BLUE BIOECONOMY IN THE ARCTIC REGION

Project Report

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ARCTIC COUNCIL

Sustainable Development Working Group

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CONTENTS

Fishing pier in Sund Flakstadoya Loftofen Norway. Photo: Shutterstock.com.

SUMMARY AND ARCTIC POTENTIAL

The blue bioeconomy is important to many Arctic communities, providing food and other valuable bioresources, generating value and employment, and supporting rural regions. This report looks at the Arctic blue bioeconomy by analyzing regional challenges, opportunities, best practices and success stories from Iceland, Norway and Northern Canada. In addition, information on the status of the blue bioeconomy in Alaska, USA, the perspective of Inuit people on the blue bioeconomy and markets for marine ingredients are described. This work was endorsed by the Arctic Council´s Sustainable Development Working Group (SDWG).

The three Arctic regions included in the analysis that follows clearly show that there is no one Arctic blue bioeconomy. This stems from diverse natural, economic and social conditions in the Arctic. The maturation and focus of the regional blue bioeconomies differ substantially and there are different regional and cultural understandings of the blue bioeconomy. However, there are important common interests and initiatives where the Arctic region can benefit from collaboration and mutual support to strengthen the blue bioeconomy:

WORKING TOGETHER TOWARDS SUSTAINABILITY

The blue bioeconomy is premised on sustainable development, considering environmental, social and economic pillars. Moving towards sustainability is the biggest task the world is facing, and the Arctic must continue to collaborate on and contribute to this mission with increasing efforts, both regionally and at global platforms. Reducing greenhouse gas emissions, ensuring healthy ecosystems and responsible resource utilization are the foundations of a thriving strong blue bioeconomy. Arctic collaboration on climate change adaptation, predicting and monitoring changes in the marine environment, its bioresources and their utilization is necessary, and the sustainable Arctic blue bioeconomy will rely on long-term monitoring and modeling, both at local, pan-Arctic and global scale.

FOSTERING ARCTIC KNOWLEDGE TRANSFER

The Arctic will benefit from increased knowledge and technological transfer, as well as sharing of best practices from the blue bioeconomy. Successes and experiences developed within and outside of the Arctic region can apply and be implemented in the Arctic with the aim to strengthen the blue bioeconomy. A way to foster these processes would be to support and encourage them through specific Arctic funding mechanisms and innovation networks (see below).

ESTABLISHING AN ARCTIC MARINE BIOECONOMY RESEARCH AND INNOVATION NETWORK

A virtual network supporting businesses within the Arctic marine bioeconomy and the implementation of innovative and sustainable solutions could be a valuable contributor to strengthening the Arctic blue bioeconomy, facilitating increased cooperation, research and development, knowledge transfer and marketing support. A virtual pan-Arctic interdisciplinary network may be established, connecting Arctic innovation centers, research organizations, businesses and entrepreneurs. Such a network may further encourage Arctic cooperation and joint research activities, such as international flagship projects.

EDUCATION AND CAPACITY BUILDING

To support a strong Arctic blue bioeconomy, relevant education and capacity building is necessary. Mapping of educational and training needs in all parts of the Arctic where the blue bioeconomy is strong or has significant potential for growth is advised. Following a mapping phase, educational programs in Arctic regions, focusing on capacity building for the blue bioeconomy could be developed, incorporating sustainable resource utilization, processing technologies, innovation and marketing training. Arctic collaboration and knowledge transfer will strengthen and speed up this process, benefiting the whole region including rural areas.

INTRODUCTION

BLUE BIOECONOMY IN THE ARCTIC REGION

The Arctic is a unique area on Earth, covering a vast and diverse region that is attracting both economic and political interest. The Arctic regions differ in their natural resources, climate, population, cultures, economies, infrastructure etc. but all share great potential for sustainable growth, particularly in the development of the Arctic's blue bioeconomy. The blue bioeconomy is the utilization and value creation from renewable aquatic biomass. The ocean is important for many of the Arctic´s inhabitants and utilization of living marine resources is a major economic factor in coastal communities in the Arctic region. Bioresources from freshwater are also economically important in certain regions within the Arctic.

Defining the blue bioeconomy is comprehensive and complex and no single definition exists. ***Rather, the modern-day blue bioeconomy includes all kinds of economic activities but is based on intelligent and sustainable use of bioresources, focusing on improving utilization, the use of novel bioresources and creating higher-value products.*** Products include food, animal feed, pharmaceuticals, cosmetics and various chemical compounds. A blue bioeconomy based on sustainable development means that the needs of the present are met without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987) and considers environmental, societal and economic dimensions.

A strong and sustainable Arctic blue bioeconomy can significantly contribute towards the strengthening of Arctic communities through supporting economic developments, building resilience and increasing self-reliance. The blue bioeconomy has great potential to transform societies towards greener, safer and more equitable societies but concrete efforts are needed to develop the bioeconomy in a sustainable and circular way. Traditional capture fisheries are not expected to increase considerably, but increased activities can be expected in related industries. These industries include technology, cultivation and improved utilization of available seafood. Utilization and value creation from underutilized and novel species also have significant potential. As the blue bioeconomy is often rooted in rural communities, it has the potential to strengthen local value creation and increase employment. Most Arctic regions are sparsely populated, and the populations are decreasing in many rural regions. It is important to counteract the population decline in these regions to prevent the collapse of inhabited settlements, as well as to maintain food security. Increasing the sustainable utilization and value of aquatic bioresources may be an important factor for strengthening settlements in coastal regions. Knowledge and innovative solutions need to be developed to enhance every community's resilience and capacity to contribute to and benefit from the blue bioeconomy. Parallel to innovative development of new products, traditions related to ocean resources should be respected and preserved.

Within the blue bioeconomy, Arctic communities are finding novel ways of balancing food security, economic growth, and the protection of the aquatic environment through product development and improved utilization methods. However, the strength, focus and progress being made in the Arctic blue bioeconomy is uneven, with some countries and regions making important progress while others lag behind. Over the past decade, important technological innovations have been made in the Arctic's blue bioeconomy. These advancements include new technologies that have enabled blue industries to capitalize on the sustainable and intelligent uses of aquatic natural resources.

Increasing our knowledge and understanding of our oceans is important and further research is needed to build up the Arctic aquatic knowledge base. This is important so that decisions on sustainable utilization and value creation can be made on a more solid foundation. The Arctic blue bioeconomy relies on responsible and integrated fisheries management. Arctic countries have largely implemented sustainable marine utilization while certain stocks are under threat from overfishing. Blue food, that is food originating from aquatic environments, has an important role in the worlds future food systems and in feeding the growing population. Many aquatic foods have lower environmental impacts than agri-foods and are an essential source of healthy nutrients.

The development of the Arctic blue bioeconomy faces diverse and variable challenges that vary from region to region. These include social, economic, logistical, and political obstacles. Some of these constraints include the high cost of food production inputs, limited infrastructure (e.g., road networks, ports), absence of supportive legislative, cultural tensions associated with commodifying traditional Indigenous foods, limited innovation, and an over-reliance of raw export. Despite these challenges the importance of the blue bioeconomy for diversifying local economies and redefining food security is generally acknowledged among communities and governments.

Climate change is affecting the Arctic at an alarming rate and severity and is increasing the vulnerability of the Arctic region. The Arctic is at risk due to continued warming, declining sea ice, rise in sea level, and Arctic communities are facing challenges that result from the impacts of climate change. The blue ecosystem in the Arctic is undergoing unprecedented changes resulting from climate change. The oceans are becoming warmer and more acidic and living conditions for shellfish and ocean plankton will become less favorable with consequences throughout the food chain, impacting the whole ecosystem. Climate change will have extensive and largely unknown effects on the Arctic blue bioeconomy, but Arctic inhabitants must prepare for these changes, adapt to them and mitigate further effects, through sustainable development.

This report was written in 2020 when COVID-19 spread across the world, affecting Arctic communities and economies. COVID-19 affected the Arctic blue bioeconomy, such as in reduction of sales of (primarily fresh) fish products due to reduced market demands and limited transport. COVID-19 generally increased awareness of food security and in many regions brought focus on increased regional food production within the Arctic. There are uncertainties regarding how extensive the economic downturn due to COVID-19 will be, how fast and how well different markets will recover. But climate change and the following predicted biodiversity loss are even more challenging threats that must be addressed. In the light of the state of the world, the development of a strong sustainable global bioeconomy is becoming increasingly important. This is reflected in the adoption of bioeconomy-related policies in many countries and regions of the world (International Advisory Council on Global Bioeconomy, 2020).

This report focuses on the blue bioeconomy in four Arctic regions; Iceland, Norway, Northern Canada and Alaska, USA (Chapters 1-4). It presents the current state of the different blue bioeconomy sectors; marine fisheries, aquaculture, algal biomass and freshwater fishing. For Iceland, Norway and Northern Canada major challenges and opportunities have been identified and examples of best practices and success cases are given. Perspectives of Inuit people on the blue bioeconomy (Chapter 5) and information on markets for marine ingredients (Chapter 6) are provided.

Salmon farming in the Westfjords of Iceland. Photo: Arctic Fish.

On the south coast of Iceland. Photo: Shutterstock.com.

ABOUT THIS WORK

This report is the outcome of the Blue Bioeconomy in the Arctic project, a desktop study endorsed by the Arctic Council´s Sustainable Development Working Group (SDWG) in 2019. The objective was to consider opportunities and challenges for the development of the blue bioeconomy in the Arctic region. With a focus on balancing economic growth, social inclusion and environmental protection, the project links to the priority area of Sustainable Business Involvement and Development in SDWG's Strategic Framework. The project was initiated in October 2019 and falls under the priorities under Iceland´s Arctic Council chairmanship 2019-2021.

The project mapped opportunities in selected regions within the Arctic for the development of the blue bioeconomy, collecting success stories and best practices, as well as identifying obstacles that could hamper progress. This was done through a desktop study, as well as seeking input from stakeholder groups at two events: an interactive workshop at the Arctic Frontiers conference in Tromsø, Norway in January 2020 and a virtual online workshop in October 2020. The input received at these events has been incorporated into the report, where judged appropriate by the report authors.

Following SDWG´s endorsement, interested SDWG delegates and other relevant organizations were requested to nominate participants to work on the project.

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THE STUDY REGION

The study is based on four Arctic regions; Iceland, Norway, Northern Canada and Alaska, USA. For Iceland, Norway and Northern Canada the current state of the main bioeconomy sectors is described, major challenges and opportunities have been identified and examples of best practices and success cases are given. Information on the current state of the Alaskan blue bioeconomy is provided, without further analysis (Figure 1).

Figure 1. The study region.

Fishing in Iceland. Photo: Magnús B. Óskarsson.

1. ICELAND

INTRODUCTION

The blue bioeconomy is an important part of Iceland's economy. The fishing industry has been one of the nation's most important industries and fish products make up around 40% of the national commodity exports. Iceland has been at the forefront of sustainable utilization and value creation from marine bioresources and technological advances in the blue bioeconomy. Iceland is now looking towards new opportunities, including further exploitation of underutilized species and biomass, novel value-added products and increased aquaculture production (Margeirsson et al., 2018).

Iceland has not adopted a national bioeconomy strategy, but issues of the blue bioeconomy are found within several national strategies, where sustainability, full utilization, value creation and regional developments are emphasized. A national food strategy together with an action plan is under development that will be of relevance.

Iceland has emphasized the importance of the marine environment and the blue bioeconomy in international cooperation, such as at the Arctic and Nordic level, and flagged as priorities during its Arctic Council chairmanship and Nordic Council of Ministers presidencies. From these, relevant desktop studies and networks have emerged[1] that have formed a basis for the analysis in this chapter.

MARINE FISHERIES

Key information
The most important fish species in Icelandic waters in 2019 in terms of values were cod, haddock, redfish, pollock and mackerel. The top species for volumes in 2019 were cod, blue whiting, herring and mackerel, see Table 1 (Statistics Iceland, 2020). The volumes of blue whiting and cod were similar; however, the value of cod products is much higher.

Table 1. Catches and catch values for three sectors in Iceland 2019. *

	Whitefish	Pelagic	Shellfish	Total
Catch, tonnes	502 583	534 373	10 082	1 047 038
Catch, value (million USD)	963	171	15	1 150
By-products, tonnes	28 764			28 764
By-products, value (million USD)	31			31

* Source: (Statistic Iceland, 2020). Currency 126 ISK/USD December 7th 2020. Data for by-products does not cover the total available amount.

Fish and fish products make up about 40% of Iceland's commodity exports. Direct employment in fisheries stands at about 8 800 people (in 2018) or about 4% of the workforce, according to Statistics Iceland. When fishing-related activities are factored in the number of employees increases considerably.

Fisheries and fish processing provided 6% of the Icelandic GNP in 2019 and for the last decade the proportion has been in the rage of 5-10% of the GNP. Almost all seafood products are exported (98%) or 619 thousand tonnes, worth of 2 064 million USD in 2019. Cod products were most valuable.

