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Turbulence of Change

A closer look at the Icelandic aquaculture industry expansion

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Globalisation and Sustainable Development
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Abstract

The Icelandic aquaculture industry has been going through a period of expansion, particularly in salmon farming at sea. This is in part thanks to investment and knowledge transfer from Norway. This research looks at the industry in terms of this expansion, asking how the Icelandic salmon industry is perceived, how it perceives itself and where it stands in terms of sustainability? Which obstacles and challenges it is facing and why, which opportunities do these present and what has the industry's response been? To answer these questions, interviews with individuals directly and indirectly connected to the industry were conducted. Furthermore, secondary data was used to supplement interview data and explore relevant issues. Theory used to analyse the industry's sustainability status was the Two Tier Sustainability Equilibrium, but to understand the complex relationship between various actors, institutions, and environmental factors and how they obstruct or enable development/change in the industry, the Multi-Level Perspective was used. This research found that the industry is (expectedly) contributing/confronted with environmental problems, although to a lesser extent than e.g. Norway and is working towards sustainable practices. Furthermore, the industry has had positive effect on adjacent societies and is gradually getting economically stronger in spite of hindrances, suggesting industry is focused on sustainable development. However, the industry is perceived rather negatively by various actor groups, particularly those that have high stakes in the case of salmon escapes. This has resulted in one of the industry's key obstacles: lack of legitimacy, which has acted as a pressure on the industry to do better and focus on sustainability. Furthermore, key monitoring institutions were identified as a second obstacle, as they were unprepared for the expansion. Furthermore, three key challenges were identified: spatial differentiation as the industry needs to adapt practices to the Icelandic environment; place, as Iceland is at a disadvantage do to distance to global markets; and environmental factors which could eventually impact the product's quality. Considering the maritime innovation environment, these challenges could spark vibrant niche development, as the industry attempts to solve these problems.

Acknowledgements

For this thesis I enjoyed the guidance and insight of Markus Steen. His patience with my lengthy and often incoherent emails, as well as his encouragement, swift replies and interest motivated me to work harder. To my partner, thank you for cheering me on, showering me with endless support and interrupting me when I probably really needed it. To my informants, thank you for your time and insight. Your interest challenged me to push a little harder. And finally, to my family, thank you for your all your help and spontaneous phone calls. I miss you!

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Abbreviations

CC	Climate Change
FAO	Food and Agricultural Organisation
FDI	Foreign Direct Investment
GHG	Greenhouse Gas
LV	Federation of Icelandic River Owners
MAST	Icelandic Food and Veterinary Authority
MFRI	Marine and Freshwater Research Institute
MLP	Multi-Level Perspective
SDG	Sustainable Development Goals
SFS	Fisheries Iceland
TTSE	Two Tier Sustainability Equilibrium
UN	United Nations

1 Introduction

As demands for food increases, so does the requirement for reliable and sustainable food resources. The Icelandic maritime sector is well established, but the unpredictability of wild fish population has led to seasonal disappointments, which can have negative consequences for rural populations relying heavily on the industry for jobs and income (see: Hálfdánardóttir, 2019). Aquaculture has therefore been viewed as an opportunity and a potential solution to a global and local problem: as a means to feed growing populations, decrease pressure on wild fish stocks, and provide secure jobs (FAO, n.d.-b; Tiller, De Kok, Vermeiren, & Thorvaldsen, 2017). In recent years, the aquaculture industry in Iceland has gone through a rapid period of expansion (Hagstofa Íslands, 2019a), but with industry growth come challenges and opposition – particularly in terms of sea-based salmon farming.

I originally planned to look at plastic waste in the Icelandic aquaculture industry but as I familiarised myself more with the topic, I became intrigued by the rapid pace of expansion and wanted to understand the dynamics of what was happening, particularly as the aquaculture debate has been saturated with conflict. Understanding which concerns the public, researchers and politicians have for the industry, and how these can be met, can be of great value to industry acters and policy makers to better understand what is required to move its development towards a more sustainable path. Therefore, the research question to be examined asks: *how is the Icelandic salmon aquaculture industry perceived, how does it perceive itself and where does it stand in terms of sustainability? Which obstacles and challenges is the Icelandic salmon aquaculture industry facing and why, which opportunities do these present and what has the industry's response been?* Obstacles and challenges are here understood to be separate, as obstacles refer to hinderances to the continued development and establishment of the Industry, while challenges are understood as environmental or geographical factors that can impact the value of the product which the regime needs to overcome.

This will be examined primarily from the perspective of sea-based aquaculture of salmon, using the multi-level perspective (MLP), which studies sustainability transitions of a socio-technical regime in terms of dynamic interaction within and between three levels: niche, regime and landscape (Markard, Raven, & Truffer, 2012), as it provides the necessary tools to understand pressures on the aquaculture industry to develop and transform. Furthermore, Lozano's (2008) sustainable development discussion on the Two Tier Sustainability Equilibrium (TTSE) will serve as a guide for the industry's sustainability development status, as it focuses on dynamic interactions within and between three dimensions: society, environment and economics. Furthermore, I will address what technological innovation or development opportunities have presented themselves during this process and predict/suggest future development paths for niche development.

An extensive research on the Icelandic aquaculture expansion has not yet been done. Young et al. (2019) have collected a summary of key limiting factors to the aquaculture expansion in five wealthy nations, including Iceland, furthermore Jóhannsdóttir (2016) analysed the main aspects of Iceland's legal environment pertaining to aquaculture. There is a gap in research focusing on understanding in depth the various interconnected factors of the social and natural environment as challenges, obstacles *and* opportunities, using the tools provided by the MLP. I hope to bridge this gap and spark further discussion on how Icelandic aquaculture can (continue to) work towards sustainable development.

Firstly, I will provide a background of Norwegian aquaculture as Norway is the primary investor in the Icelandic industry, followed by an overview over recent development in the Icelandic aquaculture history and an introduction to the main environmental issues of the aquaculture industry. Secondly, relevant theory on sustainable development and sustainability transition will be introduces, with focus on the multi-level perspective and necessary geographical perspectives. Thirdly, I will address the socio-technical system of Icelandic aquaculture, while introducing relevant institutions. Fourthly, an overview of the research design will be provided, followed by an analysis and discussion on the sustainability status of the Icelandic industry. Lastly, main obstacles, challenges and opportunities will be identified and discussed.

2 Background

In this chapter, I will provide a background of the global history of aquaculture to illustrate how the industry is built on technology and knowledge transfer from one region to another. Next, a broad introduction to the Norwegian aquaculture industry will be provided as Norway is the global leader in salmon farming and has played a great role in terms of the Icelandic salmon aquaculture expansion through transfer of knowledge and technology. Thereafter, an overview of the Icelandic industry will be provided, followed by an introduction into key environmental concerns impacting and caused by the salmon industry.

2.1 A global historical perspective on aquaculture

"Aquaculture is the breeding, rearing, and harvesting of fish, shellfish, algae, and other organisms in all types of water environments" (NOAA, 2019). Some of the earliest forms of aquaculture can be traced back to early Chinese societies well before 1000 BC, but it was not until the 1750-1880 that practices providing the foundation for modern aquaculture were laid as eggs were successfully being fertilized and transported worldwide. Hatcheries were established and successful attempts at feeding cultured fish in captivity was made in Denmark, marking the first land-based fish farming enterprise in Europe (Nash, 2011). In the following years, the industry grew somewhat but its growth was restricted by availability of feed and diseases affecting high density growth sites (European Commission, n.d.). World War II further decreased progress, but the post-war period saw interesting developments as new scientific discoveries on marine species in Japan, accelerated by food shortages, leading to many successes in sea based farming due to limited availability of flatland (Nash, 2011). For Norwegian (and Icelandic) salmon farming, the most important milestone for my discussion are perhaps the advances made in sea cage fish farming and feed. With the discovery of the fish's dietary needs and the development of artificial granulated food in the late 1950s, there was no longer a need to rely on feed such as raw meat, which supported a dramatic increase in fish farming (Alimentarium, 2020; European Commission, n.d.). Furthermore, Japan was a key influencer as the floating cage developed there – a rectangular or circular floating framework of bamboo supporting a net anchored to the bottom – and was soon transferred to Norway (Beveridge, 2004) which, alongside the introduction of plastics in the 1960s, revolutionised the industry (Nash, 2011). As is apparent, the development of aquaculture practices has been a global process relying on knowledge transfer from one country to another, therein applying creative problem solving to address the various challenges (or opportunities) posed by the unique environments of each region.

2.2 Norwegian aquaculture and aquaculture technology

In 2016, Norway was one of the largest producer and exporter of fish and fish products globally after China (FAO, 2018). This is thanks to the production of salmon, a high-value species at a global market, amounting to approximately 72% of export earnings from the seafood industry while just 40% of its volume (Norwegian Seafood Council, 2020). Since 1980, salmon production in Norway has risen from 4.000 tonnes to approximately 1,2 million tonnes, but even as Norway is the largest producer of Atlantic salmon globally, the industry's growth has stagnated since 2013, after a 20-year period of significant growth (Norsk Industry, 2017). This suggests a need for innovation and significant investments if Sjømat Norge's goals of a five-fold increase in production by 2050 are to be met (Misund & Tveterås, 2019). Norwegian salmon farming is highly industrialised and, as the Norsk Industry (2017) report suggests, there is still potential for improvement.

For sea cage farming, the technology used today could be described as traditional but modern, suggesting that there have been limited changes since its introduction to Norway, but also that it is about time for innovation to increase production capacities (Jan Tore Fagertun, presentation during workshop, November 26th 2019). Equipment used must fulfil the Norwegian standard NS 9415:2009 (see: Lovdata, 2011) to e.g. limit any incidents of escapes. This standard applies to Icelandic aquaculture as well (Reglugerð um fiskeldi, 2015). The most commonly used sea cage design are the open round pens pictured in Figure 1. These cages are made of plastic and the design was invented in 1974 by Polarcirkel in Norway. Other designs exist, such as steel cages. Perhaps the most important component is the netting, commonly made of nylon fibres, as they contain the fish and need to be able to withstand considerable wear-and-tear. To operate the fish farm, feed barges, workboats, feeding systems, underwater cameras, sensor systems for monitoring, and lights are also required (AKVA Group, 2017). To meet the demands for increased production while also ensuring sustainable production and limiting involved environmental risks (see chapter 2.4), new designs are being developed to withstand offshore farming, as farming currently takes place relatively close to shorelines. This would open up previously unavailable areas and limit the environmental impact (Norsk Industry, 2017). These designs mostly involve closed sea cages such as designed by

Aquafuture, or semi-closed systems like Midt Norsk Havbruk’s Aquatraz (Misund & Tveterås, 2019).

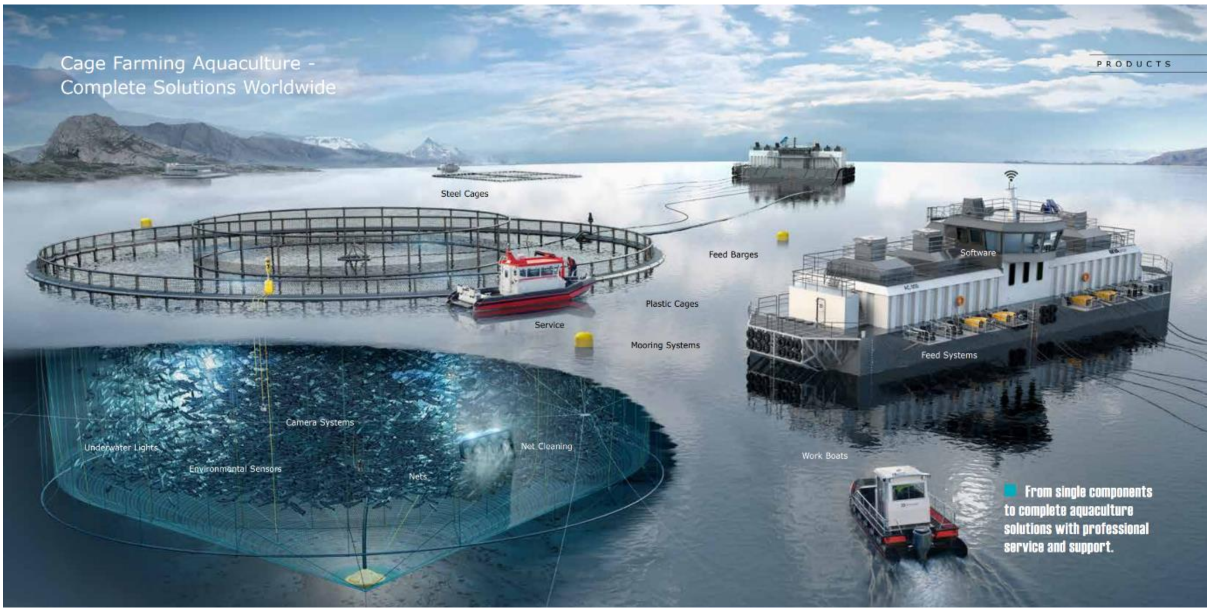

Figure 1. Example of open cage sea farming system. AKVA Group’s salmon farming solutions, displaying the equipment available for open plastic and steel cages.

