Saija Lehtonen Design and Viona Blu. Challenges for scaling up the use of fish skin are linked to funding, marketing, and logistics. Also the production time of fish skin is quite long and this brings another obstacle in the increase of the use of fish skin.

Energy

The idea of combined offshore sites for energy and aquaculture have been discussed also in Finland, but the development is still in a very early phase. Finland is investing heavily in developing its offshore ecosystem (Team Renewable Arctic Finland) and has strong offshore competencies.

Already now, some by-products of fish end up as raw material for bioenergy. For example, visceral fat left from rainbow trout during processing has been used as a raw material for bioenergy production and also as feed in mink farms. The fat and oil obtained as a

119 Kallasvuo, M., Kärkkäinen, K., Mäkinen, S., Nieminen, K., Suuronen, P. & Vielma, J. (toim.). 2021. Sininen biotalous: Tutkimusohjelman loppuraportti. Luonnonvara- ja biotalouden tutkimus 22. Luonnonvarakeskus. Page 31.

120 Uusi-Tarkka, Eija-Katriina, Kalannahan käyttö ja mahdollisuudet asuste- ja sisustusmateriaalina. Thesis on textile and clothing technology. Spring 2014. Lahti University of Applied Sciences. https://www.theseus.fi/bitstream/handle/10024/79297/Uusi-Tarkka_Eija-Katriina.pdf?sequence=2&isAllowed=y

by-product of fish can be used in the production of higher-value products than bioenergy such as so-called "virgin oil" for cooking made at low temperatures through a mechanical separation process.[121] Still if some parts of fish remain unutilized and they are suitable for bioenergy production, that is another way to obtain more value from the network of fish.

There are also other ways to combine energy production with the fish industry. Fisheries are dependent on fish stocks from the sea so restoring or creating habitats has a positive effect on fish stocks[122]. Artificial reefs in offshore windfarms provide habitats for fish stocks and potential for their growth. As windfarm areas are not suitable for trawling, the fish stock can grow undisturbed. Spillover of fish to other areas provide increased catches for fishermen[123,] Artificial reefs provide hard-substrate habitats and provide higher biodiversity values[124].

5.2 Recreation

Fishing is a popular recreational activity in Finland. Almost every third Finn fishes in their leisure time and 44 % of consumption of domestic fish was due to recreational fishing in 2016. However, recreational fishing is changing. Keen recreational fishers develop new ways of fishing but urbanization drives weaker relationship with the nature and this changes general public's relation to fishing. At the same time, the conditions for fishing tourism have developed. For rural residents, fishing is an amenity and can also be seen as a rural attraction. The management of fishing waters is also undergoing a transformation as new fishing areas become operational and state administrative structures are reformed. The most common recreational fishing methods are angling, ice fishing and casting. Trolling has become an established method of fishing. The share of net fishing is declining, but it still accounts for the majority of catches. The total annual catch of recreational fishing is estimated at almost 30 million kilograms. The highest catches are perch and pike, which account for more than half of the total catch.[125]

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121 Kallasvuo, M., Kärkkäinen, K., Mäkinen, S., Nieminen, K., Suuronen, P. & Vielma, J. (toim.). 2021. Sininen biotalous: Tutkimusohjelman loppuraportti. Luonnonvara- ja biotalouden tutkimus 22. Luonnonvarakeskus. Page 31.

122 Ahtiainen, H. & Öhman, M. 2014. Ecosystem services in the Baltic Sea – Valuation of Marine and Coastal Ecosystem Services in the Baltic Sea. Nordic Council of Ministers. TemaNord 2014:563. ISBN 978-92-893-3863-9

123 Langhamer, O. 2012. Artificial Reef Effect in relation to Offshore Renewable Energy Converion: State of the Art. The Scientific World Journal 1: 886713.

124 Glarou, M., Zurst, M. & Svedsen, J. 2020. Using Artificial-Reef Knowledge to Enhance the Ecological Function of Offshore Wind Turbine Foundations: Implications for Fish Abundance and Diversity. Journla of Marine Science and Engineering 8:332.