[1] Actions for Sustainable Bioeconomy in the West Nordic Region (2018)
https://www.matis.is/media/utgafa/actions_for_sustainable_bioeconomy_in_the_west_nordic_region.pdf
Future Opportunities for Bioeconomy - Focus on the West Nordic Region (2015)
https://www.norden.org/en/publication/future-opportunities-bioeconomy

CHALLENGES

Climate change and management of straddling fish stocks

Climate change is causing our oceans to warm with consequences for marine life, which may include changes in species productivity and phenology, altered migrations routes and changes in species distributions. Changes in the distribution and stock sizes of commercially important species have already been observed in Icelandic waters, likely caused by warming ocean temperatures since 1996. This includes northward expansion of the distributional area of some demersal species (including haddock and whiting), significant changes in stock sizes and distributions of some pelagic species (including capelin and mackerel) and increased presence of new species in Icelandic jurisdiction (Bjornsson et al., 2018). The migration of commercially important species to new areas and jurisdictions can also create severe management challenges, as has already been observed with the Atlantic mackerel. Coastal states need to come to an agreement on how to sustainably manage resources that move across jurisdictions, including allocation of fishing rights and quotas amongst them without exceeding scientific advice provided by advisory bodies.

Ocean acidification

Increased CO2 in our atmosphere causes ocean acidification, as the oceans absorb atmospheric CO2. Ocean pH has been declining over the past decades and is expected to decline further. As the solubility of CO2 is greater at colder temperatures, ocean acidification is particularly worrisome for the Arctic region. Consequently, it is likely that the negative effects of ocean acidification will emerge sooner in the northern regions than in other areas. While our understanding of the impacts of ocean acidification on marine life, particularly commercial shellfish and early life stages of finfish, remains limited and further research is needed, recent research suggests negative impacts on marine life and shellfish cultivation. More research is also crucial to understand the effects of warming oceans on Arctic marine life and to enable adaptation to environmental changes within coastal states and communities. Climate change, ocean acidification and the expected changes in marine productivity is likely to affect marine fisheries in the Arctic region and consequently, the economy. While some of these changes are likely to pose threats to Arctic communities, others might bring about opportunities.

Decreasing population in rural regions

The northern regions of Iceland are sparsely populated, and the population has been declining in the last few decades. Infrastructure development lags behind in rural communities and many of the north coast villages have suffered from changes in access to fisheries due to loss of quotas. This development creates a downward spiral, as economics of scale become more and more important in the modern seafood industry where technology and automatization play a key role.

Success story

Increased productivity in fish processing

There has been major progress within the Icelandic fish industry, with breakthroughs in productivity and value creation. The pelagic industry has moved from meal production (animal feed) to freezing for human consumption. The throughput in processing has increased from 400 kg to 13 tonnes per manhour from 1974 until today, a more than 30-fold increase, through the implementation of new automatic pelagic plants, freezing up to one thousand tonnes a day. Similar developments are happening in the demersal fish industries which are using automatic water jet robots that remove the pin bones from fillets and cut them into portions and packing robots. The new automated technologies have largely been designed and produced domestically. Since 1996, the efficiency of the demersal fish processing in Iceland has increased from 12 kg per manhour to 200 kg today. This new development has a huge impact on the Icelandic fish industry, with a targeted value chain and securing domestic processing.

Success story

Sub-chilling of mackerel

Over the last years, mackerel has been seen — and caught — around Iceland in increasing amounts, resulting in the speedy development of mackerel processing techniques. Mackerel enter Icelandic waters rather slim but fatten up in a short period of time. The mackerel oily meat is difficult to handle and spoils quickly, making only meal and oil production possible. This situation was improved by research and development projects which lead to the employment of sub-chilling of mackerel onboard fishing vessels. During sub-chilling, the fish is chilled below 0 °C with a powerful Refrigerated Water Chilling (RWC) technique, chilling the fish instantly. These methods are now the norm onboard Icelandic mackerel vessels, with the result that during the mackerel seasons nearly all the catch is transformed into valuable frozen, headed and gutted mackerel products for human consumption.

OPPORTUNITIES

Innovation and novel products

Pelagic species are found in great volumes in the North Atlantic. Innovative new processes and products are being developed to increase the value of the pelagic catch. Among the products studied are skinless mackerel fillets, high quality frozen mackerel fillets and high-quality protein from pelagic species. The processing of fish meal is being developed to meet demanding markets. Side streams from pelagic processing are being developed for valuable products. Similar advances are being made in the demersal- and crustacean sectors, as new products are developed including dietary supplements and functional foods. Innovation is also taking place within the catching and logistics sectors of the value chain and traceability and marketing based on favorable characteristics of North-Atlantic seafood provides innovation and added-value potential.

Increased seafood processing in small villages

Seafood landed in small villages is often transported to large processing units away from the landing place. Competing with the large processing units is difficult but novel, innovative and niche products can be successful. Traceability and marketing play an important part in reaching niche markets where origin makes a difference. Finding a unique position for a local product is a challenging task where support is needed. Training and capacity building programs are needed to help entrepreneurs develop products and create new jobs.

Automation of fish processing

High wages in Iceland are challenging for the labor demanding fish processing industry and automation is a key action to increase domestic processing and increase product value. To maintain a competitive advantage for the North Atlantic fisheries, increased productivity must be extended in the fish processing industry. Automation is capital intensive, which often leads to the merger of companies with larger operations to cover financial costs. Automation also results in fewer jobs within the fishing industry and it must be secured that profits from the fishing industry are shared fairly at a national level. On the other hand, automation creates new job opportunities in the seafood industry for well educated people.

Transforming fish meal production

The fish meal and oil industry has remained relatively unchanged for the past several decades. Currently, almost all fish meal produced in Iceland is used for production of fish feed. Current methods in the production of fish meal rely on the use of high heat, which negatively affects the quality of the proteins and lipids in the meal. Less harsh methods such as membrane filtering and spray drying in the production of fish meal will better preserve the composition, attributes and quality of the proteins and lipids in the meal, which in turn will enhance its nutritional value. This will yield a higher value product, with improved possibilities for applications, improved digestibility and higher value.

OTHER OPPORTUNITIES FROM THE MARINE ENVIRONMENT

Unlocking the potential of plankton biomass
A way to obtain significantly more food and biomass from the ocean is to harvest aquatic organisms from a lower tropic level than today. The utilization of these sources, such as zooplankton and algae, is increasing. Zooplankton are crucial in providing higher trophic levels with the essential n-3 fatty acids. Lipid-rich zooplankton have come under increased scrutiny as they represent a resource of oils rich in eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Zooplankton also contain enzymes, chitin, carotenoids, and other biologically active compounds that can be further utilized for the development of products for human consumption. It is estimated that the Calanus finmarchius biomass within the 200 miles zone around Iceland is about 7 million tonnes (Astthorsson, Gislason & Jonsson 2007). This resource could be used for many purposes, e.g. for oil production and the cultivation of shellfish. The utilization of ocean plankton should always be based on scientific research.

Utilization of unique genetic resources
The Central Arctic Ocean is among the least-known bodies of water in the world. This ocean and the marginal seas are home to a diverse array of microorganisms, many yet to be discovered (Pedrós-Alió, Potvin, & Lovejoy 2015) due to the difficult accessibility of this area. In addition, organisms living in this extreme, cold environment require specific adaptive mechanisms to survive, resulting in a vast treasure of genetic resources.

The largest untapped reservoir for bioprospecting in the Arctic Ocean lies within the biodiversity of microorganisms, including bacteria and microalgae. Many of those could be either cultivated from the marine Arctic environment or have their genetic potential discovered directly using molecular techniques. Potential products from the Arctic could cover antibiotics, enzymes and other bioactive compounds. In addition, there is also the potential of unique "cold-related" compounds (De Santi, Altermark, de Pascale, & Willassen 2016).

The potential of utilization of microbial resources regarding protection of the environment & climate, as well as improving the food value chain and bioprospecting, was recently addressed by AORA Atlantic Ocean Research Alliance - Marine Microbiome Roadmap (Bolhuis et al., 2020).

MOVING FORWARD

R&D funding for innovation and value increase
Governments and industries should put increased emphasis on valorization and value creation from side-products and underutilized streams through R&D. Competitive research funds are a key factor to speed up this progress. Creating or increasing value from underutilized by-products or bioresources doesn't just offer benefits for the economy, but also social benefits (e.g. job creation, rural development) and environmental benefits (e.g. reduce waste, recycle materials).

Fisheries clusters
In North West Iceland fishing plants have formed a Coop for processing side products from white fish (drying of cod heads and animal feed production). This cooperation makes a profitable production possible. This could be a model for processing marine by-products. Establishing regional clusters to handle side products, marketing, procurement and lobbying could strengthen fisheries in certain areas within Iceland. The creation of new jobs is of key importance for the survival of small settlements. This should be related to sustainable fisheries and production of seafood products and other goods for export and for the tourist industry.

Infrastructure and education needs
It is important to fight rural decline in Iceland to prevent the collapse of inhabited settlements, as well as to maintain food security. Value increase and value creation of ocean resources and waste streams could be the key for maintaining settlements in coastal regions. Important action could be to support local entrepreneurs and establish innovation centers in rural regions where various ocean resources are available. When successful, this can boost the economy of coastal communities and offer significant social benefits. It is important to disseminate knowledge and provide training in the fields of innovation. Education needs for workers in the fisheries industry and small fisheries villages should be mapped and actions taken to meet the needs.

Best practice

80% cod utilization

According to the Iceland Ocean Cluster, Icelanders utilize 80% of landed cod. In some countries this ratio is in the range of 45-55% with considerable loss of value (Sjávarklasinn, 2020). The reason behind the high utilization of cod in Iceland is the considerable utilization of cod side streams, national regulations and good cooperation between R&D organizations and companies. In Iceland, close to 50 companies process side streams from fisheries.

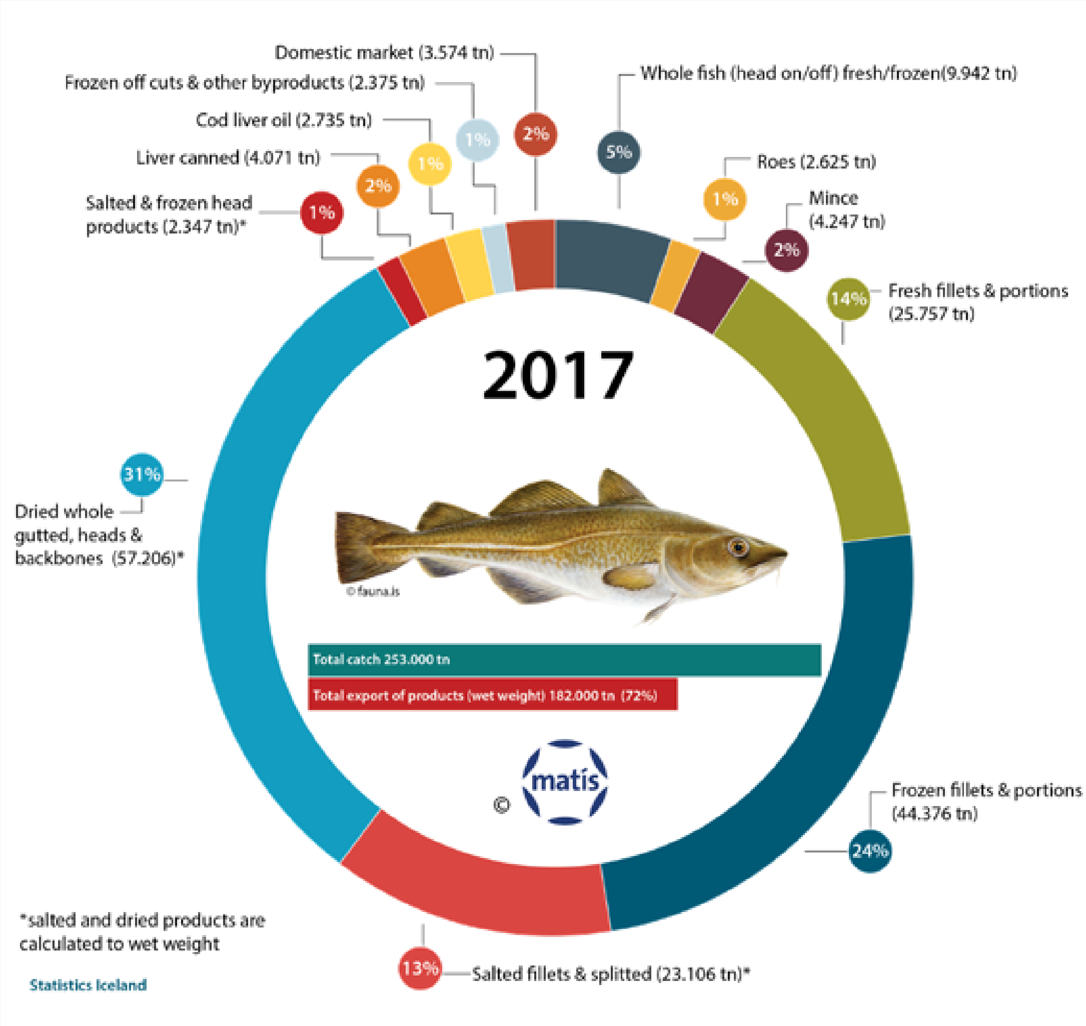

Figure 2. Utilization of cod in Iceland 2017.

Success story / Best practice

Increased value of demersal fish

The Icelandic demersal fisheries have developed considerably over the last decades. For the most important species, the Atlantic cod, a change has occurred from traditional salted and frozen products to high-end fresh fillet products transported primarily by cargo ships and airplanes to markets in Europe and North America. These products, customized to consumer needs and delivered all over Europe and North America, have delivered more added value than traditional frozen or salted products, and since 2006 the values have doubled.