The leading company in Norwegian salmon farming today is Mowi, owning “[…] the whole value chain from feed production to broodstock, roe and grown salmon, to the processing and distribution and sales” (Mowi, n.d.). However, the firms of interest here are those who have invested in Icelandic aquaculture. These are compiled in table 1 along with the respective Icelandic aquaculture firm. Arnarlax, Ice Fish Farm, Laxar and Arctic fish control the majority of issued operating licences (Bjarnason & Magnúsdóttir, 2019).

Table 1. Some of the larger foreign shares in Icelandic sea-based aquaculture firms. Stolt Sea Farm A.S. is a global firm founded by Niels Stolt-Nielsen, but official address is in Spain (Bloomberg, 2020). Source: (Arnarlax, 2020; Erlingsson et al., 2017).

Icelandic company	**Foreign shareholder**	**Country**	**Share (%)**
Arnarlax hf.	SalMar ASA Pactum AS Others	Norway Norway	59,36 6,86
Fiskeldi Austfjarða hf. (Ice Fish Farm)	Midt-Norsk Havbruk and MNH Holding	Norway	62
Laxar Fiskeldi ehf.	Måsøval Fiskeoppdrett AS	Norway	53,5
Arctic Fish ehf.	Norway Royal Salmon Bremesco	Norway Cyprus	50 47,5
Stolt Sea Farm Iceland hf.	Stolt Sea Farm S.A.	Global/Spain	Owner
Matorka ehf.	Matorka Holding	Switzerland	96

2.3 History of the Icelandic aquaculture industry

Aquaculture can be said to have begun in Iceland in 1884, as the first salmon (and trout) hatcheries were established, meant for release of cultured fry into lakes and rivers. It was not until 1951 that trout was successfully produced commercially in Laxalón fish farm for consumption purposes. Interest in salmon aquaculture increased during this time as well, with a first attempt at raising captive salmon in sea cages in 1972 (Gunnarsson & Rúnarsson, 2004; Kristinsson, 1992). Available data, presented in Figure 2, suggests production of salmon went from 11 tonnes in 1980 to 2.864 in 1990. However, up until 2012, there was limited growth in salmon aquaculture, as production fluctuated dramatically, with sudden peak production in 2004-2006, after a sudden interest in sea farming emerged at the start of a new millennia. However, operations were difficult, resulting in the sudden drop (Jóhannsson, Guðjónsson, Steinarsson, & Friðriksson, 2017).

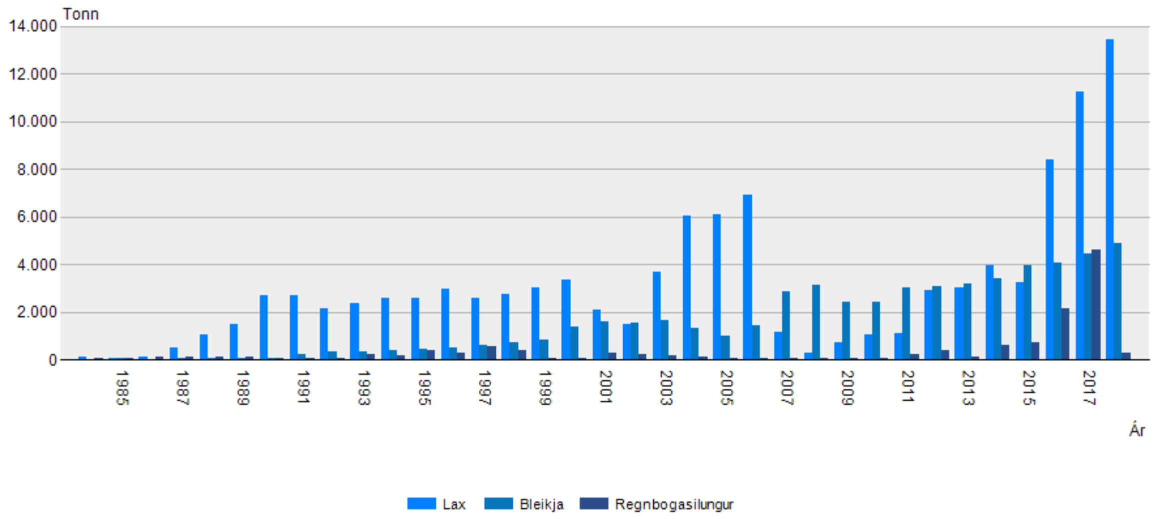

Figure 2. Aquaculture production in Icelad 1984-2018. From the left: salmon, arctic charr, rainbow trout. As the graph suggests, three waves in salmon farming can be identified. Source: (Hagstofa Íslands, 2020).

There are various reasons the Icelandic salmon aquaculture industry struggled in the past decades; financial infeasibility (lack of investment/financing), insufficient yields in sea farmed salmon due to difficulties caused by bad weather, weak equipment and lack of knowledge, and diseases hindered growth in the field (Bjarnason & Magnúsdóttir, 2019; Erlingsson et al., 2017). Furthermore, the Icelandic currency has affected exports, limiting progress in the early 2000s as the currency was strong (Young et al., 2019). However, in recent years, foreign direct investment (FDI) has substituted the lack of national capital in the field. The foreign investors – primarily Norwegian as shown in table 1 – have shared their methods and expanded the business network of the Icelandic industry. As a result, there has been a significant and rapid growth in the field, primarily in salmon sea cage farming, directly employing 435 people as of 2017 and increasing export value as suggested by numbers provided by Hagstofa Íslands (Erlingsson et al., 2017; Hagstofa Íslands, 2019a). While salmon production struggled, arctic char saw a gradual increase with some fluctuations up until 2010. Total aquaculture production remained around 3-4.000 tonnes during this period (Gunnarsson & Rúnarsson, 2004; Hagstofa Íslands, 2020).

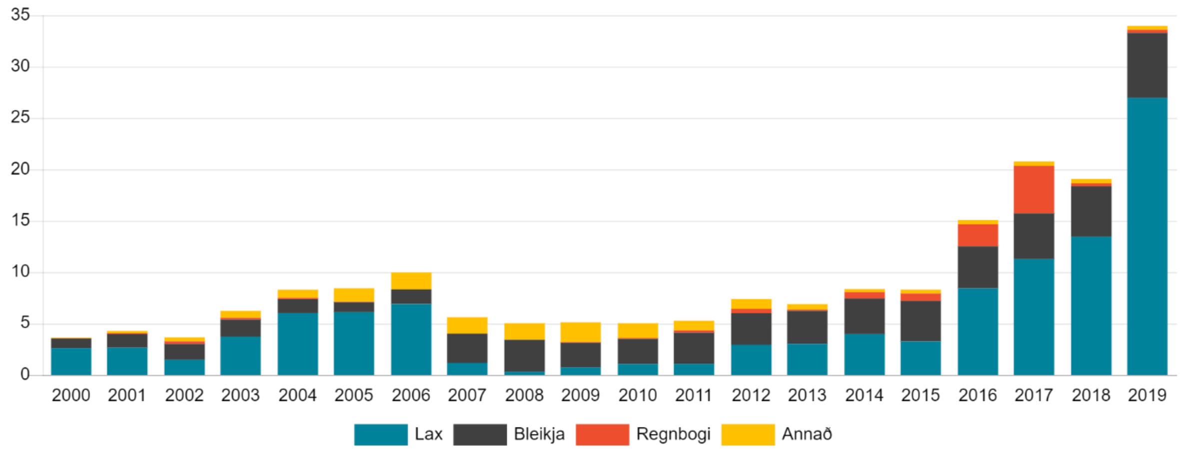

Figure 3. Total production of fish in Iceland from 2000-2019. Blue is salmon, black is arctic char, red is rainbow trout and yellow is other. Source: (Dýralæknir fisksjúkdóma, 2019).

Foreign direct investment can be a good measure of global integration. Accompanied by firms locating operations outside their home country, a corporation can engage in geographical transfer of knowledge, should the technology be made available to potential users outside the firm. In many cases, transfer and diffusion of technology is not desired by the corporation (Dicken, 2015), but in the case of Icelandic aquaculture, FDI has been a key factor for growth in the industry.

In 2012, salmon production suddenly increased from 1.083 tonnes to 2.923 tonnes (Hagstofa Íslands, 2019a). This growth in production has since been increasing, with 26.957 tonnes produced of salmon in 2019, amounting to a total aquaculture production of 34.000 tonnes as is shown in Figure 3 (Dýralæknir fisksjúkdóma, 2019). This has been referred to as the third wave in Icelandic sea cage salmon farming (Jóhannsson et al., 2017). The export value of salmon in 2019 was reported to be 18.6 billion ISK (approximately €120 million) whereas total aquaculture export value was 25 billion ISK (€160 million), accounting for 9,6% of total seafood export and is expected to increase in coming years. Considering Iceland's maritime sector is the second largest export industry in Iceland in terms of volume and value, this is a significant addition (Hagstofa Íslands, 2019b, 2019c). Furthermore, Iceland is the European leader in arctic char production as of 2016 (Hagstofa Íslands, 2019a).

It is estimated that there is still room for growth in the industry with the Marine and Freshwater Research Institution (MFRI) having assessed the current total carrying capacity of examined fjords to reach around 144 thousand tonnes (Hafrannsóknarstofnun, 2017; SFS, 2019a). These numbers might increase as other options are explored. However, this is an estimate of the carrying capacity of biomass. A risk assessment suggests much lower volumes.

In a recent risk assessment report published by MFRI, on the risk of intrusion of farmed Atlantic salmon into salmon rivers, the allowed maximum biomass calculations were changed to allow for increased volumes; The original Escape Coefficient, which assumed a 1:1 ratio between yearly production and maximum biomass, has been changed to 0.8:1. This suggests a potential 20% increase in production from 71.000 to 106.500 tonnes (including addition of other available fjords) per year (Hafrannsóknarstofnun, 2020a, 2020b). Furthermore, as the potential of salmon farming began to prove itself, the government established a working group to create conditions for growth in the field, support responsible aquaculture and secure the wild salmon stocks, building upon existing laws from 2008 on aquaculture (Erlingsson et al., 2017). The working group assessed that Iceland would never become a lead producer in salmon production, but could potentially focus on high quality and therefore higher value (Erlingsson et al., 2017).