125 Ministry of Agriculture and Forestry: Development strategy for recreational fishery https://mmm.fi/documents/1410837/11907317/Vapaa-ajan+kalatalouden+kehitt%C3%A4misstrategia/686d6db5-0131-98ef-a8e1-5bd135819b78/Vapaa-ajan+kalatalouden+kehitt%C3%A4misstrategia.pdf?t=1571221648000 (Read: 9.12.2021)

For recreational fishing in Finland, each person aged between 18-64 years must pay a fisheries management fee (kalastonhoitomaksu) in advance. The fee covers fishing with one lure or trap, and catching crayfish. Angling, ice fishing and Baltic herring splitting are activities that everyone can do without paying the fisheries management fee. On the other hand, if a recreational fisher wants to fish with more than one lure or use some other method (e.g. net fishing, etc), a separate permission from the owner of the water area is required. In addition, there are some restrictions on places where fishing is allowed. These include protected areas, special destinations requiring separate permissions, and rapids and streams containing migratory fish. The fisheries management fee does not entitle fishing in Åland.[126]

Fishing tourism is part of wilderness tourism. Companies offering fishing tourism services typically rely on guided tours and diverse fishing opportunities. Main clientele consist of company clients and private clients, and 22-35 % of clients are foreign clients. Companies usually are either companies offering only fishing services or companies that operate more generally in nature tourism where fishing tourism is one of the offered activities. Fishing tourism is a seasonal activity and can rarely be year-round, even though some companies offer ice fishing during winter. A case study on regional economic impact of fishing tourism at river Tornio area (rivers Tornio, Muonio and Könkämäeno common licence area) estimates that fishing tourism brought a regional economic impact of 10,8 million euros and 140 job opportunities for seasonal workers in 2017. Furthermore, it estimates, that one kilogram of salmon fished from the area by a recreational fisher was as high as 214 euros, which would mean that one salmon was worth of 1320 euros in 2017.[127]

5.3 Ecosystem services and environmental protection

The natural environment and habitats provide people with food and livelihood. These ecological services form the basis for the fish industry. Without spawning areas and other ecological functions in the sea, the fish populations available for fishing would be smaller. Biodiversity in natural habitats also provides healthy environments for fish farming. Ecosystem services provided by the Baltic Sea ecosystems create value for both

126 Metsähallitus: Fisheries management fee (Kalastonhoitomaksu): https://www.eraluvat.fi/kalastus/kalastonhoitomaksu.html (read: 9.12.2021)

127 Pohja-Mykrä, M. et al. 2018. Current status and development prospects of business models related to the wilderness economy. Publications of the Government´s analysis, assessment and research activities 40/2018. https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160877/40-2018-Er%C3%A4talousraportti.pdf

the fish-based industries as well as on a social plane by giving work on coastal areas and possibilities for recreational activities[128].

As an ecosystem service, fish are a good source of protein. The carbon food print of fish is small (10–50 %) in comparison to pork products. Different fishing methods have an effect on the carbon footprint of fish products: trawling and other mobile methods have a bigger footprint than, for example, seine fishing. Replacing one meat portion a week with fish would decrease consumers' carbon footprint by 6 %. Utilization of natural fish populations should still be done in a sustainable way [129].

In order to maintain the ecosystem services provided by the sea, laws and directives have been implemented at different governmental levels. The legislation of the EU has several directives that require its member states to monitor and assess the condition of their marine areas as well as to take action to improve the state of sea areas. Marine Strategy Framework Directive and Water Framework Directive are an important part of maintaining and improving the ecosystem services provided[130].

Partly due to the EU legislation, the Finnish government has an extensive mapping project for valuable underwater species, habitats and ecosystems. Finnish Environment Institute's VELMU-project's (The Finnish Inventory Programme for the Underwater Marine Environment) mapping data is publicly available as geographical information data[131]. The goal of EU's biodiversity strategy is to protect 30 % of land and water areas. At the moment, 11 % of Finland's marine areas are parts of protected areas[132].