Iceland Ocean Cluster

The Iceland Ocean Cluster (IOC)[2] is a private-sector initiative, established in 2011. The Cluster's mission is to create value by connecting entrepreneurs, businesses and knowledge in the marine industries. To serve this mission the IOC provides a range of services, including incubation, consultancy and networking, and invests resources in new marine spin-offs and projects. Among the cluster´s key goals are to increase the utilization of fish, aiming at 100% utilization. The IOC has been successful in selecting ambitious entrepreneurs that have contributed to the Icelandic economy. The IOC is considered a best practice when it comes to bringing together different actors and supporting innovation and value creation within the marine sector.

Codland

Codland[3] was founded in 2012 by seven fishing and ocean-related companies. Codland and the founding companies work together and aim at 100% utilization of by-products from traditional codfish processing. The company utilizes biotechnical solutions to create valuable new products from underutilized raw material from the fishing industry, e.g. marine collagen, mineral supplements and fish oil. The company Marine Collagen ehf was founded for further development and processing of collagen and gelatine with special properties. Recent investments in biotechnology make it possible to harvest bioactive compounds from cod to meet the needs of the future.

Genis

Genis hf.[4] is a biotechnology company founded in 2005 in Siglufjörður, North-Iceland. Genis develops, manufactures, markets and sells chitin-based products derived from the North Atlantic shrimp exoskeleton, which is a by-product, under the brand name Benecta, turning waste into high added value products. Genis is an example of a successful company that has created new products from by-products, benefitting a rural town in Iceland.

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2 *www.sjavarklasinn.is/en/*

3 *www.codland.is*

4 *www.benecta.co/uk*

AQUACULTURE

Key information

Total fish farming production in Iceland in 2019 was 34 thousand tonnes, with a value of 135 million USD, whereof over 90% were exported. The main production species is Atlantic salmon. Salmon farming is a rapidly growing industry in Iceland with 27 000 tonnes produced in 2019, compared to 13 500 tonnes in 2018. Arctic char is also an important species, where in 2019 6 300 tonnes were produced, around 60% of the total world production. Small quantities of rainbow trout and Senegal flounder are also produced (SFS, 2020).

Salmon farming in Iceland has faced several challenges. Large investments were made in salmon farming in the eighties but ended in bankruptcy. Ten years ago, entrepreneurs started up salmon production again. Salmon farming is a capital-intensive business and large Norwegian aquaculture companies have invested in the Icelandic industry. Farming of Arctic char has been increasing slowly, with land-based operations using green energy and geothermal water for heating. Arctic char is sold whole gutted or filleted to niche markets, mostly in North America.

Around 500 people worked in the fish farming industry in Iceland in 2018 with wages of 28 million USD, and 80% falling within rural areas in the western and eastern parts of Iceland.

CHALLENGES

Restricted ocean cultivation

Ocean cultivation in open cages (Open Net Pens; ONP) is the traditional way of farming salmon in Iceland. It is controversial due to its perceived environmental impact, e.g. genetic pollution from farmed salmon to the wild Atlantic species, and distribution of parasites and organic pollution. Spatial planning with restriction on farming is necessary to protect ecosystems and biodiversity. Iceland allows ONP farming in two potential farming regions, other regions are closed off to minimize the risk of genetic pollution in the case of escapes. Salmon farming in open cages is the preferred and most profitable farming method commercially available, but with considerable uncertainty and challenges. There are some environmental and economic risks associated with this method, e.g. escaping (genetic pollution), nutrient and chemical pollution, salmon lice infections and naturally occurring pathogens.

Risk assessment

The Icelandic government requires two types of risk assessment to be made before production licenses are granted. A risk assessment considering the risk of escapee's effects on the genetic robustness of native Atlantic salmon is required. The second assessment considers how much maximum allowable biomass (MAB) can be farmed within a location without irreversible environmental changes. Risk management is an integral part of future development of salmon farming in Iceland. The risk assessment must be built on solid data and a scientific basis. Figure 3 shows restricted areas, marked red, and areas open for ONP farming of salmon.

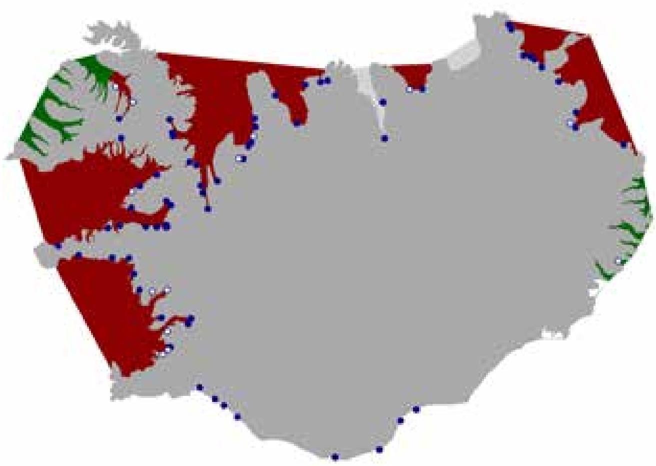


Figure 3.
Areas around Iceland open for salmon farming marked green and restricted areas marked red. Dots mark rivers that are under visual (white) or genetic (blue) monitoring for escaped farmed salmon (Marine and Freshwater Research Institute, Iceland).

OPPORTUNITIES

New production technologies

Recirculation Aquaculture Systems (RAS) for land-based farming could become promising to help reduce the environmental and economic pressures of ONP farming. Today, smolts are raised up to 200g before being released to the ONP, where they are raised to around 5-7 kg. Significantly larger smolts reared on-land, up to one kg could be beneficial as the RAS system offers improved environment control over ONP.

Land-based RAS smolt production has the potential to reduce cultivation time in ONP for up to eight months (PwC, 2017) and requires considerably less fresh water than traditional hatcheries. This would require considerable investments in technology and energy for pumping, cleaning and heating. The cost of land-based production is considerable, and the profitability of land-based production is questionable, as is the availability of production areas on land. Currently RAS farming to commercial slaughter size is only a viable option if the product can be sold to high paying markets.

Secondary processing of salmon

Today, salmon is mostly exported from Iceland head on gutted (HOG) for further processing. But future "smart" secondary production factories could make ready-to-eat production economically feasible, giving more added value to the Icelandic salmon industry. Filleted salmon will reduce export cost and allows processing of side products that are currently exported; cut-offs, bones and heads, as well as reducing the carbon footprint.

One company, Oddi hf.[5], in Vesturbyggd has started up secondary processing of salmon for export, but the company is already one of the leading whitefish processing companies in the Westfjords. Newly slaughtered fish from Arnarlax [6] in Bildudalur is purchased, filleted (pre-rigor) and packaged for niche markets.

Future aquaculture farming systems

Land-based farming in RAS systems would provide more control over the farming conditions but has its limitations. Arctic char has been cultivated in land-based farms for many years, but large-scale on-land salmon cultivation is still being developed. Closed Containment Systems (CCS) could solve many of the current challenges, making farming in fjords less controversial. Offshore aquaculture, if successful, will be a game changer and may potentially open a plethora of farming areas across the world's oceans. If successful, there will not be the same need for access to sheltered fjords for salmon farming, meaning the competitive advantage of the Norwegian and Icelandic coastline for salmon farming will not be the same.

Success story

Salmon farming in Iceland's Westfjords

The Westfjords in Iceland are a region that has experienced negative rural development with a declining population. However, over the last years the number of inhabitants in the area has risen, due to salmon farming activities. The salmon farming and related businesses have driven positive developments and strengthened settlements in the region. The Westfjords stand out in production of farmed salmon in Iceland with income from employment in the salmon farming as 30% of the total and has increased seventeen-fold from 2008 to 2018 (Byggdastofnun, 2019). However, there are many challenges that face salmon farming in the region, including cold environment, possible drift ice, sea lice and risk of genetic pollution of wild salmon.

[5] *www.oddihf.is*

[6] *www.arnarlax.is*

MOVING FORWARD

Future aquaculture strategy

For the salmon farming sector, a public strategic vision is vital, formed in collaboration with the industry and relevant stakeholders. To maximize future value creation within Icelandic aquaculture, setting realistic goals is important, together with action plans to achieve the goals. Ensuring the necessary infrastructure supporting the aquaculture industry is important. A public strategy for the salmon farming industry should be set and implemented. The government and local authorities should organize spatial planning for ONP farming and set goals to maximize sustainable value creation, maximizing productivity and lowering costs, both financial and environmental. Iceland should continue to build up a successful aquaculture industry to strengthen the country's economy. Uncertainty and lack of direction will be costly and could harm future value creation.

Aquaculture farming collaboration

Structuring clusters for supporting the aquaculture industry and fostering collaborations should be a priority. Lack of collaboration between salmon farmers is considered by many stakeholders as one of the main threats to future prosperity of the salmon farming industry in Iceland. Disease prevention starts at the farm level. Information sharing among farmers and with veterinary services can help prevent introduction of disease and accelerate control of outbreaks. Basic biosecurity measures are well established and should be implemented in aquaculture. Adopting biosecurity between farms is essential, so diseases don't spread between farms. Sharing information between farmers and collaboration is key to profitable and environmentally friendly business.

Deployment of larger smolts by RAS

Salmon farmers are planning to produce a larger share of the biomass on land in modern RAS farms. This system facilities provide ideal condition for stainable biomass growth by using more controlled environment; by water temperature, nutrition levels and fish health. By larger smolts, up to 1000 gr., the farmer will reduce the time farming time in ONP from 16-22 months down to 10 months, increasing resilience towards viruses and lice problems. Norwegian authorities have repealed the maximum smolt size restriction to stimulate this development (PwC, 2017).

Genetic pollution

Farming in ONP is controversial for environmental reasons and the risk of genetic pollution for wild Atlantic salmon. The Marine & Freshwater Research Institute of Iceland is responsible for giving scientific recommendation for salmon farming in ONP, by risk assessment. Interest are immense for economic and environmental reasons, so quality data and information on which this risk assessment is built on are of vital importance. The industry and authorities should ensure reliable and secure data and information to build on for future decision making and planning. Innovation and development in countermeasure methods (using larger smolts, eliminating early maturity, using sterile salmon in farming and more) should be considered and incorporated into decision making and risk assessment.

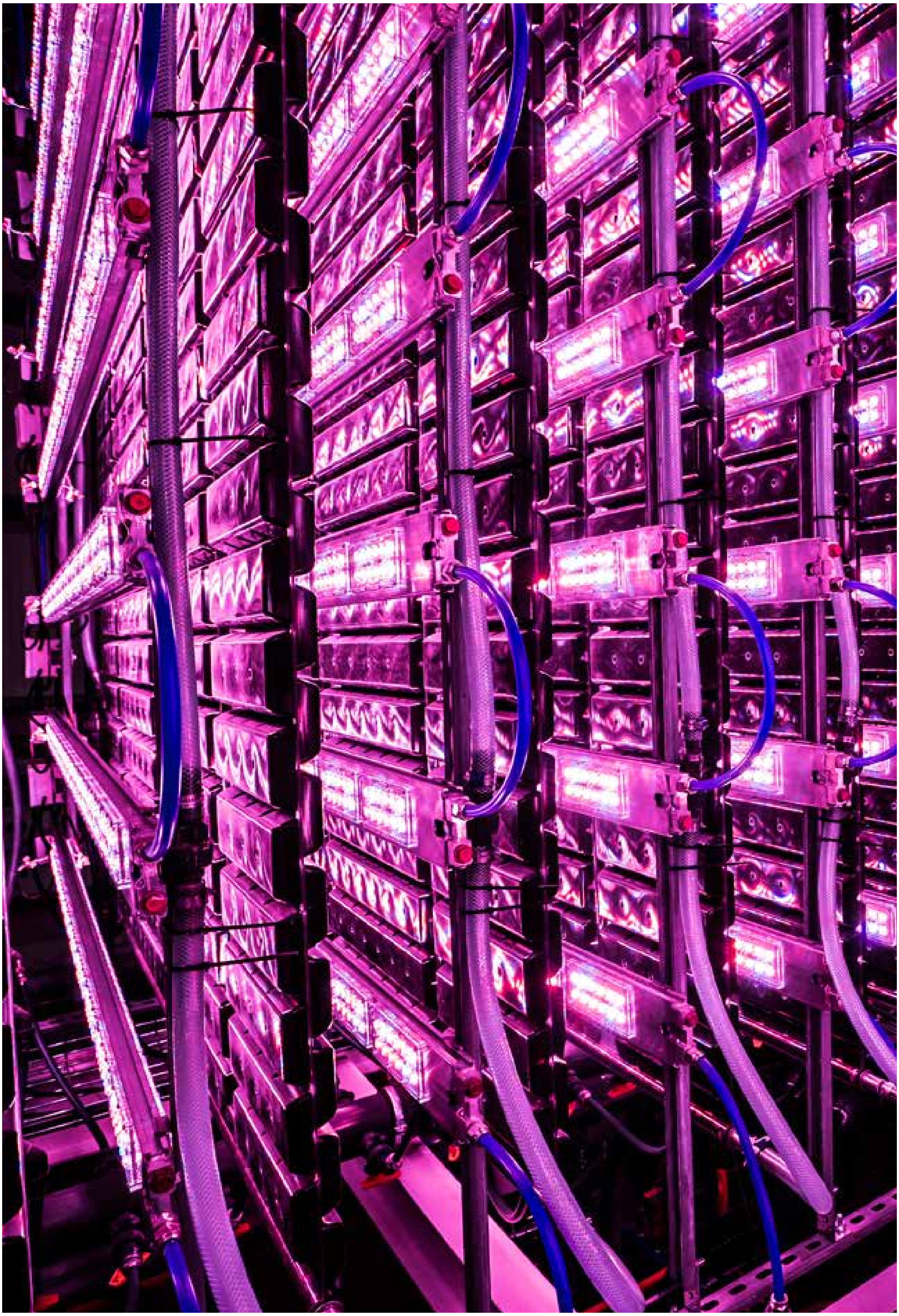
Fish farming for the local economy

Fish farming in Iceland can be a prosperous business in the future offering value creation and increased export and strengthening rural regions with improved living standards. It is important to secure the positive economic impact on the rural municipalities which are in need of improved economy to reverse the decline in population.