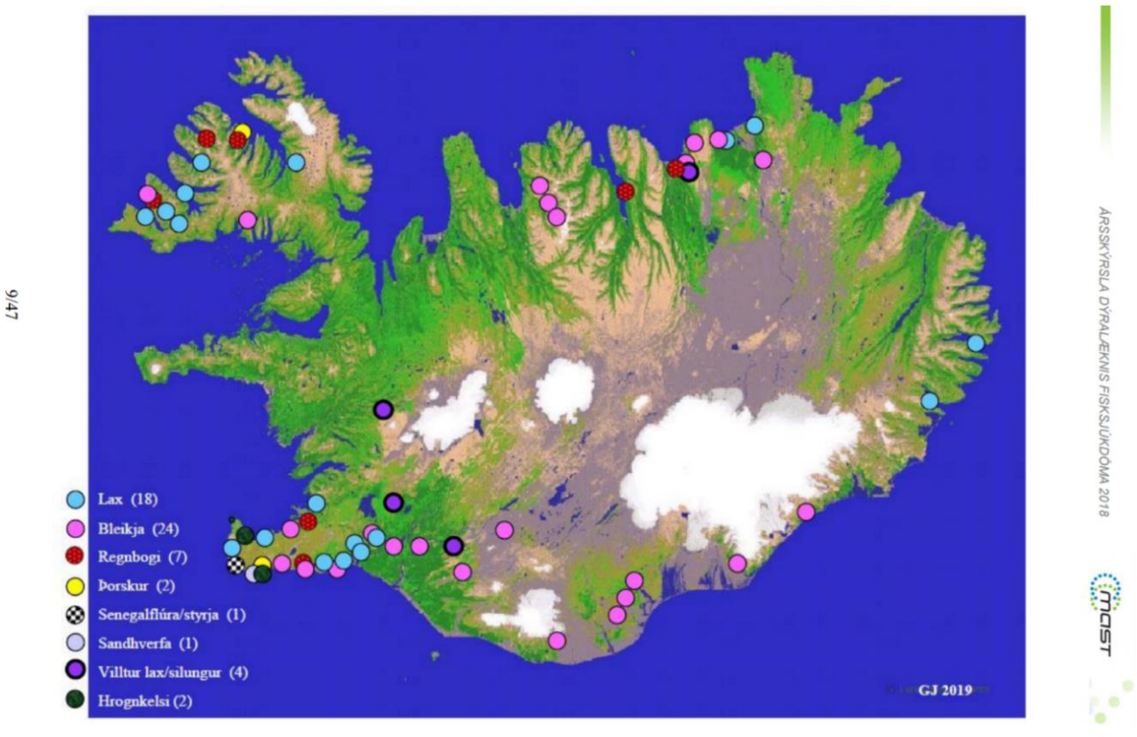

Figure 4. Aquaculture stations in Iceland by the end of 2018. From top: salmon, arctic char, rainbow trout, cod, Senegalese sole, turbot, wild salmon/trout, lumpfish. Source: (Dýralæknir fisksjúkdóma, 2018, p. 9).

As salmon aquaculture went through dramatic fluctuations and is suddenly experiencing a boom, the land based production of arctic char has remained relatively stable, showing gradual albeit slow growth as Figure 3 demonstrates. Like salmon, most of the arctic charr is sold as frozen fresh filets, whole or gutted fish, which fetches the highest value. Highest export value goes to Germany, followed by the USA (Erlingsson et al., 2017; Íslandsbanki, 2014, 2018). Even as fish farming has a long history in Iceland, there has been a lack of comprehensive official policy for the industry (Jóhannsdóttir, 2016), hitherto unable to gain the status the Norwegian industry has established locally and globally.

2.4 Environmental issues and aquaculture

As briefly mentioned, there are several environmental issues, such as farmed salmon escapes, aquaculture is directly and indirectly responsible for. However, aquaculture is also impacted by various environmental/ecological factors which negatively affect the industry. Here, a short summary will be provided of the environmental issues related to aquaculture as a foundation for the discussion in chapter 5 and 6.

2.4.1 Ecological impact

Lice and disease

Disease in farmed fish is a critical threat to growth in the industry. One of the main challenges in Norway and Iceland today are the arguably inevitable sea lice, as they carry a significant environmental and economic cost (Revie, Dill, Finstad, & Todd, 2009; Torrissen et al., 2013). This external parasitic pests attaches itself to the salmon as pictured in Figure 5, living of its skin, mucus and blood, possibly acting as vectors for viral and bacterial diseases. They are responsible for disease outbreaks and result in major losses of salmon (Johnson et al., 2004; Revie et al., 2009). As sea cage aquaculture protects the fish from predators or natural pathogen-controlling mechanisms, it enables the growth of pathogens within the cages. Furthermore, this has been suggested to negatively impact or result in a decrease of wild fish population in proximity to fish farms as salmon lice numbers are higher in areas surrounding salmon farms (Forseth et al., 2017; Frazer, 2009; Torrissen et al., 2013).

To control the outbreak of sea lice, chemical treatment had been a common practice but recently alternatives such as cleaner fish and de-lousing mechanisms have become frequent, as the chemical treatment has unwanted environmental and ecological effects (Torrissen et al., 2013). In the case of other diseases, often resulting from the high density of fish (Bleie & Skrudland, 2014; Olaussen, 2018), various drugs and antibiotics have been used.

Understandably, there are great concerns for the ecological impact of drug use in aquaculture. However, in recent years, their use in Norway has been decreasing (Fiskeridirektoratet, 2019) and as of 2018 in Iceland, no antibiotics have been used for seven years. Unfortunately, recent problems with salmon lice resulted in the use of medicated feed for treatment (Dýralæknir fisksjúkdóma, 2018).

Figure 5. Sea lice on a juvenile pink salmon. Photo credit, Alexandra Morton (Morton, 2009).

The problem with disease and lice demonstrates the two-way relationship between sea cage fish farming and its environment: it is both a victim of various environmental effects, but at the same time, these issues are a result of- and enhanced by the fish density and has the potential to increase aquaculture's impact on its surroundings.

Escapes

Escapes from net pens, as cages are damaged by storms, sea creatures or general wear and tear, are of a great concern both because of the potential ecological impact and the financial loss involved (Olaussen, 2018). The ecological concerns are various, particularly when concerning salmon; competition over territory and resources, predation, threat to genetic integrity of wild salmon population and disease spreading (Forseth et al., 2017). Of these, the greatest concern in Norway and Iceland lies in interbreeding with the wild salmon population but the scale of the problem is contested and varies based on regions and the wild population itself (Glover et al., 2017). Closed containment system have been explored as alternatives to the more common open cage farming, with companies such as Aquafuture (Eco Salmon, n.d.), showing promise in eliminating salmon lice and escapes, but so far, these are not used to a great extent (Olaussen, 2018).

Waste

In accordance with the UN SDG 14 concerning life below water aims for the conservation and sustainable use of the oceans, seas, and marine resources. This includes significantly reducing marine pollution of all kinds (UN, 2019b). Due to the high density of fish in fish pens organic matter, comprised of excrement and uneaten feed, collects under and around the fish pens (Brown, Gowen, & McLusky, 1987; Eiríksson et al., 2019; Eiríksson et al., 2017; Olaussen, 2018). The organic matter forms a sludge on the ocean floor, possibly decreasing the oxygen content of the water and a production of gases such as methane and H_2S, only exasperated by the often limited water exchange and oxygen consumption of the farmed fish and other microbes (Brown et al., 1987; Nori, Glud, Gaard, & Simonsen, 2011). Furthermore, the sludge accumulation results in a change in the benthic such as a decrease in diversity and number of organisms, and potential elimination of invertebrates. When determining the carrying capacity of possible aquaculture areas, these factors (and others) are the determinants (Nori et al., 2011). To prevent or minimise the potential negative effects, resting the aquaculture zone has shown to be an efficient method, and great understanding of the different needs of each zone, based on aquaculture time and volume, has been gained (Carroll, Cochrane, Fieler, Velvin, & White, 2003; Eiríksson et al., 2019).

As the aquaculture industry relies heavily on plastic, its properties and impact should be examined. Plastics are highly persistent materials derived from petroleum and can be made to withstand harsh environments such as the open sea (Rios, Moore, & Jones, 2007). However, this durability is also what makes plastic a potential health and environmental hazard. As plastic accumulates in the ocean – due to e.g. mismanagement of waste, harsh weather conditions, collisions or human error, which results in nets, lines or hard plastic breaking off equipment (Laist, 1995) – it becomes exposed to UV radiation which breaks it into smaller and smaller pieces. Eventually these pieces can be consumed by marine life, even planktons (Rios et al., 2007). The lines and nets can also result in entanglement of wild marine creatures (Laist, 1995; Moore, 2014). Moore (2014) discusses that the rapid expansion of aquaculture industry has not been met with proper attention to the consequences of equipment loss. This is certainly an issue worth exploring. As of now, there is limited information readily available regarding plastic waste from the Icelandic aquaculture industry. However, most aquaculture operators in Iceland have (or are in the application process for) certifications such as the ASC, Aqua GAP and MSC (Arctic Fish, 2020; Best Aquacultur Practices, 2020; Ice Fish Farm, 2020), which address non-biological waste management requirements (See: AquaGAP, 2018; ASC, 2019; Global Aquaculture Alliance, 2016). BAP, awarded to Samherji for arctic char, specifically discusses plastic waste and equipment management in their certification under section 8 (Global Aquaculture Alliance, 2016). Furthermore, the ASC is reviewing the need for additional criteria to address marine and plastic litter (Huntington, 2019).

2.4.2 Climate change

Aquaculture contributes to the emission of greenhouse gases largely through feed production which varies based on species farmed. The total energy used also depends on the location of production, as sources of energy and required transport distances vary (Robb, MacLeod, Hasan, & Soto, 2017). As the UN's sustainable development goal number 13 aims to reduce GHG emissions (UN, 2019a), the industry will have to find solutions to more efficiently produce feed. Since 1990, development of salmon feed from marine based resources has decreased from 90% to approximately 29% in Norway in 2013. Furthermore, in 2013, 0,7 kg of marine protein was required to produce 1 kg salmon protein (Ytrestøyl, Aas, & Åsgård, 2015). Today, the marine sources account for 24.9% while the rest is derived from land-based sources. The substitution for salmon feed has largely been soya protein concentrate (19,0%) and rapeseed and camelina oil (19,8%). The plant-based sources are largely derived from South America (or undefined areas) while plant oil comes primarily from European sources. (Aas, Ytrestøyl, & Åsgård, 2019). Considering concerns regarding soybean production and deforestation in South America, and general greenhouse gas emission and cost from transport, it is understandable that the industry is looking into alternative sources. Even so, this could be considered a step in the right direction as research suggests environmental impacts of salmon fed containing high quantities of animal by-products is much higher (Parker, 2018). Furthermore, Clune, Crossin, and Verghese (2017) discuss that the global warming potential[1] of salmon (3,76), is relatively low compared to many other aquaculture species, and significantly lower than that of beef (28,73). However, a recent SINTEF report suggests that the carbon footprint of salmon has often been underestimated as land use has not been properly included in the calculations. Their estimates increase CO2-equivalent/kg edible produce processed in Norway from 3,29 to approximately 7,0 (Winther, Hognes, Jafarzadeh, & Ziegler, 2020; Winther et al., 2009). Still, these numbers remain significantly lower than most land-based meat sources, which will be important to consider as demand for animal proteins increases.

Climate change is predicted to increase the frequency and intensity of storms; however, the extent of the potential impact is not fully understood. Furthermore, as diseases thrive better

[1] GWP refers to kg CO_2-equivalent/kg produce.

in warmer oceans, warming of the oceans has a potential to become a concern. Additionally, the IPCC points out possible negative impact for land-based aquaculture such as changes in water cycle and competition for water, but Iceland is not expected to be faced with a water shortage, rather, an increase in rainfall (Seggel & De Young, 2016). However, risks and vulnerabilities depend largely on the vulnerability of the regions in question and in some cases, there might be more benefits than negatives of a changing climate for the industry (FAO, 2018). An important point of the impacts of climate change is availability and price of feeds, as aquaculture feed often uses fishmeal and fish oil from wild harvests, as these might become less available, challenging a sustainable aquaculture production growth (Seggel & De Young, 2016).