Historically, many rivers and streams have been dammed or otherwise changed to meet to human needs. These ecosystems are important spawning areas for many Salmonid fishes (e.g. trout) and generally important for biodiversity. In order to maintain and to improve ecosystem services in Finnish water areas, restoration efforts have been made. Streams have been made into a more natural environments for local fauna and suitable for

128 Ahtiainen, H. & Öhman, M. 2014. Ecosystem services in the Baltic Sea – Valuation of Marine and Coastal Ecosystem Services in the Baltic Sea. Nordic Council of Ministers. TemaNord 2014:563. ISBN 978-92-893-3863-9

129 Kalakauppiasliitto: https://kalakauppiasliitto.fi/uusi-tutkimus-selvitti-kalatuotteiden-ekologisuutta/ (read: 9.12.2021)

130 Ahtiainen, H. & Öhman, M. 2014. Ecosystem services in the Baltic Sea – Valuation of Marine and Coastal Ecosystem Services in the Baltic Sea. Nordic Council of Ministers. TemaNord 2014:563. ISBN 978-92-893-3863-9

131 VELMU: https://www.ymparisto.fi/en-US/VELMU (read: 9.12.2021)

132 Ympäristö: https://www.ymparisto.fi/fi-FI/Luonto/Selvitys_EUn_biodiversiteettistrategian_(60985) (read: 9.12.2021)

spawning[133]. An example of restoration projects is the restorations of suitable habitats for freshwater pearl mussel in LIFE Revives -project. The restoration of suitable habitats does not only help the mussel populations but also other species sharing the same habitats[134]. All in all, when the environment offers suitable healthy habitats, the fish multiply and grow more efficiently. Water quality has an effect on fish growth and the survivability rate[135] so a healthy sea provides a larger yield from fishing and fish farms.

5.4 Administrative authorisation and legislation

All parts of the business ecosystem of fish in Finland are touched by legislative requirements from EU level and/or from national legislation. In the ecosystem of fish business, some of the main objectives of legislation are to ensure the good health and safety of both humans and the environment. These objectives are usually safeguarded with permit processes in which there is a constant strive to develop them to be more efficient and less time consuming.

In 2018, the Prime Minister's Office of Finland published a final report on the project "Marine Aquaculture permitting pilots" coordinated by Natural Resources Institute Finland. The project included many different permitting pilots and workshops.[136] In one of the pilots, positive outcomes were reached with preliminary discussions with the authority in which representatives of the planned project participated and provided background information for the authority and in return the fish farming company received a wide range of advice from the authority to streamline the project process. In another pilot, the experience the fish farming companies had about the preliminary discussions was that the advice was targeted at those things that companies were already relatively well aware of. The fish farming companies expected to have better information from the authorities especially on issues critical to permit applications, such as production volumes, location and the scope of the environmental impact assessment.[137] Still preliminary discussions are considered to be a useful tool that when properly used have the potential to bring greater efficiency to permit processes.

133 Vesi.fi: https://www.vesi.fi/vesitieto/virtavesien-kunnostus/ (read: 9.12.2021)

134 Metsähallitus: https://www.vesi.fi/vesitieto/virtavesien-kunnostus/ (read: 9.12.2021)

135 Boyd, C. Chapter 6 – General Relationship Between Water Quality and Aquaculture Performance in Ponds. Jeney, G. (ed.). Fish Diseases, Academic Press. 2017. Pages 147–166. ISBN 9780128045640.

136 Marine Aquaculture permitting pilots. Final report. Prime Minister's Office Finland 25.5.2018.

137 Suomen Kalankasvattajaliitto ry, Sujuvuutta lupakäytäntöihin – Merikasvatuksen luvituspilotit. https://www.kalankasvatus.fi/sujuvuutta-lupakaytantoihin/ (read 9.12.2021)

Furthermore, the above discussed report identified 10 recommendations on how environmental permit practices could be reformed in order to accelerate the sustainable growth of aquaculture activities. Each of these recommendations discusses important issues. One in particular is important to point out and that is the recommendation on clarifying the significance of the Weser Court's decision (EUTI C-461/13) for the purposes of the environmental permit decision, taking into account the uncertainties surrounding the ecological status assessment.[138] This case has had big effects on the fish business and its influence still keeps unravelling.

5.5 Consumer trends and behaviour

Finnish consumers are among those consumers that most want to eat domestic fish within the EU as 63 % of Finnish consumers want to prioritize domestic products.[139] At the moment, however, the volume of fish imports is larger than the domestic production: two thirds of Finnish fish consumption is credited for imported fish, mostly from Norway.