Success story

Senegal flounder production at Reykjanes

Stolt Sea Farm produces Senegal flounder in land cages at Reykjanes peninsula in South West Iceland. The production is at 500 tonnes a year but with plans to produce 2 000 tonnes annually. The conditions at Reykjanes peninsula for farming are ideal, using surplus energy from a geothermal electric powerplant to heat up its aquaculture water. The powerplant uses saltwater from wells for cooling its generators which is subsequently pumped directly to Stolt Sea Farm at ideal temperature for farming, around 20 °C. Senegal flounder is an in-demand product on EU and US markets, with cultivation time around 16 months. The fish is exported fresh, with a guarantee of 16 days self-life (Guðmundsson G. , 2019).



VAXA microalgae cultivation facilities in Iceland (*https://www.vaxa.life*). Photo: Pétur Gunnarsson.

ALGAL BIOMASS

Regional key information

In Iceland, macroalgae (seaweed) are mainly wild harvested. It is estimated that over 50% of the algae biomass in Iceland is growing in the fjord of Breiðafjörður and the total number of species that can be harvested counts over one hundred. The main species currently harvested are ***Ascophyllum nodosum*** (about 20 000 tonnes/year, half of the maximum allowance), ***Laminaria digitata*** (< 5 000 tonnes/year) and ***Laminaria hyperboria*** that are dried and grinded to seaweed meal which is then sold as fertilizer or exported for alginate production. Other seaweed species are harvested to a lesser extent e.g. ***Saccharina latissima*** (ca 50-70 tonnes), ***Palmaria palmata*** (ca 10 tonnes), ***Alaria esculenta, Fucus vesiculosus, Desmarestia aculeata, Devaleraea ramentacea*** and ***Fucus serratus***. These are mainly dried and sold as food. Seaweed cultivation in Iceland is still at its incipient stage and is mainly done on lab scale. Several companies are experimenting with cultivation of differenct species, such as ***Schizymenia jonssonii*** and ***Saccharina latissima.***

Cultivation of microalgae is a growing industry in Iceland. There are currently four companies with products on the market: cultivating blue-green algae for cosmetics, ***Haematococcus pluvialis*** for astaxathin and ***Nannochloropsis spp.*** for omega-3 fatty acids. There are also companies experimenting with cultivation of ***Nannochloropsis gaditana, Chlorella vulgaris*** and ***Spirulina***. Estimation of biomass and value is difficult as there are no official published statistics on microalgae.

CHALLENGES

Macroalgae – Main challenges related to increased value and improved utilization of macroalgae include: (1) Wild macroalgae are a limited resource and an important part of the ocean ecosystem. Based on the precautionary approach, the advised harvest is relatively low, or a maximum of 3% of the biomass. (2) The legal framework around cultivation and integrated multi-trophic aquaculture (IMTA) systems is not clear, and this gray area causes uncertainty for investors. (3) Some macroalgae have high concentrations of inorganic arsenic, iodine and/or heavy metals. Monitoring of potentially undesirable compounds in edible seaweeds is needed. Official safety limits have not been published. (4) More knowledge is needed on the effects of macroalgae and macroalgae ingredients on the human body and effects on health. Public awareness and knowledge of the beneficial qualities of macroalgae regarding nutrition and sustainability is lacking. (5) More knowledge is needed on the impact of harvesting techniques and post-harvest handling on the quality and stability of macroalgae.

Microalgae – The main challenges identified related to microalgae include the following: There are (1) complications regarding registration of products on different markets. (2) More support is needed for basic research and for fast growing companies. (3) There are high salary costs compared to competing countries and (4) difficulty recruiting skilled specialized employees.

OPPORTUNITIES

Macro- and microalgae have high economic potential as feed, food, ingredients in food and on supplement and cosmetics markets. Further processing of algae into these categories increases the value greatly, i.e. the price of spices from macroalgae is about 100-fold from that of dried macroalgae meal. Price of specific active compounds from algae sold into food supplements and/or pharmaceutical markets is much higher and in demand.

Iceland is known for its pristine nature and ocean as well as its harsh environment, both responsible for a uniquely strong and pure macroalgae resource which is particularly rich in bioactive ingredients. The possibilities for increased harvesting of wild macroalgae is however limited. The greatest long-term opportunities for increased value and utilization of macroalgae lie in cultivation.

Experimental macroalgae cultivation has started in Iceland in connection with salmon farming in a so called integrated multi-trophic aquaculture (IMTA). It offers opportunities in sharing of existing fishing boats, utilization of excess nutrition, creates employment and value in coastal communities. Other opportunities are in cultivation of macroalgae on land using seawater from boreholes, providing clearer sea (e.g. less epiphytes) and more stable conditions.

Commercial microalgal cultivation, especially for low prize products like biomass for food and feed, is often done in sunny, southern countries in open ponds due to free energy (sun). However, disadvantages are low control of growth conditions (light, temperature, nutrients) and high possibility of contamination. Controlled growth in bioreactors is preferable because conditions can be optimized for biomass growth and compound production for each strain, as well as drastically reduce contamination. For microalgae cultivation in the north, closed photobioreactor systems are required. Iceland is in many ways optimal for growing microalgae due to its pristine environment and resources such as relatively inexpensive green energy (geothermal, hydropower), cool environment and cold fresh water used to cool growth lamps / LEDs of algal bioreactors. It offers possibilities for synergetic effects i.e. using inexpensive carbon dioxide from geothermal powerplants to grow algae resulting in high utilization of land per kg biomass. Additionally, Iceland's extreme environment offers opportunities to discover and utilize novel algal strains to produce high value products. The potential use of microalgae is being investigated in many ways in Iceland including supplementing fish feed with microalgae cultivated in aquaculture wastewater (Matorka[7]), isolating microalgae from the environment for future screening for bioactive compounds (BioPol[8]) (Capasso & Klitkou, 2020) and producing natural blue food colors from thermophilic microalgae (Matís[9]).

Best practice

Capturing CO2 to grow microalgae

The Blue Lagoon[10] is a spa and cosmetics company established in Iceland in 1992. In their line of cosmetic products, the company uses algal biomass and algal ingredients. Algae contribute to carbon sequestration by converting CO2 into biomass and oxygen gas (O2). To facilitate faster growth, the algae are fed on non-condensable exhaust gas rich of CO2 from a nearby geothermal powerplant. Even though this exhaust gas has high (> 2%) concentration of H2S (detrimental to most plants), it can be used in this algal cultivation without any pre-treatment. A key element in this is that the algae strain was originally isolated from the same geothermal environment and has thus adapted to such conditions. The cultivation media used (geothermal seawater) is obtained after a large part of its thermal energy has been extracted for energy harvesting at the powerplant. The company's approach provides a model of how to turn otherwise unused geothermal streams into biomass while lowering the CO2 green-house gas concentration.

[7] www.matorka.is

[8] www.biopol.is/efni/english

[9] www. matisiceland.org

[10] www. bluelagoon.com

MOVING FORWARD

Life sciences education on algae and their utilization needs to be strengthened. Establishing co-operation between the Arctic countries on algae education could be beneficial. At the same time, there is need for increased participation of universities and public research institutions in research and experimentation on algae, including:

- Mapping of habitats of macroalgae, recording of species and monitoring of their development. Studies to investigate which areas would be most suitable for cultivation for each species.
- Research and monitoring of macroalgae composition. Is the content of macroalgae in Iceland/the Arctic different from substances in macroalgae that grow in warmer seas? Are there undesirable substances in macroalgae and in what quantities are they? Risk-benefit analyses are needed to evaluate health risks related to macroalgae consumption.
- Research and experimentation on cultivation of macroalgae from spore stage for development of the strongest and healthiest breeds for cultivation.
- Research on processing and storage of macroalgae. Different processing methods may apply depending on where the cultivation takes place, i.e. wet or dry processing depending on energy prices.

Harmonization in legislation on macro- and microalgae utilization, as well as on the main market areas would be helpful. Quality standards for macroalgae products are needed as well to harmonize lists of ingredients/components and promote traceability and transparency.

Macro- and microalgae cultivation is a new industry in Iceland and in development. Public involvement is needed, especially regarding the health, environmental and societal effects it can have. Research on cultivation and cultivation techniques (such as monitoring systems, automation and equipment) are expensive and require support. Investment funds, both public and private, should be established to support entrepreneurs and companies working on the cultivation and utilization of algae.

European and USA markets for macro- and microalgae products are in their infancy. They are however expected to grow rapidly in the coming years. Consumer environmental and health awareness will play a significant role. As consumer knowledge grows on the health benefits of algae and the positive environmental impact of their cultivation, markets can be expected to grow.

From the production at Biotep in Tromsø. Photo: Lars Åke Andersen/Nofima.

2. NORWAY

INTRODUCTION

Norway is a port nation rich in living marine resources. The large quantities of fish in Norwegian waters have historically yielded food, work and income to Norway. Today, the employment in the Norwegian marine bioeconomy makes up a small share of the total employment. However, the productivity is high and so is the socioeconomic impact. Especially the productivity in fishing and aquaculture has peaked in the last ten years and the value added has increased (Capasso & Klitkou, 2020). The Norwegian bioeconomy strategy is very broad, targeting a range of areas relating to the use of renewable biological resources. An overall aim, however, is that the national focus should lead to increased value creation and employment, reduced emission of climate gasses, as well as more efficient, profitable and sustainable use of renewable biological resources. In the government's national bioeconomy strategy from 2016 (Nærings- og fiskeridepartementet, 2016) there are three principles that should be applied in the development of the bioeconomy.

- 'Food first' is highlighted as a top priority as the population's need for food is of paramount concern.
- Resources should be used and re-used in an efficient manner.
- The use of resources should be profitable.

One of the main focus areas for increased growth is a more efficient and sustainable utilization of the resources by minimizing waste and increasing the use of by-products from the different productions. For the blue bioeconomy, increased production and extraction from the sea is seen as a potential for growth. The harvesting potential from the most commercially important stocks is considered to be more or less fully utilized. The opportunities are therefore related to harvesting of low-trophic species not utilized today, increased aquaculture production, including new species, and increased utilization and access to by-products.

MARINE FISHERIES

Key information

The most important species in Norway in terms of value is the cod. In 2018 the value from this species made up for around 44 % of the total export value of marine fisheries. In terms of volume, the most important species are mackerel and herring, together with cod. The last main sector is shellfish, consisting of shrimps and crabs.

As a result of the national bioeconomy strategy of promoting increased utilization of renewable biological resources, the strategy for increased value creation from marine by-products was published in 2019. Traditionally, Norway has been a raw material supplier rather than a processing country within the seafood industry. Good access to raw material and labor shortages have built up under this tradition. This also means that a large proportion of the by-products are exported out of the country and that there are no Norwegian estimates of the utilization rate for these. However, the by-products landed in Norway are registered in the statistics and the utilization rate can be measured.

Table 2 shows the volumes of catch, available by-products and by-product utilization for whitefish, pelagic species and shellfish in Norway in 2018. These are estimates published yearly based on available statistics from both public and private sources. In 2018, 82% of the by-products were utilized, which is the highest utilization rate measured so far.

Table 2. Volumes and utilization of available by-products (tonnes) in 2018 broken down into different sectors.

	Whitefish	Pelagic	Shellfish	Total
Catch, tonnes	756 000	1 296 000	52 100	2 104 100
Catch, value (million USD)	1 493	790	230	2 512
Available by-products	320 000	205 000	10 800	535 800
Utilization	188 300	205 000	3 900	397 200
Utilization rate	59%	100%	36%	74%

Richardsen, Myhre, Nystoyl, Strandheim & Martinussen, 2019 and Statistics Norway. Currency 8,1338 NOK/USD

Whitefish: Cod, haddock, saithe, ling, cusk, redfish and catfish. The by-products from whitefish consist of trimmings/backs, melke (milt), roe, gut, liver and heads. Heads count for the biggest part of unutilized rests, thereafter gut, liver and roe. Most of the unutilized by-products in this group come from cod trawlers and the bigger long liners. These vessels do not have the tradition of utilizing the by-products, but rather throw them back into the sea. In 2018, it was estimated that 93 % of the unutilized by-products came from this group. By-products that are brought ashore are more or less fully utilized.

Pelagic fish: Herring, mackerel, blue whiting and capelin. Most of the mackerel is exported as whole, frozen fish, meaning that availability of the by-products in Norway is low. Most of the available by-products from the pelagic fisheries come from herring. In 2018, around 65-70 % of the herring landed was fileted in Norway.

Shellfish: Shrimps, snow crab, king crab and crabs. Shell from shrimps is the dominant by-product in this group.