3 Theory

With the objective of exploring the obstacles, challenges and opportunities the Icelandic aquaculture industry faces in light of its recently rapid expansion, furthermore as I aim to analyse the industry's response to these factors and its own perception of itself and current status in terms of sustainability, sustainability transition theory has been selected as the theoretical approach. As we are confronted by sustainability challenges in essential *socio-technical* sectors of modern society – such as the energy and food sector, some of the industries where sustainability transitions are considered most necessary (Geels, 2011) – we are faced with the need to *transition* the industry towards sustainability. However, the industries are often characterised by strong path-dependencies as established technologies are woven together with user practices, political and organizational structures, value chains, etc., so change rarely happens instantaneously. Thus, sustainability transition theories focus on the dynamic interactions of these elements and the changes necessary to shift, e.g. the Icelandic aquaculture industry, towards a (more) sustainable production model (Markard et al., 2012). However, before discussing these key concepts relevant for understanding sustainability transition of the aquaculture industry, properly defining sustainable *development* is of value, as it clarifies what I will assume to be required for a truly sustainable industry. Development has been highlighted here to emphasise the constant adjustment and rethinking required of an industry to meet new sustainability challenges and to address further development in our understanding of sustainability and its relevant requirements.

3.1 The three dimensions of sustainable development

The UN's SDG number 14 addresses life below water, stating: "Careful management of this essential global resource is a key feature of a sustainable future" (UN, 2019a). Aquaculture has the potential to reduce hunger, generate economic growth and ensure better use of natural resources (FAO, n.d.-b). As Irarrázaval and Bustos-Gallardo (2019, pp. 5-6) have argued, "[…] the process of transforming nature into a commodity" is an *ecological contradiction*, comprised of two opposed forces; the firm's drive for generating maximum profits of nature and the obstacles and opportunities nature presents to capitalist production. When considering the widely acknowledged Brundtland definition of sustainability, "[…] development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987), the dimension of managing these resources adds to it a dimension of environmental preservation and responsible production methods. Furthermore, when examining the expansion and/or analysis of an industry, it is of great value to explore how it can contribute or impact the *sustainable development* of a region or country in terms of the commonly defined dimensions of sustainable development: environment, society and economics. The understanding of what sustainable development is has been under development for over 30 years but viewing sustainable development as an integration of the natural, social, and economic systems has gained solid footing. Many different approaches exist but the overall assumption of three separate systems has been criticised for assuming that those are separate at all (Mebratu, 1998). For the sake of this paper, I will discuss these separately, all the while keeping in mind that these are tightly integrated as a part of a whole.

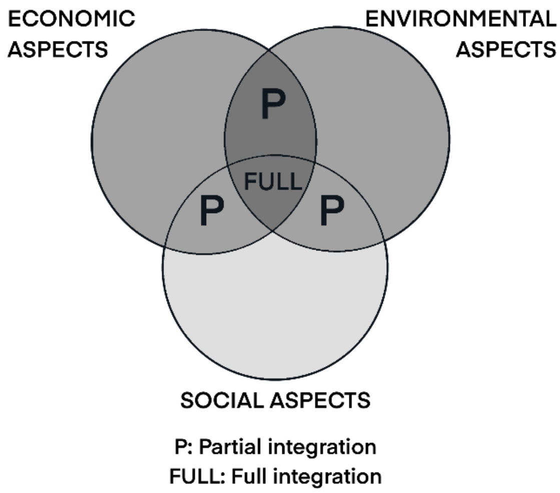

Figure 6. Sustainable Development Venn diagram. A commonly used Venn diagram showing three aspects of sustainability overlapping, economic, environmental and social, suggesting full sustainability when all aspects overlap. (Lozano, 2008)

It is worth noting the difference Lozano (2008) discusses between sustainability and sustainable development. The two are inherently different terms, where sustainable development includes a path or process towards achieving sustainability, "[…] the ideal dynamic state". This, he believes, to be somewhat lacking in many theories addressing sustainable development; such as the conventional economists' perspective, where sustainability is a steady state and economists are unable to predict the environmental impact, considering sustainable development as simply a desirable development path; and the integrational perspective, where integration and relations of economic, environmental and social aspects are considered but lacking in continuity as in accordance with the focus of the Brundtland report. Lozano therefore seeks to add to and improve the various theoretical models and graphical representations, like the Venn diagram pictured in figure 6, by including integration, dynamics and time as a part of the illustration. The result is a *Two Tier Sustainability Equilibrium* (TTSE) pictured in Figure 7, which represents sustainable development as the three dimensions having a dynamic interaction over short-, long- and longer-terms to adapt and change based on what is required to be sustainable.

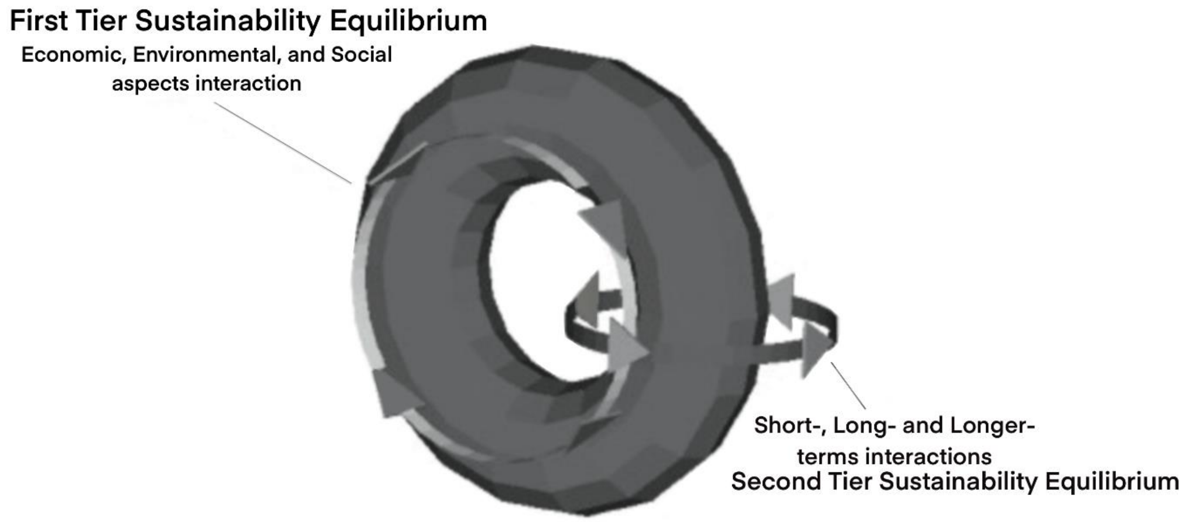

Figure 7. The Two Tier Sustainability Equilibrium model. Lozano's (2008) representation of the TTSE, where economic, environmental and social aspects are in a interrelated dynamic interactive relationship (first tier sustainability equilibrium), paired with the time dimension, considering long-, short- and longer-term interactions (second tier sustainability equilibrium).

Even as these three dimensions provide good insight into an ideal sustainable relationship between nature and human interactions, there are other theories that provide deeper insight into the complex pressures, dynamics and actor-relationships when exploring technological expansion (or transition) from a sustainability perspective.

3.2 The Multi-Level Perspective

Markard et al. (2012)'s road-map for sustainability transition studies suggests four key contributing theories: Transition management, strategic niche management, multi-level perspective and technological innovation system. For this research, the multi-level perspective (MLP) developed by Rip and Kemp (1998) has been selected[2], as the aquaculture sector is already established in terms of technology and user practices as suggested by chapter 2. Furthermore the MLP observes and aims to understand the links and pressures between three

[2] Although the technological innovation system would provide insight into the dynamics between technologies, actors, networks and institution, its focus is on novel technologies and furthermore, it has failed to incorporate the particularities of transformative changes in the way MLP has (Markard et al., 2012).

levels – socio-technical landscape, regime and niche – as suggested in Figure 8, leading to transformation in the socio-technical regime. The levels can be said to correlate with each other along a temporal and a structural scale, but clear territorial boundaries of levels had been less of a concern although frequently used (Raven, Schot, & Berkhout, 2012). In general, the MLP has been criticised for a lack of spatial sensitivity, but this will be addressed in more detail in chapter 3.2.2. Köhler et al. (2019) summarise several characteristics of sustainability transitions, namely their multi-dimensionality, multi-actor process, the relationship between stability and change, the long-term process of transitions, the inevitable of open-endedness and uncertainty of which innovation prevails, the problems with different values on what is considered sustainability, and the normative directionality which suggests the need for public policy in shaping the direction of transitions. Sustainability transitions are therefore in their nature about interactions between technology, institutions of power and regulations, economics and the public (Geels, 2011), and – of no lesser importance – time and *timing* (Geels & Schot, 2007; Raven et al., 2012). As this suggests, transitioning towards a sustainable production requires creative problem solving and rapid change of infrastructure, institutions, technology and society, referred to as *socio-technical* transformation. Furthermore, as the term reflects, these factors are dependent and evolve together. For a major permanent transformation, such as those needed to respond to climate change and other related industrial environmental threats, the entire socio-technical system must react (Markard et al., 2012; Van den Bergh, Truffer, & Kallis, 2011; Whitmarsh, 2012). However, it is important to acknowledge that socio-technical change is generally incremental and path-dependent, as stability in the system comes from strong links and alignments between various elements of the socio-technical system, supported by institutionalized formal and informal rules and habits (Fuenfschilling & Binz, 2018; Geels, 2002, 2004).

According to the MLP, transitions are a shift from one socio-technical *regime* to another which happen through a combination of (macro) landscape pressures and (micro) niche developments (Fuenfschilling & Binz, 2018; Geels & Schot, 2007). The MLP further argues that transitions happen due to dynamic processes within and between these levels, using them as analytical concepts for understanding socio-technical change (Köhler et al., 2019). As has been established, this socio-technical change reaches stability as interconnectivity is established between different elements as a result of the activities of different actor groups (Geels, 2002). However, as the main objective of this research is exploring a revitalisation or growth in the Icelandic aquaculture industry and to analyse it from the sustainability development perspective, this approach will be borrowed to examine the factors leading to transformation towards increased production volumes, rather than a complete transformation of production methods. In other words, the breakthrough of innovation – or change in general as the different transitional pathways suggest – depends on context and therefore the MLP is useful (Geels, 2002) for the unique examples in this research.

For a proper analysis to take place, it is of value to establish and define the three levels of the socio-technical system as understood by the MLP.

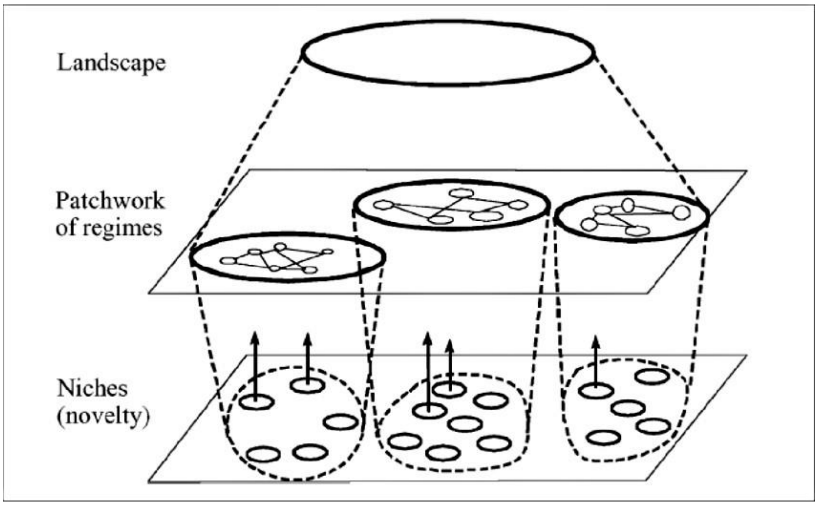

Figure 8. Visualisation of the three levels of the multi-level perspective and interactions between them. The nested hierarchical characteristics suggests embeddedness between and within levels (Geels, 2002).