A large proportion - 94 % - of Finnish consumers eat fish, and 80 % of them would like to increase the consumption of fish. Finns tend to buy their fish from retail stores along with all other foodstuffs they buy and 39 % of the consumers would buy fish more often, if selection was wider and availability better. Climate reasons are one of the main reasons behind the shift to eating more fish instead of meat. Main factors affecting buying decisions of the consumers are quality and freshness of the fish. In addition, eating fish has to be easy: gutted and filleted fish are the choice for many consumers. Other easy ways to eat fish include e.g. quality ready-made foods, frozen foods, and take-away products (such as sushi). Consumers also appreciate variety between quick and cheap option and more expensive luxury products.[140] [141]

138 Marine Aquaculture permitting pilots. Final report. Prime Minister's Office Finland 25.5.2018

139 Pro Kala ry:n tiedote: Suomalainen suosii suomalaista kalaa, kertoo eurooppalainen kuluttajatutkimus https://merijakalatalous.fi/pro-kala-ryn-tiedote-suomalainen-suosii-suomalaista-kalaa-kertoo-eurooppalainen-kuluttajatutkimus/ (read 9.12.2021)

140 Pro Kala ry:n tiedote: Kuluttajatutkimus: neljä viidestä suomalaisesta haluaisi syödä enemmän kalaa. https://www.epressi.com/tiedotteet/ruoka-ja-elintarvikkeet/kuluttajatutkimus-nelja-viidesta-suomalaisesta-haluaisi-syoda-enemman-kalaa.html (read 9.12.2021)

141 YLE Luonto: Suomalaiset haluaisivat syödä enemmän kotimaista villikalaa – Kalasta vastaus ruokamurrokseen? https://yle.fi/aihe/artikkeli/2019/12/02/suomalaiset-haluaisivat-syoda-enemman-kotimaista-villikalaa-kalasta-vastaus (read: 9.12.2021)

A desire for local fish has come up repeatedly in research in Finland. This is why during the last over ten years a lot of effort has been put towards increasing availability of local fish in Finland. Research and product development projects have concentrated especially on Cyprinid fish which are plentiful in Finland's waters. Development has resulted various new Cyprinid fish products such as fish fingers, patties, tinned fish, and minced fish. This development shows in consumption volumes: whereas in the beginning of 2010s only a few tens of tons of roach were consumed mainly due to export to Russia, in 2018 already 800 tons of roach were consumed.[142]

New fish products that are easy to use and palatable are developed by fish value network actors, such as fish processing companies, research institutes and universities, other project owners, other stakeholders and Pro Kala ry. Blue Products, fishing innovation programme has been one instrument facilitating joint innovation.[143] Some research institutes are specialized in consumer research, such as Functional Food Forum at the University of Turku, which has sensory and consumer research among the topics of research. Functional Foods Forum also has Flavoria® Research Platform for multidisciplinary research of food.[144] Other project owners may come up with new project ideas such as John Nurminen fund did with their Local Fishing Project, where they created the first market-driven value chain from sea to plate for Cyprinid fish from the Archipelago Sea. The project also significantly enhanced Cyprinid fish's image as edible fish. Five products for institutional kitchens and consumers were launched during the Local Fishing Project.[145] Pro Kala ry (a non-profit association) helps consumers and offers useful information on fish, including basic information on fish species, how to handle and store fish raw material correctly and how to prepare food from fish.[146]

142 YLE Luonto: Suomalaiset haluaisivat syödä enemmän kotimaista villikalaa – Kalasta vastaus ruokamurrokseen? https://yle.fi/aihe/artikkeli/2019/12/02/suomalaiset-haluaisivat-syoda-enemman-kotimaista-villikalaa-kalasta-vastaus (read: 9.12.2021)

143 Blue products innovation programme: https://merijakalatalous.fi/innovaatio-ohjelmat/kalastuksen-innovaatio-ohjelma/ (read 22.12.2021)

144 University of Turku, Functional Foods Forum: https://www.utu.fi/en/university/faculty-of-medicine/functional-foods-forum/research (read 22.12.2021)

145 John Nurminen Fund: https://johnnurmisensaatio.fi/en/projects/local-fishing-project/ (read 22.12.2021)

146 Pro Kala ry: https://prokala.fi/ (read 22.12.2021)

6 Development opportunities for Finnish business ecosystem in the fish value network

The global demand for fish and seafood has increased by 122 % during the last 30 years. It has been predicted that this demand will continue to increase by another 18 % between 2018 and 2030. Asia, Europe, Latin America and Oceania are expected to be the biggest drivers in the increasing consumption of fish and fish products. The richer countries are predicted to mainly be dependent on imports. However, Norway will remain as one of the most important fish export countries[147].