CHALLENGES

At-sea processing and utilization of by-products

Profitability is one main obstacle for trawlers to effectively utilize by-products. The market value of these products is too low, and their valorization is associated with extra costs instead of increased profitability. There are also other challenges, like limited onboard storage capacity and lack of technological solutions that hamper utilization on these vessels. Especially the older vessels do not have the technology to produce oil and meal and freezing of this unprocessed raw material is not considered a feasible alternative among the shipowners. Capacity relates to high vessel quotas and days at sea, making the vessels prioritize the high value main product instead of keeping the residuals. (Svorken, Hogstad, Esaiassen & Nostvold, 2020).

Limited access to raw materials and markets, regulatory environment

Among companies in the marine ingredients industry, access to raw materials and the market is mentioned as the most challenging. Access to raw material relates to freshness, but also uncertainty among regulations. The latter is especially relevant for the ones that depend on raw materials from novel biomass/species. The market challenge is described in more detail in chapter 6.

The regulatory framework is also a challenge as it often appears too difficult and complex. The Novel Food Regulation from 2018 (EUR-Lex, 2020) is an example of this. This regulation has created uncertainty as some applications, for example enzymatic hydrolysis, do not require a Novel Food approval, while other hydrolyzed products fall under the regulation. Such regulations may make it less attractive to participate in developing new products, as it leads to uncertainty related to the companies' potential profitability (Food navigator, 2011; Holle, 2014).

OPPORTUNITIES

Increased utilization of by-products from whitefish

Currently the utilization rate of whitefish in Norway is around 59%. This mainly refers to cod trawlers and some of the big coastal vessels that do not have the tradition of taking care of the by-products even if it is possible to use it in different processes. One opportunity for these vessels are producing meal, oil or silage on board. Many of the newer ones already do this or have positioned themselves to do so and there are at least two ongoing research projects looking into processing and product opportunities for these by-products.

Increased utilization of novel biomass/species

Increased utilization of novel biomass refers to by-products and species that currently are not used in any commercial products. The commercial fishing of mesopelagic species is still in its infancy and the biomass is unexplored as a food or feed source. Commercial Calanus fishing was opened in 2019, and fishing licenses are currently being applied for. Today, there is one company selling products from Calanus in Norway and with increased catch the utilization of this biomass needs to be diversified. Krill is a more established fishery involving three Norwegian companies, with Aker Biomarine the largest. Presently, krill shell and part of the soluble phase are discarded due to lack of economically viable processing technology on board the fishing vessels. Development of more cost-effective process technologies and novel product applications are required in order to obtain maximal value creation and total utilization of the biomass (SFI HARVEST, 2020).

Increased value from side products

Even if the utilization rate of landed by-products is close to 100%, there are still opportunities of increasing the value of this raw material. As Richardsen et al. (2019) showed, processing of silage is the biggest processing category for by-products. However, this is also regarded as a low value product with low price (Svorken, Hogstad, Esaiassen & Nostvold, 2020). Alternative use of already utilized by-products is therefore associated with an opportunity to increase the value. Some examples of this is production of collagen from fish skin (Nofima, 2019) or protein powder from cod heads . Use of new technology for better or different utilization is another opportunity of increasing the value . In the bioeconomy strategy there is also a focus on increased cooperation both within and between value chains.

Success story / Best practice

Support to move from innovation to commercial level

Biotep is a flexible mini-factory located in Tromsø in North of Norway, owned by the research Institute Nofima. The factory opened in 2013 and is designed to be a mini-factory where high technology companies may receive help to transfer promising research from the laboratory into advanced products on a larger scale. In addition to commercial use, the facility is intended for use in research and for educational purposes. At Biotep, companies can test their production on a larger scale without the risk of large investments. From the test production, a cost estimate can be made, and a product prototype can be tested in the market. Companies can perform test productions based on their own processes and technology or collaborate with Nofima. Smaller companies can rent the facility to perform periodical or regular production. One example of this is the company Calanus, producing omega3 oil for the nutrition market from the marine crustacean calanus. For years, the company has used the facilities for producing their product based on a novel resource that has proven to be successful in the market. Biotep shows the importance of public support for making necessary infrastructure available for small scale business to move from the innovation to a commercial level.

The Myre cluster - Full use of resources

Myre, in Øksnes kommune, is with its approximately 2000 inhabitants a large fishing community in Norway. It is the second largest landing site for whitefish and receives fish from both small fishing boats as well as larger trawlers. Along the port of Myre several businesses are established. Myre Fiskemottak AS where whitefish is landed, securers access to the raw material. At Primex Norway AS the fish is produced to fillets and residual raw material is collected. Vesterålen Marine Oljer (VMO) is also located here, producing high quality marine oils. This company also owns Vesterålen Marine Proteiner (VMP) that is producing marine proteins for feed, petfood and human consumption from the residuals collected. Further along the docks, Biomar, a large producer of feed is located, buying the marine proteins for their production. The key to success is described as the willingness to cooperate among the businesses at port as well as internationally, and the cooperation process for development of joint interest. The challenges lie in securing enough raw material and profitability. Sustainability and environmental focus, as well as competence and knowledge building are listed as important guidelines for innovation and further development.

11 *HEADS UP I and II projects (2016-2020). Protein powder from cod heads. Funded by FHF – Norwegian Seafood Research Fund.*

12 *Notably project (2018-2022). Novel cascade technology for optimal utilization of animal and marine byproducts.*

AQUACULTURE

Key information

Aquaculture is one of the biggest export industries in Norway, with an increasing export value each year. In 2018, the total volume produced was 1 466 thousand tonnes, most of which is exported. The export value was around 4,8 billion USD in 2018. About 50% of the production is in Northern Norway. Salmon is the main species, counting for 95% of the volume, followed by trout. There is also some farming of whitefish, like cod, and shellfish, but in terms of volume and value these are insignificant compared to salmon. It is a "mature" and highly industrialized and profitable industry. In the national bioeconomy strategy utilizing by-products is highlighted as an important area for growth. However, for the aquaculture industry the large and stable volumes of farmed salmon have already provided the basis for an industry based on the processing of fresh raw materials from by-products for the extraction of oil and protein hydrolysates, flour or fish protein concentrate (FPC). Blood is actually the only unutilized by-product from this production, which today is sterilized and buried or thrown back into the sea. The potential for growth in the aquaculture industry is rather related to increased production in terms of volume, in addition to increased processing in Norway to retain more of the added value. High labour costs and tariff scaling (the more processed a product is, the higher the tariff rates are) in the EU, as the main market for Norwegian salmon, are however an obstacle to attain added value from the main product (rather than from by-products).

Table 3. Volumes and utilization of available by-products (tonnes) for Norwegian aquaculture.

2018	Aquaculture
Volume, tonnes	1 466 000
Export value (million USD)	4 734
Available by-products (tonnes)	418 000
Utilization of by-products (tonnes)	381 200
Utilization rate	91%

OPPORTUNITIES

New species

The production of new aquaculture species is considered an opportunity in Norway (Akvaplan-niva, 2019). There is some small-scale production of halibut, mussels and char, and in addition several species like spotted catfish and cod are ready for upscaling to commercial production. At present the profitability is low, but improvement in breeding, feeding and disease prevention and treatment are continuously improving.

CHALLENGES

Animal welfare

Animal welfare is an important aspect that is getting more and more attention. Overall, the animal welfare of farmed salmon is good, but there are significant problems related to the effect of sea lice and diseases such as ISA (infectious salmon anaemia) and PD (pancreas disease). Salmon lice are parasitic crustaceans on salmonids (salmon, trout and char), which are found naturally in all sea areas in the northern hemisphere. Since salmon farming largely takes place in open cages along the coast, parasites such as salmon lice can spread freely from farmed to wild fish. Monitoring of salmon lice in the cages shows that the extent is increasing, and that the lice in many cases have become resistant to chemical treatment methods, and new methods such as cleaner fish and fresh water or high temperature bath treatments are introduced. In addition to the problems that the fish experience, it inflicts great losses on the industry both in terms of finances and reputation. Large resources are invested in controlling the lice, but still this is the main challenge for further growth in the aquaculture industry in Norway (Institute of Marine Research (IMR) Norway, 2020).

Feed

Another challenge is related to the access of sustainable feed. The industry is criticized for using too much plant-based ingredients, like soya. There is a general claim for more marine ingredients in the feed, and for sustainably sourced feed. Increased salmon production will therefore require harvesting of more marine ingredients, mainly small pelagics, which might not be available (BarentsWatch, 2017). The availability and usability of new feed ingredients, like krill, calanus, meso-pelagic fish as well as insects and algae are examined. In that regard, studies have shown that microalgae in the salmon feed have a positive effect on the growth rate and health of the salmon (Det Kongelige Norske Videnskabers Selskab og Norges Tekniske Vitenskapsakademi, 2012).

Access to new/more production areas

Finally, access to new and suitable production sites will eventually become a limiting factor for increased salmon production, or aquaculture at sea (Nærings- og fiskeridepartementet, 2015). Two strategies to overcome this challenge are land-based production (The Directorate of Fisheries Norway, 2015) and production off-shore (Nærings- og fiskeridepartementet, 2018). So far however, the challenges related to sea lice is the main limiting factor.

Success story

SALMA

The Norwegian SALMA salmon is known for its good and stable quality and is currently one of Norway's most recognized brands. Back in the mid-1990s, Bremnes Fryseri developed a completely new cooling method in cooperation with the Agricultural University of Norway, which led to reduced stress levels for the salmon and extreme freshness, which in turn resulted in even better quality. The "cold fish" method entails that the fish is first cooled naturally in cold seawater, then processed immediately after it is pulled from the water. This was a revolutionary approach in the 1990s. Today, the method is recognized by the entire aquaculture industry. The first product from this method, cured salmon that resembled a normal cured sausage, was not a success. However, when an American customer exclaimed "Never mind the sausage, where can I get that damn fish?", it became clear that the potential was in the raw material, not the cured salmon. The innovation behind natural cooling was continued, but the product was changed to a pure salmon loin fillet that also managed to achieve a higher price in the market because of the good quality.

Coastal fishery Norway. Photo: Frank Gregersen/Nofima.

Fish farming in Norway. Photo: Frank Gregersen/Nofima.

Success story

Macroalgae as consumer products

Algae production in Norway has spurred the establishment of several small innovation companies producing consumer products based on macroalgae. One example is Sjøsaker (Seastuff) producing spices based on seaweed. The company harvest different kinds of wild microalgae by hand. They are selling their products online, in grocery stores and delicatessens. The company is registered with 11 employees[13]. Another example is Tango Seaweed AS, established in 2018, producing sugar kelp and winged kelp. The kelp is sold both as frozen and dried biomass, while at the same time having a small production of products developed for the local market. The products are small delicate packages of dried kelp and different kinds of nuts flavored with kelp. The company is registered with 12 employees.[14]

13 *teksloseaweed.no*

14 *tangoseaweed.no*

ALGAL BIOMASS

STATUS, OPPORTUNITIES AND CHALLENGES

Macroalgae - Norway has a long tradition of harvesting macroalgae. *Laminaria hyperborea* is the most common macroalgae in Norway, which has the highest abundance of the species in Europe. Also, smaller volumes of *Ascophyllum nodosum* are harvested. The algae are used as raw materials for production of alginate and seaweed meal respectively. Annual harvest has been between 160 000 and 170 000 tonnes in the last years, with a first-hand value of nearly 4,6 million USD in 2019 (Fiskeridirektoratet, 2020a). There is a natural limitation on the volume available for harvesting macroalgae at a sustainable level, and hence the potential for increased harvesting is limited. The greatest long-term opportunities for increased value and utilization of macroalgae lie in cultivation.

Farming of macroalgae is new in Norway, where industrial production started just a few years back. So far, the production is rather modest. Saccharina latissima is the main cultivated species, with 174 tonnes harvested in 2018 at a value of 100 200 USD. This is an increase of 30 tonnes from the previous year, but with a more than doubling in value, indicating an increase in expertise in production and post-harvest handling. There is also a modest production of Alaria esculenta (Fiskeridirektoratet, 2020b). The farming of algae is regulated through the allocation of licenses, to be produced at particular production sites. The first licenses were allocated in 2014. In 2018 there were 23 companies holding 172 licenses, mainly producing in two regions in Norway (Nordland and Hordaland) and currently giving employment to 58 persons.

There is a great potential for increased production. Norway has a long coastline, characterized by fjords and islands and cold water, which provide good conditions for macroalgae production. Water quality is also good in the north, with clear water high in nutrients (Nofima 2020, personal communication).

Estimates (Det Kongelige Norske Videnskabers Selskab og Norges Tekniske Vitenskapsakademi, 2012) indicate that an annual production of 4 million tonnes could be achieved in Norway in 2030 and in 2050 20 million tonnes a year at an estimated value of around 4 billion USD.

As a new industry, the first years of production have mainly been used to build experience in production and harvesting. The producers have faced several challenges. At present, harvesting is time consuming and costly. Technological development is taking place, among others to develop vessels designed and specially equipped for the task. A major challenge is biofouling (on-growing). This occurs in late spring and shortens the growing season, and reduces the quality, and hence yield, sometimes making the products unfit for human consumption. It is however documented that production under the low temperatures at higher latitudes delays the onset of biofouling, allowing a longer cultivation season and higher growth rates in summers. This allows for a later and longer harvesting season in the north. With increased experience and much ongoing research, more of the algae harvested is becoming suitable for human consumption. Still, more knowledge is needed on post-harvest handling to improve the quality and stability of macroalgae. A large increase in production will require heavy investment in drying mills. Producers report high demand for their products and there are several companies that have succeeded in making high value consumer products, like seaweed flakes, seaweed salt and seaweed pasta.