Socio-technical landscapes

The landscape describes the broader external context – the macro level – which influences the niche and regime, such as the general natural landscape, technological environment, political ideologies, demographic trends, environmental factors etc. Landscape level changes are generally considered slow, but they can apply pressure of varying degrees on the regime, resulting in its destabilisation, creating sudden opportunities for niche innovation or breakthrough (Geels, 2011; Geels & Schot, 2007). Hinrichs (2014) discusses the landscape on a national or international scale, depending on the situation. An example in a landscape shift could therefore be specific national or supra-national policy mandates, shortage of supply, a natural disaster, or the recent COVID-19 pandemic. As is apparent, the landscape is a broad concept, applying to any unspecified outside factors impacting the regime. For this research, political environment, society discussions and reactions to the aquaculture industry and the physical landscape and environmental influences are of key concern.

Socio-technical regimes

Geels (2002) refers to the socio-technical regime as the "semi-coherent set of rules carried by different social groups" (p. 1260). These rules and practices lead to the stabilization of not only the regime, but the entire socio-technical system (Geels, 2011). In aquaculture, the regime could refer to the dynamic interconnectivity of existing technology, user practices, infrastructure, and formal regulatory frameworks. In recent years, scholars have expressed the need to developed the regime concept further to include a better analysis of institutional structures and how institutional change takes place, having argued the regime is a representation of the dominating institutional rationality of a socio-technical system which, thus, leads to transitions being understood as institutional change which will be address below (Fuenfschilling & Binz, 2018). The regime is therefore a macro level structure, or regional. Although the scale can be ambiguous. A valuable addition to the regime concept is Fuenfschilling and Binz's (2018) definition of a *global* socio-technical regime as: "the dominant institutional rationality in a socio-technical system, which depicts a structural pattern between actors, institutions and technologies that has reached validity beyond specific territorial contexts, and which is diffused through internationalized networks" (739).

Niches

Geels (2002) claims that radical innovations are usually generated in *niches* due to being protected from market selection in the regime. The niche is an important micro level phenomenon where learning through trial and error has been allowed or encouraged to take place. Furthermore, social networks are built within the niche through interactions which supports innovation. However, in Bilali's (2019) paper, the MLP is explored from the agro-food sector, relying on a broader definition of niches as being involved in "new technologies and practices, new configurations of actor groups, new beliefs and values, new networks, new policies" (Darnhofer, 2015, p. 17). For this research, this approach will be more useful due to the revitalisation (rather than transformation) of the industry. Still, the niche will be considered according to the original MLP's understanding in terms of potential future pathways, such as when exploring how a socio-technical regime or the landscape can impact niche development (or even result in "spill-over" as firms invest in services and future solutions to specifically cater to the regime).

3.2.1 Landscape-regime-niche interactions towards transitions

Geels and Schot (2007) distinguish between six different *transition pathways* of the MLP, depending on timing and the nature of interaction between the three levels; reproduction process, transformation path, de-alignment and re-alignment path, technological substitution, reconfiguration pathway, and a sequence of transition pathway. The transition pathways are summarised in table 2.

Table 2. The six transition pathways of the MLP as discussed by Geels and Schot (2007), discussing nature of pressure, timing and maturity of niche.

Transition pathway	Nature of interaction between levels	Timing
Reproduction process (P0)	No landscape pressures applied to the regime. Regime is dynamically stable, reproduces itself. Dynamics such as investment in new products, firm competition present. Niche can be developed, but innovation does not break through.	Irrelevant
Transformation path (P1)	Moderate landscape pressure such as protest from social movements. Regime actors re-orientate, i.e. modify the direction of development paths. Generally, a gradual/slow process. Niche innovation is not developed enough.	Timing of landscape pressure not beneficial to niches.
De-alignment and re-alignment path (P2)	Landscape change is divergent, large and sudden ('avalanche' change) such as various combined factors of urbanisation, immigration etc. Regime actors lose faith – destabilisation takes place. Niche not fully developed or no stable niche-innovation taking place which can fill the gap – multiple niche-innovation takes place. One niche eventually fills the gap.	Sudden and inconvenient to niches. Rapid development.
Technological substitution (P3)	Landscape pressure is high ('avalanche' change) such as mass migration which boosted the trans-Atlantic passenger market in the late1840s. Regime becomes unstable – niche replaces regime as it no longer meets demands of the landscape. Niches are fully developed, radical innovation present which was unable to break through – pressure enables breakthrough to regimes	Sudden. Timing fits with the stage of niche development
Reconfiguration pathway (P4)	Landscape pressures present and varied (niche and regime development potentially influence landscape change). Regime gradually adopt niche solutions to solve local problems – further (substantial) adjustment takes place and a new regime grows out of the old regime Niche innovation is developed, and they have developed symbiotic innovation – adopted in regime	Timing is convenient for regimes and niches.
Sequence of transition pathway (P5)	Landscape pressures take the form of disruptive change, suggesting slow speed, possible resulting in a sequence of transition pathways. Transformation → reconfiguration →substitution or de-alignment and re-alignment. Regime address landscape pressures originally with re-orientation. If successful, (P1). If architectural changes in the regime are triggered, (P4). If problems grow worse and niche breaks through, (P3) but if niche is not developed, (P2)	Pace of pressure is slow. Timing can be beneficial to niches. Inconvenient timing results in multiple niche-innovation taking place

Pressures from the landscape, anticipated but often unexpected, can result in shifts or changes in the socio-technical regime (Hinrichs, 2014; Markard et al., 2012). A change in the regime is generally incremental – its pathway dependent on timing and level interaction as elaborated in table 2 – and the regime maintains stability through regulations and standards, adaptation to technical systems, investment in technology, infrastructure, routines and know-how (Geels & Schot, 2007). Radical technological change in a stable socio-technical regime was typically considered difficult as the regulations, infrastructures, user practices and existing maintenance networks are (or were said to be) made to cater to the existing technologies, requiring the co-evolution of new technologies, markets, and user preferences, as well as policy and formal and informal institution change (Geels, 2002, 2004). This, co-evolution of social and political institutions, paired with available material resources can act as a transformation blockage that limiting breakthrough of new innovation and leading to path dependencies (Hinrichs, 2014). However, this rather simplified view has been further developed in recent years.

It is important to understand the dynamic regime structure interaction – such as strategic alliance building – between different types of actors, as actor agency has been shown to play an important role in enabling transitions (Markard et al., 2012), possibly questioning the criticality of user preferences or every day practices. Furthermore, new perspectives on niche and regime interaction; such as political struggles, selective adaptations of niche innovations into regimes, roles of outside actors, active resistance to transition of regime actors, and institutional processes, in addition to studying particular actors and their role in transitions have emerged as the field expands (Köhler et al., 2019), illustrating that factors hindering radical transformation might be rooted in actor agency, rather than dependency and 'inevitable' co-evolution of technology. Understanding who is profiting or bearing the cost of specific transformation trajectories is therefore a key factor when looking at transitions (or lack of transition) in a socio-technical regime. As Hinrichs (2014) discussed: "In the MLP, then, a sustainability transition involves a dynamic socio-material shift in how the regime operates, what it expects, obstructs, sanctions, nurtures or facilitate". This understanding suggests the importance of choice, or perhaps actor-agency, which has become a valuable addition to the MLP's understanding of sustainability transitions. Yet another one is the above-mentioned attention given to institutions.

As institutions are "[…] durable systems of established and embedded social rules and conventions that structure social interactions" (Hodgson, 2006, p. 13). They form stability for expectations and behaviours which, in turn, makes them durable and enforcers of consistency which can limit or enable certain behaviours. In this way, the concept path dependency captures the role of institutions as enablers and obstructers of change (or transformation) in a socio-technical regime, as past experiences or pre-existing frameworks influence the outcome. Furthermore, from an institutional perspective, the response to incentive structures and actors' response to incentives – or the possible influence they might have – is dependent on the underlying knowledge base (Zukauskaite & Moodysson, 2016).

As Fuenfschilling and Binz (2018) discussed, the institutions of a *global* socio-technical regimes have gained validity beyond their national borders. Furthermore: “Actors are believed to copy institutional templates that are perceived as highly legitimate in a field, particularly in situations characterized by high uncertainty and complexity” (737). Looking at Norway, a major salmon producer, it could be observed as a dominant socio-technical regime, empowered to exert its influence on the sector in other countries. This can be a risk as illustrated with their example from the water sector, where foreign aid and knowledge transfer resulted in China following a less than ideal path to construct their water sector considering an opportunity to develop a more efficient system. However, this also applies to larger world policy scripts; actors and practices in various fields are becoming increasingly similar, potentially because of globally applicable policies (such as from the UN or the European Union). This results in the need for actors to conform to certain models, should they want to gain legitimacy beyond their borders. Legitimacy, generally referred to as the assumption or generalisation that an entity – such as legislative framework or aquaculture firms – “[…] are (desirable) [parenthesis introduced as an improvement by (Deephouse, Bundy, Tost, & Suchman, 2017)], proper or appropriate within some socially constructed system of norms, values, beliefs and definitions” (Suchman, 1995, p. 574), and can be obtained or challenged by a variety of sources, even individuals (Deephouse et al., 2017). Global institutions structured for the dominating socio-technical systems can result in varying positive or negative paths of development for sectors in different countries or regions. Therefore, examining a socio-technical regime such as aquaculture in a suddenly growing industry, can provide interesting insights into how the system is established and adjusted based on pre-existing knowledge and to the requirements of the new region to meet environmental, social and political challenges, and to build a sustainable industry through gradual adjustments in regulations or technology. Furthermore, it can be insightful to explore the system as it struggles to reach stability.

3.2.2 Limitations to the MLP approach

It is understood that there are certain limitations to the MLP approach. Critiques include issues with scale, or a lack of ‘territorial sensitivity’ (Coenen, Benneworth, & Truffer, 2012). Sustainability transitions can be argued to be an inherently geographical processes, as they are tied to particular places of various scales (T. Hansen & Coenen, 2015). Scale is not simply defined, as it consists of various dimensions such as time, structures, and space. Time and structures (institutional, social) have already been addressed as an essential dimension to the MLP, leaving spatial scale as the dimension which the approach had been lacking (Raven et al., 2012). Researchers have commonly responded to this by relying on the MLP while adding spatial sensitivity to their geography of sustainability transition studies. Therefore suggestions have been made to apply more systematic approaches to investigating how scale or place influences the transition process, to considering geographies of scale and the various extent of external impact on specific localized activities (T. Hansen & Coenen, 2015). Raven et al. (2012) have e.g. attempted to incorporate a spatial scale to the MLP; a second generation multi-scalar MLP, which "theorises development in and between regional, national and international contexts", and where "multi-scalar refers both to the existence of different scales […], as well as different levels along these scales" (p. 65). This requires the introduction of new dimensions: distance, spatial differentiation, and reach. Distance is important for niches as they frequently form in close proximity to markets/regimes; spatial differentiation takes into consideration the regional variations of niches, regimes and landscapes; and reach suggests that actors can influence or operate in a system from a distance, much like the global socio-technical regime would suggest.

Spatial differentiation is especially relevant for resource-based industries like aquaculture, as interaction between nature and firm plays a key role in forming the organisational web of the spatial production network (or the socio-technical regime) and impacts value creation. Space and natural resources are furthermore important, as spatially concentrated production is cheaper but carries certain risks when proximity between salmon production sites (or production sites' proximity to wild salmon populations) becomes a risk factor (Irarrázaval & Bustos-Gallardo, 2019). Furthermore, the location of natural resources, and the natural landscape itself are all of great importance when considering approval or potential changes in operations. Social attachments or lack of infrastructure might limit or prevent transformation of the landscapes for sustainability transition. This should illustrate the importance of considering geographical distribution as well as the geographical variations when considering transformation of a regime. But while geographical approaches have added to the understanding of local variables which can impacts niche formation and innovations, T. Hansen and Coenen (2015) still find regimes to be approached as relatively "homogenous configurations across space" (104). They conclude place matters but *how* place matters has yet to be set up in a generalisable way. Therefore, Raven et al. (2012)'s multi-scalar MLP approach, proposing a relative or relational scale dependent on the relevant networks and dynamic actor relationships over heterogenous space will provide much needed insight for the analysis.