The biggest increases in value and production volume since 1990 have happened in aquaculture. Production has increased by 527 % to 114,5 million tonnes. Aquaculture's production surpassed the volume of capture fisheries' production of 96,4 million tonnes despite a 14 % increase in fisheries' production during the same time. Accordingly, the predicted increases in production are estimated to come from aquaculture while capture fisheries' growth is expected to be modest, 3,1 % in the EU by 2030. The capture fisheries' production is limited by the fact that 90 % of worlds wild fish stocks are overfished. This is possible because of an unequal progress in fisheries management[148].

Climate change poses risks to the industry in the form of rising water temperatures and acidification of the ocean, although this risk is not uniformly distributed across the globe. The Nordics are in a lucky position, as these risks are estimated to be lower for the region than more southern parts of the globe.[149]

Finland's export of fish is concentrated to raw material and feed. Although the exported amount of Baltic herring and sprat is fairly high, the value creation remains low, as the products are processed elsewhere. There are developments in Finland aiming at replacing raw material with higher-value products for export, opening new opportunities for positive development. As new food products are developed, the use of Cyprinid fish as

147 Food and Agriculture Organization of the United Nations 2020
148 Food and Agriculture Organization of the United Nations 2020
149 Food and Agriculture Organization of the United Nations 2020

food is increasing. Recent years have seen remarkable product development in food products made from domestic fish, although the market value remains modest.

There are strong business ecosystems in Finland in other industries linked to the fisheries and aquaculture. Finland is a high-tech country for green technological solutions, although not yet prominent in the aquaculture market. Finnish port solutions are internationally well-known and development related to automation and electrification provides a competitive edge as pointed out in chapter 1.2. Also, the efficient transportation logistics, like Finnair Cargo as introduced in chapter 4.2, enhance Finland's position in the international aquaculture market. Ports are located at the interface between different parts of the value network: between the fishermen and fish farmers, and the rest of the value chain. Seamless operations are important for the operations of the whole network.

The key development opportunities for Finnish fish value network include the following:

1. **Raising the level of value creation** in the fishing and fish processing industry towards higher-value products for domestic use and export. Instead of using fish as it is as a food product or raw material for fish feed, higher value can be attained for example through processing fish to novel food products like pulled Baltic herring as introduced in chapter 4.3.and by utilizing fish side-streams in production of fish peptides for pharmaceutical and cosmetic applications as explained in chapter 5.1. This opportunity is relevant also for development of fishing technology and equipment. In addition, Finnish companies have potential to offer high value products to export and attract foreign fishing tourists.

2. **Further development of the quality of operations and a smart and sustainable aquaculture**. A sustainable and ethical fish industry that preserves and increases fish well-being will have growth potential also in the future. Smart and sustainable solutions developed in Finnish aquaculture to function in smaller-scale operating environment than open seas, can be useful in similar conditions in the Nordics. Examples of such innovative companies and solutions are introduced in chapter 3.2. These include technology solutions for closed loop fish farming and digitalization innovations for gathering biomass and growth data in fish farms.

3. **Combined use of maritime areas** emphasizes comprehensive thinking in planning and use of maritime areas. One maritime project could help host another project and thus joining for example offshore wind installations with fish farming projects could increase the efficient and sustainable use of

maritime areas. Growth in offshore wind development increases the need for aquatic ecosystem services but can also provide new opportunities and technology development for aquaculture. Generating energy from offshore wind in the Nordic region faces still many challenges and must find solutions for example on how to anchor wind installations and protect them against the harsh sea conditions. Once these innovations emerge, offshore aquaculture can also benefit from them.

Development of business-led innovation ecosystems in the fish value network is crucial for success. Business-led innovation ecosystems combine big and small companies with different sectors of government and reconcile different perspectives. This gives a solid growth base for innovations and international cooperation. There are good experiences of realization of such ecosystems in maritime sectors in Finland. Business-led innovation ecosystems have three levels of operation: domestic development, export of products, and Finland as an attracting partner and model country. Arctic cooperation opportunities can be found for example with ocean clusters and ecosystems in other countries.

Electronic publications
ISSN 1797-3562
ISBN 978-952-327-740-3

Electronic version: julkaisut.valtioneuvosto.fi
Publication sales: vnjulkaisumyynti.fi