Microalgae - Microalgae cultivation is in development in Norway. There is a biounit in Northern Norway that is at the semi commercial stage. It is a ferrosilicon producer producing microalgae in the spill off steam from an electric power turbine, based on thermal energy and CO2 from off-gases from the metal production. This is run in conjunction with University of Tromsø. Number of several small companies are experimenting with microalgae production; none is yet on a commercial scale. As mentioned in the aquaculture section, microalgae are found to have a positive effect on the growth rate and health of farmed salmon. Hence, there should be a great potential in the production of microalgae.

MOVING FORWARD

The main opportunity in the blue bioeconomy in Norway is the utilization and value adding of underutilized resources, mainly rest raw material from the whitefish sector, increased aquaculture production and increased production of algae.

There is a lot of innovation taking place in established companies and there are new start-ups within biotechnology and algae production and processing. Still, there is a great untapped potential in the development of the blue bioeconomy. Public regulations and facilitation, including economic support schemes and funding of research, are contributing to the realization of the Norwegian blue bioeconomy strategy.

3. NORTHERN CANADA

INTRODUCTION

Over the past decade, important technological innovations have been made in the Arctic's blue bioeconomy. These advancements include new technologies that have enabled marine industries to capitalize on the sustainable and intelligent uses of aquatic natural resources. Through new product development and improved utilization methods, Arctic communities are finding novel ways of balancing food security, economic growth, and the protection of the marine environment. However, the progress being made in the blue bioeconomy is uneven, with some countries and regions making important progress while others lag behind. This is the case in northern Canada, which includes Yukon Northwest Territories, Nunavut, Nunavik and Labrador, where the development of the blue bioeconomy is challenged by a host of social, economic, logistical, and political obstacles. Some of these constraints include the high cost of food production inputs, limited infrastructure (e.g., road networks, ports), absence of supportive legislative, cultural tensions associated with commodifying traditional Indigenous foods, limited innovation, and an over-reliance of raw export. Despite these challenges, northern communities and Federal and territorial governments all recognize the importance of the blue bioeconomy for diversifying local economies and redefining food security in Northern Canada.

FISHERIES

Regional key information

Marine products (e.g., char, turbot, shrimp) accounted for 89% of northern Canada's total export over the period 2008-2018. Since 1988, approximately 3 470 745 tonnes of fish and aquatic products were exported from the Canadian North, adding more than CAD 18 billion, or approximately CAD 600 million per year, to the Canadian economy. The major commercial fisheries in the Canadian North are turbot, shrimp (northern and striped), and Arctic char, that are shipped fresh and frozen as whole and as fillets. Other commercial products include dried fish, fish meal, mollusks, live fish, and other aquatic invertebrates. Among 133 export destinations, the United States, China, Japan, Denmark, and Russia are the leading importers of Northern Canadian seafood. The revenue generated from commercial fisheries has increased slightly in recent years, from CAD 709 million in 2010 to CAD 798 million in 2019. Although exports from northern Canada decreased between 1988 and 1995, exports have since increased and now average approximately 136 719 tonnes/year.

The economic impacts of stemming from Canada's northern fisheries are significant for territorial economies. In Nunavut alone, it has been estimated that the commercial fishery contributes CAD 112 million to GDP, is responsible for the creation of 912 sustained jobs, and has supported the training of over 1 200 Inuit in fishery sectors (Nunavut Fisheries Association, 2019). Although the majority of the direct and indirect economic impacts are realized outside of Nunavut, the fisheries make an important contribution to Inuit communities.

It is also noteworthy that northern Canada exports more than CAD 66.6 million worth of seal products annually (pelts, meat, oils) to 48 countries. Three types of seal products are produced: pelts, meats and oils.

CHALLENGES

Development of a sustainable blue bioeconomy

The development of a sustainable blue bioeconomy in northern Canada faces considerable challenges that effect product development and marketing strategies chosen by producers. Whereas challenges with infrastructure and food security are important issues, marketing access, lack of available raw material, and skilled workforce, and environmental issues are some of the other main challenges.

Food safety and inspection standards

Legislation at various levels of government prohibits or severely restricts local food production, particularly for export markets. The requirement to meet federal food safety and inspection have also restricted the commercial development of these foods for export, which in turn, has limited entrepreneurial development.

Lower cost of imported foods
In Canada a national Nutrition North Canada subsidizes the transportation costs for selected foods shipped from the south to northern communities. The objective of the NNC is help make healthy foods more affordable and accessible to northern communities. As of 2018, 121 northern communities were eligible for subsidized food rates. While well intentioned, the NNC may in some cases create economic disincentives for local food producers, as the subsidized costs of imported foods may be lower than actual costs of food produced in the north.

Infrastructure gaps
Northern Canada, as compared to most other arctic jurisdictions, is subject to wide infrastructure gaps. For Nunavut, the extent of these gaps was recently outlined by Nunavut Tunngavik Inc. in its report, Nunavut's Infrastructure Gap. One example for the marine bioeconomy is Nunavut's fishing industry which does not have a deep-water port in Nunavut where it can offload its product and resupply its vessels, resulting in major economic leakage to other jurisdictions (Greenland and Newfoundland and Labrador).

OPPORTUNITIES

Value-added production
Opportunities for increasing food production and adding value, improving product quality, and increasing food tourism and local markets exist for Northern Canada. This has been demonstrated to some extent in the growth of prepared or value-added foods. Since 2000, the export volume of prepared foods has increased by approximately 18 000 tonnes per year, or an increase of 384%. These exports consist mainly of value-added fisheries products (e.g., farmed char). Identifying special chemical attributes within raw materials and using this for marketing or as extractions of valuable compounds used within the industry may also be an opportunity for growth. Other food innovations could include the introduction of full-utilization methods and new production methods, e.g. using waste products from the seafood to produce medicine or fabrics or seaweed production as both a food source and for CO_2 sequestration.

Access to adjacent resources
In the Canadian fishing industry, northern regions do not have access to the majority of their adjacent commercial resources, as is the case in the south. For bioeconomy development of the fishery in this region and optimizing socio-economic benefits, this is a key opportunity for the future. In Nunavut, for example, the territory only has access to 49% of its adjacent turbot and shrimp quotas, with the remaining held by southern entities, and has the potential to more than double its impact with increased access. Other areas, such as northern Labrador, have even lower access to their adjacent resources.

Potential
Very little of the marine quota makes land fall in northern Canada. For that reason, by-product utilization remains limited. This is one of the major challenges for developing northern Canada's blue bio potential. However, if modest improvements could be made in northern infrastructure, opportunities for northern Canada's blue bioeconomy could be considerable.

Marine production in northern Canada can be characterized by a north to south value chain. This is reflected in the annual export of marine resources from northern Canada to 133 international destinations. Greater attention needs to be directed to the development of a north-to-north (Arctic-to-Arctic) value chain. Increased harvesting and production of marine resources that are produced and sold locally have the potential to alleviate northern food insecurity and contribute to the social and economic development of northern communities.

Best practices

Nunavut Fisheries Association

The Nunavut Fisheries Association (NFA) was established in 2012 to present a united voice for Nunavut's commercial fishing industry to stakeholders and the public at the territorial and federal levels. NFA also supports fisheries and ecosystem science and research activities in the Eastern Arctic, working collaboratively with stakeholders and conducting its own annual research program, all in support of sustainable fisheries development in the north.

The current membership of NFA consists of four Inuit owned companies which hold 100% of the commercial allocations of Greenland halibut (turbot) and shrimp managed through the Nunavut Wildlife Management Board. These companies are: Arctic Fishery Alliance (AFA), Baffin Fisheries (BF), Pangnirtung Fisheries/ Cumberland Sound Fisheries Partnership (PFL/CSFL), and Qikiqtaaluk Corporation (QC). All companies are owned by the HTOs, communities, and/or Inuit of the Qikiqtani region of Nunavut.

At present NFA members have a fleet of five factory freezer vessels operating primarily in the Eastern Arctic and employing approximately 200 individuals, producing over $100 M annually in fish products. Members of NFA are also the owners of the Nunavut Fisheries and Marine Training Consortium (NFMTC), an organization established in 2005 to train Inuit for involvement in the fishing and marine sectors. All members are focused on maximizing benefits for their respective HTAs and communities.

First Inuit-owned company

Torngat Fish Producers Co-operative Society was established in 1981. Its processing facilities are located along Labrador's north coast. The Torngat Fish Producers harvests turbot, Arctic char, brine-frozen snow crab sections, and Icelandic scallops from the Labrador Sea. Once landed and processed, the products are shipped to international destinations, particularly China, Taiwan, and the USA. Baffin Fisheries is the first 100% Inuit-owned company. Baffin Fisheries' quota is used to support the development of local infrastructure and local economic growth.

AQUACULTURE

Aquaculture production is limited in Northern Canada. Currently, there are no commercial aquaculture producers in the Northwest Territories, Nunavik or Nunavut. The most significant aquaculture enterprise is Icy Waters Ltd. which is a land-based aquaculture facility located in Whitehorse, Yukon. Icy Waters Ltd. produces approximately 140 tonnes of Arctic char and ova annually.

CHALLENGES AND OPPORTUNITIES

Distance to markets
Icy Waters is challenged by distance to markets (2 400 km), access to wild stocks to collect mature brood stock, regulatory consistency, and insurance support. This challenge also represents an opportunity for Icy Waters and other potential enterprises in that there is currently limited industry competition. The market indicates potential for industry growth and expansion.

Success story

Icy Waters Arctic char

Founded in 1985, Icy Waters Ltd is considered one of the premier Arctic char farms in the world. It is also one of the world's largest suppliers of Arctic char ova. Icy Waters is a family company operated by five people. Its major products and value-added products include fillets and dressed forms. The company has a year-round operation for dressed or fillet products and its products are available either fresh or frozen. The company processes and ships fresh products within hours of harvest. Its operation is certified through "Best Choice" by the Monterey Aquarium Seafood Guide for Healthy Oceans and the Vancouver Aquarium's "Ocean Wise" program. Ice Waters is a zero-waste operation, as compost created while processing by-products are sold to local dog mushers, poultry, and pig farmers as a high oil food. In addition to recycling waste, this practice reduces the burning of fossil fuels required to ship such food from the south.

ALGAL BIOMASS

Commercial algae cultivation in Canada occurs in regions where sunlight energy is prevalent, temperatures are moderate, and there are ready sources of water and low-cost nutrients. These requirements have typically precluded commercial algae production in northern Canada.

In order to enhance algae production in northern Canada, Pankratz et al. (2017) called for R&D to demonstrate improved crop yields with sustained and consistent growth; more efficient dewatering, processing, extraction and refining capability; cost-effective scalability of related technologies; and reduced energy inputs in the algae production platform." For this to occur, innovations achieved through multidisciplinary and multisectoral collaborations are required.

Given the high capital and operating costs of closed photobioreactor systems, most analysts are skeptical that economically sustainable microalgae cultivation can take place in northern Canada.

FRESHWATER FISHING

The inland fishery in northern Canada accounts for a small percentage of the total freshwater fish harvest but is critical to many Indigenous peoples and in northern and remote communities. The majority (80%) of inland commercial harvesters are First Nations or Métis. Canada's inland fishery produces approximately 28 million kilograms of freshwater fish annually, with a landed value of $67 million. In northern Canada (Northwest Territories) 421.88 tonnes of freshwater fish are harvested annually, accounting for 0.64 million Canadian dollars in annual revenues.

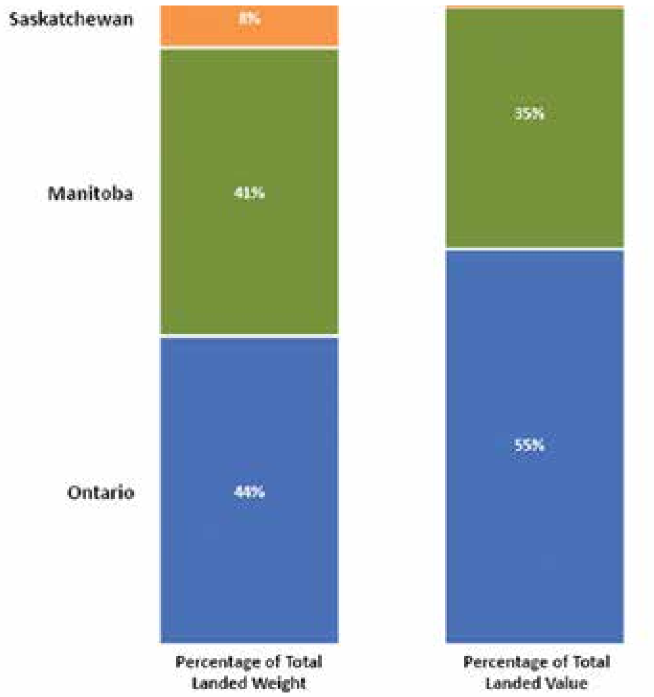


Figure 4. Freshwater landings. Source: Fisheries and Oceans Canada, 2019.

Currently, the United States is the largest importer for Canadian-caught freshwater fish. However, Canada is the largest supplier of Northern Pike in France and of Whitefish in Finland and Sweden and distributes fish products to a total of 14 countries in North America, Europe and Asia.