In addition to a lack of territorial sensitivity or spatial scale, the MLP has been criticized for its 'mechanistic' emphasis on technological change and prioritising how states and markets can hinder or encourage innovation. A proper understanding of power and institutions requires more attention to actor agency, resources and expanding upon what or who relevant actors are beyond what would be considered the 'core' actor groups (Hinrichs, 2014). As discussed above, more recent work on the MLP has addressed these issues, particularly with actor agency and looking beyond the actors directly involved in the regime. For this research, paying attention to the available resources (which here refer primarily to marine spaces) and how it controls or impacts relationships and communication between actors, and perhaps more importantly, what role it plays for institutions, will be of great value.

3.3 The aquaculture value chain and socio-technical systems

Much like in Norway, as a socio-technical system, Icelandic aquaculture provide marine proteins (and other biomass products) from the breeding of salmon and other fish. The fish is exported primarily as frozen loins, whole or gutted fish (Íslandsbanki, 2014). As Iceland is an island in the North Atlantic Ocean, all products must be transported over great distances, adding to cost and potentially decreasing value, putting the industry at a disadvantage compared to mainland producers in close proximity to larger markets like Norway. Irarrázaval and Bustos-Gallardo (2019) point out that Atlantic salmon production is time consuming, but the exchange of final product must be rapid as it is sold fresh. Understandably, closer proximity to global markets would therefore be an advantage. As for any product, value of the final consumption ready fish is the sum of value added through the various intermediate steps. The overall price at any given step is the cost of previous and currently required inputs plus company profit.

3.3.1 Value-chain

A generic aquaculture value chain, as shown in Figure 9, can be divided into seven segments; supply, breeding, grow-out, primary- and secondary processing, distribution and markets. Salmon or other similar aquaculture species are considered rather complex – compared to e.g. oysters – and therefore have considerable upstream inputs (suppliers) and require significant downstream (processing and distribution) (Bostock, Lane, Hough, & Yamamoto, 2016).

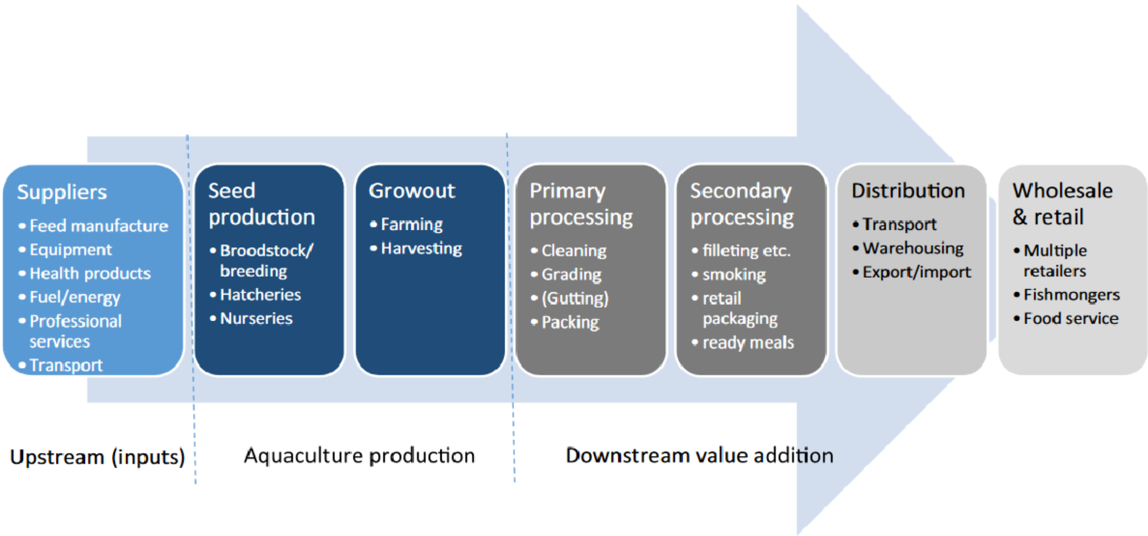

Figure 9. A simplified aquaculture value chain. Source: (Bostock et al., 2016)

In the salmon aquaculture value chain, Icelandic actors are primarily involved in the production step. Supply goes largely through Norwegian firms. Seed production and grow-out is commonly done by the same company as is the case for Ice Fish Farm, Arnarlax and Arctic Fish, with Icelandic salmon roe purchased from the now Benchmark Holding plc firm Stofnfiskur[3] (Stofnfiskur, n.d.). Primary processing is furthermore largely undertaken by the grow-out companies in relative proximity to the grow-out locations. An example is Arctic Fish which has smolt (Arctic Smolt), salmon farming (Arctic Sea Farm) and processing (Arctic Oddi) operations located at the Western Fjords (Arctic Fish, n.d.). However, as mentioned in chapter 2.3, most of the fish is sold abroad as whole and gutted fish, and frozen filets. Secondary processing by Icelandic firms is uncommon.

For this research, primary focus will be on the grow-out stage of salmon which takes place in seawater. The grow-out stage has been chosen as the key point of interest as operations are located in Icelandic marine waters (and run by Icelandic companies), operations require significant costly supplier inputs and services – such as equipment, health products, fuel/energy, professional services such as technical assistance, equipment cleaning/repairs and feed – and has gained significant attention by invested actors and the public. It is worth noting that feed production is of considerable importance due to the environmental issues explained in chapter 2.4 but also due to feed being one of the highest cost factors (Environice, 2018). Furthermore, some attention will be given to the seed production as an important step to assist with optimal grow-out condition. Additionally, downstream value addition steps will be considered in terms of the location of operations and resulting limitations and opportunities for

[3] Became a part of Benchmark Breeding and Genetics in 2014 (Stofnfiskur, n.d.).

Icelandic firms and society. Lastly, wholesale and retail will be considered in terms of the products reputation and legitimacy, pertaining to the grow-out stage (and other value chain steps).

3.3.2 Institutions

To understand the socio-technical system and to be able to properly analyse interaction and dynamics within and between the three MLP levels, as well as putting the analysis in context with the complex interaction between the three sustainable development dimensions, understanding and accounting for the key institutions is essential.

An important precautionary step was taken in 2004 when the Icelandic costline was divided into areas where aquaculture is *not* permitted (Alþingi, 2018; Bjarnason & Magnúsdóttir, 2019; Jóhannsdóttir, 2016). These areas are pictured as yellow in Figure 10. Young et al. (2019) have identified several political-ecological factors affecting the prospects for expansion in Icelandic aquaculture production, of which the lack or absence of comprehensive or consistent policies for marine spatial planning processes[4], “private ownership of aquatic spaces” and “lack of legitimacy (hegemony) for aquaculture industry and policy” (220) are major limiting factors. Comparatively, these factors are considered minor for Norway, as the ownership of fresh and marine waters are controlled by the government and the industry has been strongly established as an export industry.

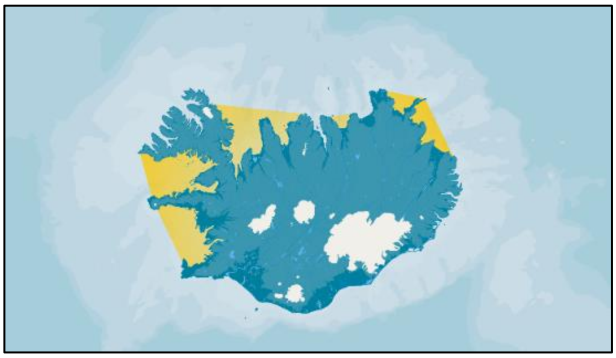

Figure 10. Areas where sea-cage aquaculture is not permitted. An important step taken in 2004. Figure from (SFS, 2019b).

As Young et al. (2019) further discuss, the Icelandic government regulatory and monitoring bodies were not prepared for the rapid expansion that took place in salmon farming as regulations are still relatively incomplete and monitoring still requires some streamlining (Jóhannsdóttir, 2016), which will be discussed further in chapter 6.2. Concerning policy, the

[4] Young et al.’s (2019) paper was written prior the addition of article 4 a. act 71 on division of marine space into aquaculture regions, their advertisement and assignation.

recent SFS (Fisheries Iceland) report criticizes the government for not doing enough to support the growing industry, by e.g. implementing fees on the industry as it is currently going through a build-up phase and untimely fees would decrease Iceland's competitive advantage on foreign markets (SFS, 2019a). However, with recent changes to legislations and regulations, we might be seeing an increase in political support.

Before discussing the changes in legislations and regulations, it is important to introduce the key governing bodies of aquaculture. The Ministry of Fisheries and Agriculture and the Ministry for the Environment and Natural Resources are the main governing bodies (Bjarnason & Magnúsdóttir, 2019), while Matvælastofnun (Icelandic Food and Veterinary Authority, MAST), Hafrannsóknarstofnun (Marine and Freshwater Research Institute, MFRI) and Fiskistofa (the Directorate of Fisheries) are the key monitoring bodies, supervising health, safety and assessing the production capacity of regions. The Directorate of Fisheries plays a smaller role after significant legislative changes were made and now deals with escaped salmon and in the occasion of escapes the operators are required to inform the institution immediately by law (Fiskistofa, 2015). MAST promotes health and welfare of animals "[…] and quality of food by enforcing legislation and providing education and services to the fisheries and agricultural sectors, businesses and consumers" (MAST, n.d.). More specifically, MAST has an operating fish disease committee, operating under legislation nr. 60/2006 on defence/cautionary measures against diseases in fish (MAST, 2019a). Furthermore, to operate an aquaculture station, licence from MAST is required along with an operations licence from the Environmental Agency of Iceland (MAST, 2020). MFRI plays an important role in strengthening the aquaculture industry in harmony with nature and society through research, providing knowledge to the industry and creating a generation of scientists to lead future research. Furthermore, they publish risk and carrying capacity assessments (MFRI, n.d.).

As briefly mentioned in chapter 2.2, some portion of the Icelandic legislations and policies have been adapted from Norwegian regulations, such as the Icelandic regulation on aquaculture equipment stating that equipment should fulfil demands in the NS 9415:2009 regulations (see further: Reglugerð um fiskeldi, 2015). Furthermore, it has been suggested to follow similar provisions as in the Norwegian regulations regarding acceptable rate of aquaculture salmons in rivers (Erlingsson et al., 2017). Over the past decade, as aquaculture continues to grow in Iceland, the 2008 legislation have been going through a transition, albeit lagging behind the development of the industry (Jóhannsdóttir, 2016). Significant changes were made in 2014; administration operations were transferred from the Directorate of Fisheries to MAST, polluting activities became subject to an operating permit issued by

Environment Agency of Iceland (previously issued by the local environmental authority), the permit procedure was changed and requires the application for a general operating permits and permit for pollution prevention to be submitted only to MAST (not MAST and the Environmental Agency) in an attempt to streamline the permit procedure (Jóhannsdóttir, 2016). Furthermore, duty to assess carrying capacity of a defined marine area was made obligatory (act 49, 2014 art. 8). Again in 2018, important additions were approved, mainly regarding the spatial planning of the marine areas for aquaculture, their advertisement and distribution, assigning MFRI the role of distributing marine space based on carrying capacity and best total-utilisation. Where assessment of coastal planning according to law is available, MFRI should take it into consideration upon dividing into aquaculture zones. Should a coastal planning be non-existent, the Planning agency must publish MFRI's suggestion publicly on its website and allow for a three week notice to submit comments before providing MFRI with its review. It is important to note that land-based aquaculture must follow completely different rules when it comes to spatial planning.

Several other additions and changes have been made to the laws since 2018. Committee shall be appointed every four years to advice the government on aquaculture matters, risk assessment due to genetic mixing with wild salmon populations, carrying capacity assessment procedures, regular reconsiderations by MAST on operation permits, MAST shall advertise publication and when operating licenses take effect, immediate reporting of escaped salmon by operators to the Directorate of Fisheries, requirements for establishing up internal control of aquaculture firms which MAST is to regularly asses if it being properly conducted, publication from MAST and MFRI of poor farm management is to be allowed, etc (See further: Lög um fiskeldi, 2020). As for area restriction legislations, new restrictions were put in place in 2019 on where permits for sea cage stations are allowed, restricting operations to 5 km to salmon rivers with >100 salmons and 15 km to rivers with >500 salmons (Reglugerð um fiskeldi 54/2019, 2019).