CHALLENGES

- Transportation and processing costs for freshwater fish are still significant factors in the profitability of harvesting and marketing.
- Inconsistent and unreliable supplies of freshwater fish limit industry growth and market expansion.
- The considerable Asian and Chinese markets are not yet prepared to pay high prices for Canadian freshwater fish.

OPPORTUNITIES

- On-land freshwater aquaculture presents economic growth opportunities in remote and rural communities across Canada.
- The Asian market for freshwater fish is emerging. Freshwater fish is not well recognized in China, but the size of the market and the demands of the population for seafood represent an emerging market opportunity.
- FFMC is currently a significant supplier Lake Whitefish and Whitefish caviar to Finland, and the number one supplier for buyers of Tullibee roe in Scandinavia. The continued development of these European markets, most notably in Whitefish, Tullibee (herring), Pike and Carp roe, could result in increased returns for Canadian fishers.
- The sale of fresh fish lies predominantly in Canadian and U.S. markets (e.g., 25% of total fish sales). Opportunities exist for the expansion of domestic markets and entry into new international markets for fresh fish sales.

MOVING FORWARD/POTENTIAL

A federal panel review of the FFMC offer a number of recommendations for the development of northern Canada's inland fisheries. The report and program recommendations are available (Fisheries and Oceans Canada, 2019).

Best practice

The Freshwater Fish Marketing Corporation (FFMC, Freshwater)

FFMC, Freshwater is responsible for collecting, processing and marketing freshwater fish for approximately 1 600 - 1 700 inland fishers. FFMC was established by the federal government in 1969 with a mandate to:

- purchase all fish offered to it for sale
- increase returns to fish harvesters
- promote international markets for freshwater fish
- increase interprovincial and export trade in fish

FFMC seeks to do this through effective marketing, efficient supply chain management and value-added processing of quality freshwater fish products. FFMC also provides important services to northern communities, such as providing seasonal loans and / or credit advances to fishers at the beginning of each season for new equipment, manages and operates centralized fish packing facilities, provides employment insurance, and helps deliver food, diesel and other necessary supplies to isolated communities.

4. ALASKA USA

INTRODUCTION

The United States Arctic region covers waters off the coast of Alaska including the Arctic Ocean and the Beaufort, Bering and Chukchi Seas and the Aleutian Islands. This region supports rich and productive ecosystems. The Bering Sea supports some of the most important commercial fisheries in the world.[15]

FISHERIES

Regional key information
The Bering Sea ecosystem provides fish and other seafood products that are consumed all over the world. Residents of Bering Sea communities as well as those from communities throughout the West coast and United States interact with the Bering Sea ecosystem through federal and state commercial fisheries. The Federal fisheries of Alaska are managed by the North Pacific Fishery Management Council, the State of Alaska, and the National Marine Fisheries Service (NMFS). The largest fishery is the Federal groundfish fishery, which primarily targets pollock, cod, and flatfish, along with rockfish and other species. State-managed commercial fisheries in the Bering Sea include salmon fisheries, as well as nearshore groundfish, herring, octopus and squid fisheries. The Council has joint management agreements with the State of Alaska for the Federal crab and scallop fisheries. The Council also has jurisdiction over the Bering Sea halibut fishery, with the International Pacific Halibut Commission (IPHC); the IPHC oversees the biological management of halibut throughout its range in the U.S. and Canada, while the Council and NMFS oversee the allocative management of halibut within EEZ waters off Alaska (North Pacific Fishery Management Council, 2018).

Table 4. Bering Sea commercial fisheries production value and volume in 2018.

2018	Whitefish	Pelagic	Shellfish	Total
Catch, tonnes	824 000	93 000	10 000	927 000
Catch, value (million USD)	2 261	754	173	3 188

Source: Fissel et al., 2019 (Table 5).

By-products from the Bering Sea fisheries such as meal and oil are available mainly for pollock, cod, and sablefish, and by-products are unavailable in significant quantities for other species including flatfish and rockfish. For example, pollock noodles are a recent innovation. The total volume of wholesale (i.e., processed) production from the Bering Sea and Aleutian Islands groundfish fisheries was about 823 thousand tonnes in 2018, and meal and other products represented about 7% of the total volume. This percentage share was about 7% for pollock, 13% for cod, and 12% for sablefish, in 2018.

AQUACULTURE

Finfish farming is legally prohibited in Alaska, and no permitted aquatic farming operations occur in the Bering Sea-Aleutian Islands region (Alaska Department of Fish and Game, 2020).

ALGAL BIOMASS

There are over 500 (and counting) species of seaweeds in Alaska. The three primary species currently grown are Nereocystis luetkeana, Saccharina latissima and Alaria marginata. Kelp farming is in its infancy in Alaska, with farms currently operating near Ketchikan, Craig, Kodiak and soon - Sand Point. Wild kelp harvest for commercial use is a new sector in the state's commercial fishing industry and has helped stimulate interest in kelp farming.

15 *www.arctic.noaa.gov/Fisheries*

FRESHWATER FISHING

Subsistence fishing is an essential part of Alaska's cultural heritage with thousands of participants each year. According to data from Fall et al. (2019), the majority of the recent subsistence harvest of salmon in Alaska occurs in the Arctic region. In 2016, the largest subsistence harvest of Chinook salmon occurred in the Kuskokwim Management Area, followed by the Yukon Management Area. The largest subsistence harvest of sockeye salmon occurred in the Bristol Bay Management Area (followed by the Glennallen Subdistrict, which is south of the Arctic region). The largest subsistence harvest of coho salmon occurred in the Kuskokwim Management Area, followed by the Norton Sound-Port Clarence Management Area. The largest subsistence harvest of chum salmon occurred in the Yukon Management Area, followed by the Kotzebue District. In 2016, the largest subsistence harvest of pink salmon occurred in the Norton Sound-Port Clarence Management Area, followed by the Yukon Management Area.

Pamiilaq Crew in Utqiagvik, Alaska after a successful fall whale hunt. Photo: JakyLou Olemaun.

About ICC

Founded in 1977 by the late Eben Hopson of Barrow, Alaska, the Inuit Circumpolar Council (ICC) has flourished and grown into a major international non-government organization representing approximately 180 000 Inuit of Alaska, Canada, Greenland, and Chukotka (Russia). ICC is one of six Permanent Participants at the Arctic Council and holds Consultative Status II at the United Nations.

To thrive in their circumpolar homeland, Inuit had the vision to realize they must speak with a united voice on issues of common concern and combine their energies and talents towards protecting and promoting their way of life. The principal goals of ICC are, therefore, to strengthen unity among Inuit of the circumpolar region; promote Inuit rights and interests on an international level; develop and encourage long-term policies that safeguard the Arctic environment; and seek full and active partnership in the political, economic, and social development of circumpolar regions.

5. INUIT FOOD SECURITY, FOOD SOVEREIGNTY & THE BLUE BIOECONOMY

INUIT CIRCUMPOLAR COUNCIL

Achieving food security will require holistic approaches, Inuit innovation, and depends on the capacity to mobilize governments, regional stakeholders and community residents to address the challenges faced and to move toward food sovereignty. To achieve food sovereignty there is a need for Inuit to hold authority to manage our living resources (Inuit Circumpolar Council, 2018).

Inuit hold a strong spiritual connection to the animals, land, water, and air. Hunting, fishing, and gathering are important for clothing, building materials, art, medicine, spirituality, self and community identity, health and wellness, connecting to the land, and all of the other components that make up food security. The reciprocal relationships held between Inuit and the environment in which they are part [is] a source of happiness (Inuit Circumpolar Council Alaska, 2020).

Inuit are a maritime people and we have relied on the ocean to sustain us for millennia. The sustainable use of our lands, waters and resources is at the heart of our traditional economies of hunting, fishing and harvesting. Sustainable development, including a blue bioeconomy, is not a new concept for Inuit. Our economy has always been blue.

Inuit have always relied upon a traditional economy that continues to evolve today, where our values, including respect and sharing, naturally embody sustainable development. Inuit value every part of the ecosystem that sustains us -- from the animals that nourish our bodies and our spirits, to the seal skins and animal fur that keeps us warm, to the seal and walrus skins that cover our umiat, to the walrus and whale liver membranes that cover our Inuit drums, to the tendons that provide the threads to hold everything together.

Our traditional economy is tied to the environment. This is an intimate and profound relationship that encompasses economic, social, cultural and spiritual dimensions. Our sustainable development practices are embedded in our language, cultures and overall social fabric.

A healthy ecosystem depends on the health of the animals and plants we rely on, which in turn affects the health of our people and the different states of land, sea, and air as well as the cultural fabric held together by language, cultural expression, and social integrity. Within Inuit knowledge, it is impossible to separate some of these relationships. When we discuss Inuit food security, we are talking about the interconnection and the relationships between everything within the ecosystem we call home (Inuit Circumpolar Council, 2015).

To better understand the changing Arctic environment, a holistic view is needed, one which can only be achieved by bringing together Indigenous Knowledge and science. The Inuit knowledge system continues to grow and is relied upon every day. It holds its own methodologies, evaluation, and analysis processes that provide a pathway for holistically understanding the Arctic.

ICC defines Indigenous knowledge as "a systematic way of thinking applied to phenomena across biological, physical, cultural, and spiritual systems. It includes insights based on evidence acquired through direct and long-term experiences and extensive and multigenerational observations, lessons, and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation."

Jakylou and her cousins preparing to serve the community after a successful whale hunt. Photo: JakyLou Olemaun.

However, as governments at all levels have laid claim to Arctic resources, our "sovereign rights and Indigenous management systems have too often been undervalued or ignored. Oftentimes, there is a lack of knowledge about what Inuit food security is. Many assume that it is just about nutrients, calories, and money, rather than about culture, spirituality, Inuit knowledge, and Inuit rules/laws/practices (Inuit Circumpolar Council Alaska, 2020)."

The quote above emphasizes important points raised by Inuit in our new report, ***Food Sovereignty and Self-Governance: Inuit Role in Managing Arctic Marine Resources.*** The report focuses on what impedes or supports our food sovereignty through a co-management comparison between Alaska and the Inuvialuit Settlement Region in Canada. It links Inuit Food Sovereignty to holistic and adaptive management strategies and recommendations that can ensure the food security, health, and well-being of Inuit throughout the Arctic for generations to come.

Inuit management practices have been relied upon for thousands of years and continue to guide our decisions today. These decisions have always been sustainable and reflect our responsibility to be the best stewards of our lands. Today, this requires there to be meaningful roles for Inuit in the management of our resources.

Within Indigenous Knowledge is an ecosystem approach inherent with the way we monitor, the questions we ask about the environment we live in, and how we manage our behaviour within our environment. Because the blue bioeconomy relies on healthy ecosystems, the health of these ecosystems needs to be monitored and assessed.

A changing climate will have implications for the future development of this economy. Inuit food security is an important indicator of ecosystem health and a major determinant of health – physical, spiritual and cultural. Without Inuit food sovereignty, we cannot achieve Inuit food security.

Food Sovereignty and Self-Governance: Inuit Role in Managing Arctic Marine Resources[16]

Inuit Food Security

In our report we define Inuit Food Security as "the natural right of all Inuit to be part of the ecosystem, to access food and to care-take, protect and respect all of life, land, water, and air. It allows for all Inuit to obtain, process, store, and consume sufficient amounts of healthy, nutritious, and preferred food — foods Inuit physically and spiritually crave and need from the land, air, and water. These foods provide for families and future generations through the practice of Inuit customs and spirituality, languages, knowledge, policies, management practices, and self-governance. It includes the responsibility and ability to pass on knowledge to younger generations, the taste of traditional foods rooted in place and season, knowledge of how to safely obtain and prepare traditional foods for medicinal use, clothing, housing, nutrients and, overall, how to be within one's environment. It means understanding that food is a lifeline and a connection between the past and today's self and cultural identity. Inuit food security is characterized by environmental health and is made up of six interconnecting dimensions: 1) Availability; 2) Inuit Culture; 3) Decision-Making Power and Management; 4) Health and Wellness; 5) Stability; and 6) Accessibility. This definition holds the understanding that without food sovereignty, food security will not exist."

Inuit Food Sovereignty

Food sovereignty is defined as the right of all Inuit to define their own hunting, gathering, fishing, land, and water policies; the right to define what is sustainably, socially, economically, and culturally appropriate for the distribution of food and to maintain ecological health; and the right to obtain and maintain practices that ensure access to tools needed to obtain, process, store, and consume traditional foods. Within the Inuit food security conceptual framework, food sovereignty is a necessity to support and maintain the six dimensions of food security.

[16] *ICC Alaska 2020. Food Sovereignty and Self-Governance: Inuit Role in Managing Arctic Marine Resources. Anchorage, AK, page 17.*

6. MARKETS FOR MARINE INGREDIENTS

One of the most highlighted areas for growth in the blue bioeconomy in the Arctic is the utilization of by-products as marine ingredients. In this chapter we focus on the markets for ingredients based on marine raw material. The chapter is based on a study of the Norwegian marine ingredient industry in 2018, together with more general knowledge about the different markets. The opportunities for marine ingredients are often described as enormous compared to what is currently achieved (Richardsen, Nystoyl, Strandheim & Viken, 2015). There seems to be a lack of knowledge, bridging the gap between expectations and factual market knowledge, meaning that there is little market information available for those that seek to profit from these opportunities. This may be an important reason for the limited development in this part of the marine industry, compared to the development of the agricultural by-product industry.

APPLICATIONS OF BY-PRODUCTS

By-products from fisheries and aquaculture are used in different productions. Some are used directly for human consumption, but most are processed in some way and used as marine ingredients. Figure 5 shows the main processing methods of fisheries by-products in Norway.

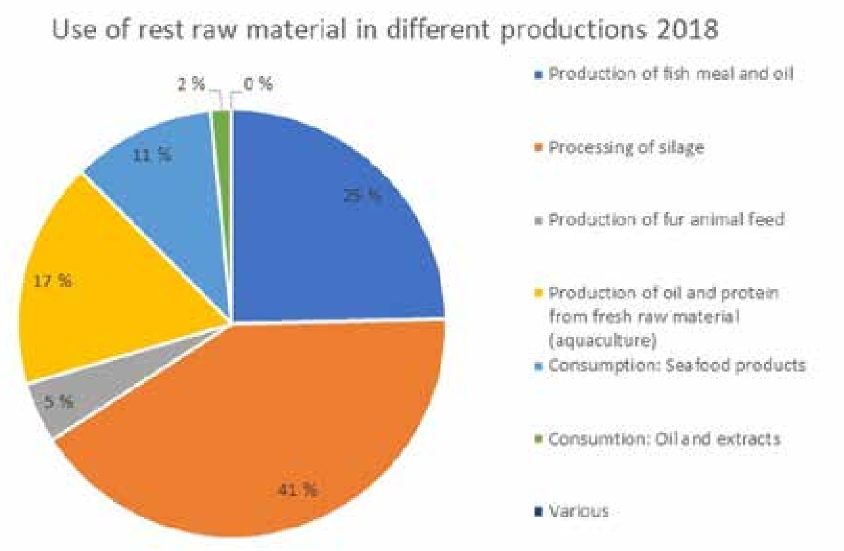


Figure 5.

The use of by-products in Norway in 2018 by main processes, based on product weight.

The most important side stream products from fisheries are fish meal, silage and oil. There is also production of functional food products, cosmetics, food supplements and pharmaceuticals (Richardsen, Myhre, Nystoyl, Strandheim & Martinussen, 2019). The volumes of these are small compared to the bulk products, but the products are in the high value end of the market.

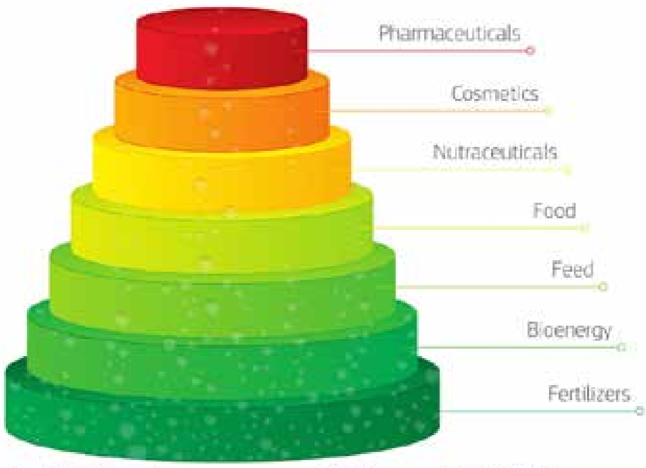
It is difficult to estimate the exact value created from marine by-products. Some of them are used by the fish processors themselves, while some are sold to what is called the marine ingredient industry. Roughly, the Norwegian marine ingredient industry consists of 60 companies, either producing ingredients from marine by-products or using marine ingredients (from by-products) in a finished product. In Iceland, the number of such companies is around 40. The Norwegian marine ingredients industry is characterized by great diversity and large differences between the companies regarding factors like source of raw material, ownership, size and market (Pleym, Svorken & Vang, 2019). As this industry is very dynamic and difficult to study, it is also difficult to estimate the value creation. However, in 2017 there was made a rough estimate of around 2,6 billion

NOK (320 million USD).[17] This study also showed that the total value creation from this industry increased by 26% from 2014 to 2017, but both the value creation and the profitability vary a lot between the different companies. The profitability is also very polarized. While some struggle to reach an acceptable profitability, others are doing very well (Pleym, Svorken & Vang, 2019). This shows that it is possible to have success with producing ingredients or products based on marine by-products, but not given.

[17] *Large fish producers also producing from by-products were not included in this estimate to get an undisturbed picture of the value creation from the rest the raw material itself.*

MARKET OPPORTUNITIES

According to interviews with the Norwegian marine ingredient industry, market issues are the biggest challenge for these firms (Pleym, Svorken & Vang, 2019). They describe market challenges as access to markets on equal terms (e.g. tariffs, custom handling, certification and legal acceptance in markets) and market competition. The firms also reported meeting unserious business actors, and that they must spend a lot of time educating buyers to develop an understanding of the different product properties. As mentioned, there has been limited research on market opportunities for the marine ingredients, but there are some objective measures of the market accessibility. Figure 6 summarizes different markets/industries according to how easy they are to access, expected volume demands and value.



Products	Time to Market (years)	Product Development costs	Resource Availability	Need for Documentation	Potential Market Value	Skills and Competencies
Pharmaceutical	10-15 (+)	very high	limited	very high	very high	Extensive medical and market
Cosmetic	3-5 (+)	low to high	fair	medium	high	Toxicology and effects
Nutraceutical	3-5 (+)	medium to high	fair	medium to high	high	Nutrition and medicine
Food	2-5 (+)	low to medium	good	medium	medium to high	Nutrition, food science
Feed	2-5 (+)	low to medium	very good	medium	medium to high	Nutrition, animal and science
Bioenergy	2-5	low to medium	very good	low to medium	moderate	Energy
Fertilizers	1-2	low	very good	low to medium	moderate	Agriculture, agronomy

Figure 6. Markets for marine ingredients. Source: Whitaker, Altintzoglou, Lian & Fernandes, 2021.

PHARMACEUTICALS

The potential market value of pharmaceuticals is very high, but difficult to access. First, to produce a pharmaceutical product demands both skills and special competencies, such as all aspects of drug development and clinical trials and market position and knowledge. This takes years to develop and the knowledge is very costly to acquire. Second, in order to get approval as a pharmaceutical the product must go through clinical trials in several phases. Third, pharmaceuticals require high quality ingredients. Volumes may therefore be less important than stability and even performance, but still costly as the quality needs to be secured.

COSMETICS

As there is a global increase in willingness to pay for well-being and anti-aging products, the potential in this market is regarded as high. The products claim to have a cosmetic effect by giving a visual effect on the body. Even though requirements for documentation of effect is not the same for pharmaceuticals, there is a restriction in what kind of claims that are legally accepted in different markets and what must be documented to get market access[18]. Important documentation requirements for cosmetics are level of toxicology, possible non harmful side-effects (i.e. allergies) and statements regarding animal testing. As documentation is often used as a sales argument, there is a growing demand for proof of effect from human trials. Even though the documentation is not as stringent as for pharmaceuticals, developing such products demands both skills and knowledge in dermatological effects, formulation, degree of penetration and toxicology. The cost of developing cosmetics can therefore be anywhere from low to medium high, as it depends on resource and documentation needs.

18 *www.efsa.europa.eu/*


Protein powder from fish heads. Photo: Øyvind Ganesh Eknes/Nofima.

NUTRITION

This category includes all products for the food, feed and nutraceuticals industries. Feed is the lowest value category and nutraceuticals the most valuable of the three.

A. Nutraceuticals

Nutraceuticals are defined as "food or part of food playing a significant role in modifying and maintaining normal physiological function that maintains healthy human beings." (Lipi, Bhaumik, Raychaudhuri & Chakraborty, 2012). Nutraceuticals have high potential market value as increased wealth and education has led to focus on health and quality of life across the globe. Studies also predict high market growth for Omega-3 oil[19].

The cost of developing a nutraceutical is from medium to high, dependent on the need for documentation of claims. Normally it takes 5 years or more to reach the market. Nutraceutical development demands both skills and competencies in nutrition and medicine, competencies that often are expensive to acquire. Further, in order to make health claims a nutrient profile must be developed, that is nutritional requirements that foods must meet in order to bear nutrition and health claims[20]. The EU and USA are important nutraceutical markets and the need for documentation is (relatively) high. In the USA health claims are regulated by "Novel Food Generally Recognized as Safe" (GRAS) and in the EU by the Regulation 1924/2006 on nutrition and health claims made on foods (EUR-Lex, 2020). Health claims on food products in EU are supervised by EFSA (European Food Safety Authority).

In terms of resource availability, there are potentially large amounts of marine biomass that can fit this purpose. However, it varies considerably from country to country how well the raw material is preserved, and how the industry is organized. For instance, a telephone survey of the Norwegian marine ingredient industry showed that sufficient raw material of the right quality (e.g. fit for human consumption, fresh/frozen) is a challenge, as the Norwegian seafood industry to a high degree lacks a system to preserve these biomasses in sufficient quantities. To develop such systems and establish the logistics to transport it will add to the costs of producing it.

B. Food

The food category from rest- and under-utilized raw materials consists of niche food products such as fish tongue, cheeks, skin and stomach, as well as ingredients for food, both dietary and generic foods. As ingredients by-products can be delivered as protein, fat, smell and/or taste enrichers and as thickeners. Producing food from marine by-products is an opportunity that seems to be somewhat overlooked, at least in Norway. According to sources in the food industry, the industry is constantly looking for new sources and ingredients and marine ingredients are interesting as they are perceived as a potential source with additional health benefits (Svorken, Hogstad, Esaiassen & Nostvold, 2020). Producing food demands skills and possibly investments, e.g. if it requires new technology to separate and pack the products. Knowledge about markets and strategies for market penetration is also vital. When providing raw materials as ingredients for food there is also a need for competence in nutrition and food science. Documentation of product content is required, and documentation of processing might also be required. Of all the by-products available from marine resources, less is suitable for food than feed, due to regulations and requirements. Utilization as food or ingredients in food also demands a more complex sorting process, which can contribute to increased costs.

C. Feed

Ingredients for feed is the most common application of marine by-products. The market for feed is generally considered as a high-volume rather than a high-value market. However, there are niches, such as increased interest for high quality feed for pets. Producing products for animal feed (aquaculture and animal husbandry) and pet food markets demands skills in nutrition, both animal and human if the animal is to be eaten, animal science, veterinary medicine, processing and so forth. Large producers of feed buy marine ingredients to use as protein and fat in their products, but also for flavoring and as an odor additive. Depending on the feed market, there are different documentation requirements on food safety, as well as need of clinical trials documenting nutritional value and efficacy. Increasingly there are also requests for sustainability and other certifications. The increase in production of animal protein for human consumption and competition amongst producers of feed, has led to an increase in the production of more sophisticated feed products. This is a result of demands from buyers and a strategy to differentiate in a highly competitive market. Companies which sell the raw material to the feed producers have a considerably shorter time to market. Interviews with some of the Norwegian feed producers and international pet food producers indicate that they want to buy the by-products in an unprocessed state which lowers the value creating potential for the by-product owner.

[19] *www.marketsandmarkets.com/Market-Reports/omega-3-omega-6-227.html*

[20] *www.efsa.europa.eu/en/topics/topic/health-claims*

THE MARINE INGREDIENTS INDUSTRY

The study of the marine ingredients industry in Norway shows that most companies target the nutrition market. The pharmacy market is probably too costly and complicated, while the cosmetic market still seems to be unexplored, even though there is a fair amount of marine resources that may fit this industry, given the right price (Svorken, Hogstad, Esaiassen & Nostvold, 2020; Pleym, Svorken & Vang, 2019). However, high prices for cosmetics do not necessarily mean higher prices for the raw material as the production costs in cosmetics are high. Further, the marine ingredients need to compete with other (existing) raw materials and substances, and there are many competitors with similar products, as the cosmetics market offers a plethora of products.

Most of the companies in this industry describe the global markets as tough (Pleym, Svorken & Vang, 2019). This may be due to limitations within the firms, where human and capital resources may be restrained, but also due to the already mentioned market access aspects. Competition in the market affects the price, which again influences the ability to pay for the raw material. Another challenge may be that it takes a long time before firms reach the commercialization phase. Companies that reported market as the biggest challenge in the marine ingredient industry in Norway were older than five years (Pleym, Svorken & Vang, 2019). This indicates that it is after five years of business that market growth receives attention as a challenge. It seems like the first five years are utilized to develop the physical product and the process for production, rather than focusing on where the product will be sold. This goes against a common innovation principal of failing early to learn and speed up the iteration process, and thereby reduce costs in the long term.

Markets for marine by-products are also diversified across the globe which complicates the value creation, but also poses the ultimate source of opportunities. Competition is fierce and spotting the right opportunity demands a certain investment in knowledge building and time. There are for instance many participants at industry fairs like HiEurope and Vita Foods (Global Nutraceutical event), and just the number of Omega-3 providers is daunting. Choice of market depends on the internal resources of the company and what they are willing to invest in development. The companies buying marine by-products in Norway today are mainly small, which means limited human resources, but may also entail limited capital. The company's resources affect their competitiveness, but ultimately, it's how they deploy the resources they have that's decisive.

Finally, the study of the marine ingredient industry in Norway also indicates that there are challenges to get market acceptance for unique properties in marine ingredients, or that they are better than the competing ingredient. One important question is whether the market has willingness to pay for ingredients with better or different properties than the alternatives from other sources, and if marine properties should be used in marketing. It is also relevant to address the markets importance for volume and quality specifics of the by-products, along with the possibility of flexing between source of by-products in relation to documentation and marketing strategy.

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