3.4 Summary

In this chapter, the sustainable development concept was introduced according to Lozano's (2008) TTSE, which generally assumes that sustainable development is achieved with integration of the three levels, as well dynamic interactions between levels over short-, long- and longer term as they change over time. The MLP was furthermore introduced, which studies sustainable transitions at three socio-technical levels: niche, regime, and landscape. In recent years the regime has been assumed to represent "[…] the dominant institutional rationality of a system", and therefore requiring more focus on understanding institutions (Fuenfschilling & Binz, 2018, p. 735). An important contribution of the MLP are the various transition pathways introduced by Geels and Schot (2007) summarised in table 2. Critics of the MLP have pointed out a lack of geographical sensitivity, suggesting a need to adjust the perspective to account for regional differences to better understand hindrances or enablers of transition within a regime. Lastly, the Icelandic aquaculture socio-technical regime and value chain were discussed. Primary focus will be on the grow-out stage, which is dependent on the supply of raw materials and various technical services. The relevant institutions such as the key monitoring and licensing bodies – MAST, MFRI, the Environmental Agency of Iceland and Directorate of Fisheries – were introduced along with the recent legislative changes relevant to the development of the industry.

4 Method

4.1 Research design

The selected research approach was a qualitative case study of the Icelandic salmon aquaculture industry expansion and its legitimacy and sustainability status. Case studies are generally considered useful when *how* or *why* questions are being asked, particularly about a current event which cannot be influenced in any way by the researcher, typically relying on multiple data sources (Rowley, 2002). The value of case studies applies to the extent the results can be generalised, i.e. can the results be applied to other situations (Schell, 1992), but also as supporting information, that the case study can serve as a frame of reference or lesson for future similar cases.

A qualitative approach was selected for this research – although results from a quantitative survey conducted by (Gallup, 2018) was utilised as supplementary data – as the research question focuses on understanding the underlying reason for the challenges and obstacles the aquaculture industry is confronted with, in addition to understanding how the industry has reacted to them. Furthermore, looking at the industry's sustainability status, a qualitative approach provides the insight to understand how the industry is perceived and perceives itself, and how this can impact the industry's success during its build-up phase. To gain deeper understanding, I relied primarily on interviews as they provide personal experiences and insights on the relevant issues the industry is confronted with. However, secondary data in the form of newspaper articles, survey, journal articles, and reports, to supplement data from informants.

Semi-structured interviews with a theme centred approach was taken for the research design. Twelve individuals from the Icelandic aquaculture industry, or individuals directly or indirectly related to the industry, were interviewed. As the main objective was to gain insight into the challenges, obstacles and opportunity the Icelandic aquaculture industry has been confronted with, as well as its response and status in terms of sustainability and legitimacy, it was considered essential to gain insight from not only key actors employed in the industry, but also 'outside' actors which could be considered to have unique insight. These include academic researchers specialising in environmental limitations and issues of the industry such as Rob, John and Mark, investors and advisors to Norwegian firms involved in Icelandic aquaculture expansion like Bjarne and Leif, local government employees of municipalities where sea-cage aquaculture has played a key role such as Ned, as well as insights from actor groups members – like Ted – that aquaculture will potentially impact negatively. Industry members I spoke with were employed at larger salmon aquaculture companies and I will refer to here as Paul, Steve, and Greg. I also spoke with an industry member who is interested in entering the Icelandic market, referred to here as Chris, and a land-based aquaculture industry member, referred to as Fred. Names of all participants have been changed to protect their privacy.

Table 3. Overview of informants.

Industry members in Iceland	Paul, Greg, Steve
Industry member interested in entering the Icelandic market	Chris
Land-based aquaculture industry member	Frank
Local government employee where aquaculture is a key industry	Ned
Academics with extensive knowledge in aquaculture	Mark, John, Rob
Negatively impacted actor group member	Ted
Norwegian investment firm insights	Leif, Bjarne

Semi-structured interviews were selected because they provide the opportunity to ask follow up questions should the informants bring up issues I had not thought about, while simultaneously seek answers or insight to predetermined questions or themes (Thagaard, 2010). Every interview was started by asking the informants to introduce themselves and their work related to aquaculture. This was followed by a question, asking them to describe the change in the industry since 2011/2012. This provided a brief insight into their key focus and concerns which then assisted with which theme to focus on first. After covering key topics (environmental challenges, the public, media and government's views on aquaculture, institutional concerns, opportunities and value creation), I closed the interview by asking for their future predictions for the industry: realistic vision (raunsýn) and dream vision (draumsýn). The interview guide is available in the Appendix.

The interviews could be said to reflect personal experiences to some extent as the informants were asked about their opinions and experiences on the topics, but most individuals spoke on behalf of a company or an organisation, therefore giving a more general insight into the themes. However, all informants provided me with their own reflections and experience of the industry and its developments. For the analysis, the interviews recordings were transcribed and coded based on several main themes, as suggested in (Thagaard, 2010) – such as sustainability, legitimacy and spatial differentiation – to identify patterns and reoccurring opinions and attitudes. Sub-categories were used – such as environmental, economic, and social sustainability, trust in government, industry and institutions, and rural vs. urban experiences.

I believe this research could have been conducted by relying primarily on secondary data, although it would provide a somewhat more limited insight into the industry. Furthermore, I could have applied structured interviews, rather than semi-structured interviews, but as much new information was brought up due to the fluid structure, I believe it would not have provided the same/better results.

4.2 Reflections on the research's success

The interviews were conducted through phone or video calls for the time-period February 18th through April 23rd. Each interview was recorded and lasted between 30 to 90 minutes. In-person interviews have been shown to be marginally superior to video calls, and as budget and COVID-19 travel restrictions did not allow for in-person interviews, this justifies the use of video/phone calls (Krouwel, Jolly, & Greenfield, 2019). I would argue, however, that the flow of the interviews could have been significantly better if conducted in-person based on previous experience. Furthermore, I noticed that it was occasionally difficult to hear what the informants said, leading to misunderstanding or asking for them to repeat sentences. This sometimes disrupted the flow of the conversation, leading to potential frustration. However, I do not believe this had a major negative impact on the results, as in most cases clarification was provided promptly and with ease. However, there was a noticeable difference in quality of interviews when they were conducted through a video call compared to phone call. Interaction was friendlier and more open, leading to a more natural conversation. Nevertheless, I believe the interviews were of great value and the main objective was reached.

All the informants were engaging and had a positive attitude towards the interview. In some instances, questions were interpreted in unexpected ways or misunderstood, but in those cases, follow up questions were asked to emphasise the key point of the question. I made an effort to ask open ended question, but as the interviews were semi-structured to work around topics – if needed – questions had to be improvised at certain points. In those instances during earlier interviews, I found myself stumbling around question formulation, resulting in poorly phrased questions or a leading question such as: "hasn't the rapid development been largely due to Norwegian investment and knowledge transfer?" However, when this occurred, the informant pointed this out to me, or I realised my mistake and the question was rephrased in a more appropriate way (what role do you think this foreign/Norwegian investment has had for the industry?), if informants did not bring up the topic themselves – which occurred on occasions for following interviews. Overall, I do not believe this was an issue as I reflected upon this during the analysis of the recordings.

Considering power relations, there was some asymmetry present. I became aware that I did not always feel comfortable during the interviews due to the higher status of my informants and their extensive knowledge after decades of experience in the field. This is common for interviews, as discussed in Dowling (2016), who suggests reflecting critically – both during and after interviews – on their success and interviewers' performance.

There were no significant setbacks due to the COVID-19 pandemic as I had conducted most of my interviews before it significantly started to impact firms in Iceland. Furthermore, even during the high point of uncertainty, informants still responded and were willing to participate. I noticed that conversations shifted towards mentioning what this might do to the industry, new possible challenges but as majority of the interviews were complete, it would make it difficult to redo them while including questions on future concerns for the industry related to the pandemic.

4.3 Ethical considerations

Approval from the Norwegian Centre for Research Data was gained for the data collection of these interviews. The informants agreed to have the conversation recorded on a special digital recorder, not connected to the internet. All data was stored on a secure server and has been deleted upon the conclusion of this research. To further secure the informants' personal information, all data has been anonymised, as emphasised by Dowling (2016); Thagaard (2010). Bias is a concern in any research – such as the informants or interviewer being strongly against or for the aquaculture industry or certain actor groups – but focusing on writing questions that are open-ended and reflect a neutral and observing perspective can aide in mitigate any bias of the researcher, instead of forcing an answer that they want or need (Roulston & Shelton, 2015). However, as mentioned, I unintentionally asked a leading question, so to mitigate I attempted to identify any mistakes I could have made when analysing the interviews. I expected my informants to be partial in their answers, and therefore secondary data plays an important role.

Concerning validity and reliability of the research (as suggested in: Rowley, 2002), multiple sources were relied upon to supplement information from informants or to verify claims they made, when possible. I do not have approval to publish interview data and therefore reviewing it for confirmation is impossible. However, every interview focused on the same topics, relying on several key questions designed to answer the research questions, contributing to a consistent interview process and has been made available in the Appendix. Furthermore, pattern in answers eventually emerged, suggesting validity and consistency (although experiences and circumstances could vary). In terms of external validity, as this is a case study, it is difficult to conclude if these results can be generalised for other cases, however, as this case study builds on existing theories on the MLP and sustainable development, with insights from geography, I believe it adds to the existing literature and can be of benefit when looking at cases focusing on industry expansion – particularly agro-industries – relying on FDI and technology/knowledge sharing, particularly should the industry be confronted with issues of legitimacy.

I have always been concerned with negative environmental impacts from large industries, but I attempted to approach the research from a neutral and observational perspective. However, taking a stance does not necessarily have to be negative. I am aware that perfect sustainability in any industry is near impossible, therefore we can always expect some negative environmental impact. As I am neither a part of the industry, nor part to any actor groups opposing the industry, I believe my bias will be of limited concern. However, I attempted to be aware of this issue as I worked with the research material and when speaking with informants. Therefore, I considered it of great value to include other voices aside from industry members, such as scholars and opposing actors, as they provided me with valuable insight and helped me with critically observing every topic. On occasions I shared my reflections with the informants after they made a statement, which I found to encourage further discussion on various issues.

5 The industry and sustainable development

The Icelandic salmon aquaculture industry has been expanding at a rapid rate in recent years (Hagstofa Íslands, 2020). In 2019, the salmon industry produced 26.957 tonnes of salmon, and the aquaculture industry now accounts for 9,6% of the maritime sector's export value (Hagstofa Íslands, 2019b, 2019c). The SFS, Fisheries Iceland association, assesses that the aquaculture production has been a dear addition to the rural regions in Iceland, encouraging the industry to grab the opportunity to expand production and explore all available fjords (SFS, 2019a). Currently, there are four leading aquaculture companies: Arnarlax, Ice Fish Farm, Laxar and Arctic Fish (Bjarnason & Magnúsdóttir, 2019), and majority share of these is owned by Norwegian firms (as summarised in Table 1). Looking over the past decade and the changes that have occurred, we observe a dramatic increase in production of salmon enabled by FDI, technology and knowledge transfer, largely from Norway (Erlingsson et al., 2017) – as addressed briefly in chapter 2.3. This is confirmed by the informants, particularly the industry members. To better understand the causality behind what has prompted this expansion – or *why* this expansion is taking place – it is beneficial to look at the Norwegian industry development path.

As the Norwegian salmon industry appears to be reaching its maximum capacity in volumes with the current limitations in regulations, geography and available technology (EY, 2019), a *de-alignment and re-alignment path* (Geels & Schot, 2007) could arguable be taking place. The regime is experiencing difficulties in meeting demands of increased production, value of the product is decreasing on global markets, and niche innovation still does not have a strong contender. Actors wonder how they can meet increased production volumes and while niche innovation is rapid and diverse, it still has not managed to break through (see discussion in chapter 2.2). Aquaculture firms seek solutions in the meantime, and as these solutions rely on the current technology, the most feasible option is to find new marine spaces. According to Bjarne, the firms naturally seek opportunities in Iceland, where natural resources are available and similar enough to Norwegian waters, but not being used to their full potential. However, as Bjarne informed, to obtain an operation licence in Iceland, the firms must be Icelandic, therefore they sought to invest in Icelandic firms and connect their key personnel to them. However, claiming that expansion in the Icelandic aquaculture industry is taking place only because Norway has shown interest would be an oversimplified generalisation, as "landscape changes only exert pressure if they are perceived and acted upon by regime actors" (Geels &

Schot, 2007). After all, there was willingness and motivation within the industry to expand, Norway might just have been a shortcut towards the goal.

As the above discussion suggests, the Norwegian industry is struggling with sustainable development, but even so, aquaculture is generally considered a strong contender in meeting the demands of feeding a growing global population – this is particularly true for developing countries (FAO, n.d.-b). On the FAO website, some bullet points for sustainable aquaculture development strategies and goals are specified (FAO, n.d.-a). I have identified the following points as especially relevant for discussing the Icelandic aquaculture industry (expansion) based on information provided from informants, policy makers and Young et al. (2019):

- Responsible management of the environment for the sake of future generations
- Securing orderly aquaculture development, which includes proper organisation of authorities and industry
- Securing equitable distribution of cost and benefits
- Contributing to more opportunities for improved livelihoods (e.g. income)
- Promoting wealth and job creation

Analysing the Icelandic industry's status in terms of environmental, social and economic sustainable development, I attempt to establish the foundation for understanding the key challenges and obstacles the industry is confronted with (see chapter 6) – as well as the opportunities – during its transition. Furthermore, it will help understanding where – if any – pressures on the industry to transform are coming from and how pressures, obstacles, and challenges are impacting the various actors of the industry from the MLP.

5.1 Environmental sustainability

All industry members spoke of their initiative to strive towards sustainable manufacturing, speaking of "responsible farming" and operations as an important strategy in value creation and/or building trust. There is no doubt that salmon farming in sea cages is confronted with environmental challenges, such as salmon lice, disease, harsh weather, and potential impacts related to climate change (Forseth et al., 2017; Moore, 2014; Olaussen, 2018; Torrissen et al., 2013). Furthermore, it is apparent salmon farming has a negative environmental impact, such as CO_2 emission, organic and inorganic waste generation, and the potential ecological impact of escaped salmons (Brown et al., 1987; Glover et al., 2017; Laist, 1995; Nori et al., 2011; Robb et al., 2017). These are introduced in more detail in chapter 2.4. However, the extent of these impacts can be mitigated with proper equipment, technology, regulatory framework, and monitoring. Comparatively, the issues with escapes and lice are non-existent for aquaculture on land. Instead the industry is more concerned with control of water quality and monitoring to prevent incidents such as Atlantic Sapphire's loss of 227.000 fish in February 29th (Mutter, 2020). The environmental status of the Icelandic salmon farming industry is in some cases very different from the industry in Norway, Faroe Islands, and Chile, and the following summary will illustrate where its current advantages and weaknesses lie.

Disease

As discussed in chapter 2.4.1, salmon lice remains a critical threat to the industry, particularly in Norway (Revie et al., 2009; Torrissen et al., 2013). Furthermore, viral diseases such as infectious salmon anemia (ISA) which emerged as a major concern in Norway and Faroe Island in 2001 (Lyngøy, 2003), have the potential to disrupt production. Viral diseases in farmed salmon have insofar not been an issue in Iceland, while certain viral diseases have been found within wild salmon populations – but not ISA – and as of 2018, no antibiotics have been used for seven years (Dýralæknir fisksjúkdóma, 2018). Informants from the salmon farming industry are proud of this achievement and suggest environmental factors – such as cold waters and clean, "pristine" oceans – are of key importance here. The Icelandic aquaculture industry was hopeful that salmon lice would not become a major issue like seen in Norway. This they attributed to the colder waters. However, the salmon lice was eventually found in farmed salmon in the Western fjords – resulting in a need for using medicated feed – and in 2017 its numbers increased as the winter ocean was unusually warm (Dýralæknir fisksjúkdóma, 2018). Industry members with operations in the Eastern part of the country report that they are still free of this parasite and hope this remains so. The researchers John and Mark, remarked they were not confident in this lice free situation lasting, as they always doubted the potential of colder oceans to prevent the lice from ever being a problem, suggesting it is only a matter of time before this becomes an issue in the Eastern fjords as well. Informants report that steps the industry takes to mitigate this problem are e.g. relying on naturally present lice eaters like lumpfish, not mixing generations of salmon in net pens, resting farm areas, and limiting density.

Organic waste

Having had the opportunity to learn from the mistakes of neighbouring countries, the Icelandic industry generally shows success in managing the impact of organic waste which collects under and around the fish pens. Rest periods have been generally successful in mitigating the impacts and this has been applied in Iceland (Carroll et al., 2003; Eiríksson et al., 2019). As John discusses:

> There are considerable volumes of excrement that collect on the bottom. Now there are methods used to prevent the impact from being permanent. This builds on rest periods […]. This is monitored while the benthic layer recovers to some extent. This system is being worked on in places, amongst other things with research together with the aquaculture firms. This system could be improved greatly.

Some of the ways in which the system can be improved, John specifies, is to quit relying on specific GPS locations for cages, instead making the system more mobile, enabling dynamic rotation of areas without impacting production volumes.

Inorganic Waste

Ned discussed that during the start-up days of Ice Fish Farm, there were complaints of improper waste management and general trash. However, this has not remained an issue as no recent complaints of improper waste management have been reported. Generally, improper waste management in countries with developed waste management infrastructure is less of a concern (Mmereki, Baldwin, & Li, 2016). Furthermore, waste it is not predicted to become an issue as the industry is/has been actively working towards international certifications such as ASC and BAP (see discussion in chapter 2.4.1). Industry members further remark that these certifications generally set stricter requirements than the national legislations.

Salmon escapes

The 2017 ministry of fisheries report suggested limiting maximum thresholds for salmon production based on a risk assessment of environmental impact. This risk assessment is the above-mentioned assessment of the risk of intrusion of farmed Atlantic salmon into Icelandic salmon rivers. Several other suggestions about licences, fees, monitoring and access to information on aquaculture, were made, whereas it is hoped that further regulatory development will mitigate disputes between supporters and opponents of the industry. (Erlingsson et al., 2017; Young et al., 2019).

The wild salmon stocks are considered of great value – as published in a 2018 report written for LV – culturally, financially and in terms of biodiversity. Sustainable salmon rivers with wild fish stocks hold more cultural and financial value to line fishermen compared to those of cultivated and released salmon. Furthermore, the estimated direct financial value of the wild river hobby-fishing industry is estimated around 72,5 billion ISK or €460 million (however, report from MFRI estimates this around 15-20 billion ISK or €95-130 million (Jóhannsson et al., 2017)). The value of biodiversity of the wild fish populations concerns even those that never fish, who care about environmental preservation, as most salmon rivers hold unique populations. This value is difficult to estimate (Ottesen, 2018). In 2018, holes were discovered in the nets of Arnarlax's pens in Tálknafjörður[5]. It was estimated that 5000 fish had escaped (MAST, 2018). Furthermore, Arnarlax reported a hole in one of their pens in January 2019 (MAST, 2019b). Steve remarks: "We make strong demands to ourselves regarding monitoring. We dive and examine our nets regularly and when holes are discovered, it is because we – the companies – report them ourselves to MAST." In recent years, human error is believed to be one of the main causes of salmon escapes, particularly after the NS 9415 standard was implemented (Thorvaldsen, Holmen, & Moe, 2015), suggesting a positive trend toward a decrease in escapes. MFRI's recently published risk assessment which suggests allowing an increase in number of salmon. This report included salmon rivers from the Eastern fjords of Iceland for their calculations. A recent report from RORUM on Breiðdalsá, a river in the Eastern parts of Iceland where salmon aquaculture currently takes place, argues that many of the rivers in the region – particularly Breiðdalsá – would not be able to sustain a wild salmon population naturally as currently, fish is being released into these rivers (Ágústsson & Eiríksson, 2020). Ned furthermore states that before fish releases started, there was no salmon to speak of in these rivers so there is little concern regarding potential salmon escapes. The report did not discuss the Westfjords, where salmon fishing rate is estimated around 2,7% of total salmon fishing in Iceland. The Eastern municipality accounts for 7,7% comparatively (ATVEST, 2015), suggesting there is 'not as much' value to be lost.

A critic of legislative changes made in 2019 and of MFRI's risk assessment suggest the approach is allowing for – or expecting – the genetic mixing of salmon, as actions to prevent mixing in the case of escapes are unsatisfactory. Furthermore, there is criticism of MFRI's working methods as there seems to be a focus on protecting salmon waters where populations are large and profitable while restricting access to fjords, such as Ísafjarðardjúp, for purely political reasons even if assessment should allow for 3000 tonne production (Gunnarsson, 2019). Mark furthermore points out, that critics have been a bit focused on the preservation of these profitable salmon waters, suggesting the focus might be more on cash flows rather than preservation. He further adds that the wild salmon populations have shown, with time, to reach their previous state after escapes/mixing but emphasises the need for caution and "rushing slowly" in the expansion. As the main concern lies within the fact that the Norwegian Arctic salmon is not sterile, farming of sterile fish would decrease the concerns of many opposing parties, suggests Ted.

[5] Tálknafjörður is in the Westfjords of Iceland

Climate change

A report published in 2018 for Landssamband Fiskeldisstöðva (national association of aquaculture farms) addressed the carbon footprint of Icelandic salmon farming and actions to decrease it. Feed production and transport remains the single largest cost in salmon farming and weighs heaviest in terms of carbon footprint (93%). Transport and manufacturing of packaging and transport of final product to markets is the second highest contributor (5%). This suggests limited capacity for actors in Iceland to limit their emissions. Therefore, improved use of feed is perhaps the most critical factor (Environice, 2018). However, looking at a recent report from SINTEF, it is not unlikely this carbon footprint has been underestimated, as land use change resulting from feed production – such as soya – has typically not been included due to uncertainties in methodology of calculation (Winther et al., 2020), but we need to consider differences in geography, mortality rate due to e.g. disease, energy source and other factors which might contribute to lower or higher carbon footprint. Suggested actions to decrease greenhouse gas emissions includes better monitoring to limit wasted feed, which usually ends up on the bottom of the ocean and forms sludge. This is actively done using underwater cameras and shows success, discussed John. Here, actions to limit environmental impact lines up with the industries motivation to decrease costs. Other possibilities could be finding alternatives for environmentally taxing ingredients which require long distance transports. Overall, industry members did not bring up CC as an environmental challenge to the industry, but actions that decrease costs simultaneously decrease greenhouse gas emissions. Other actions to mitigate emissions from feed include land reclamation and re-forestation (Environice, 2018).

5.2 Social and economic sustainability

Considering the three dimensions of sustainability, it is commonly claimed that true sustainable development cannot be achieved without the integration of environmental, social and economic systems, although it is still contested if these should be considered as separate systems at all (Lozano, 2008; Mebratu, 1998). It was the consensus of industry members that the salmon aquaculture industry has aided rural communities. Furthermore, Ned, from the local government of Eastern part of Iceland, claimed:

> […] can't be forgotten that this is a major opportunity for scattered rural settlements that have been struggling. No single rural settlement actions taken by the government has done as much for these towns and communities like here and in the western parts. I think it matters.

Furthermore, he said there is no doubt this is bringing the municipalities earnings. Prior to 2012, Djúpivogur had relied heavily on processing of fish from wild fisheries but the community was suddenly faced with the disappearance of their main source of jobs as the quota was moved to another region, resulting in a shutdown of the local fish processing plant. However, the aquaculture industry stepped in – ahead of their plans – to prevent that from happening, thereby keeping the processing facility in business, Greg tells (see also: Unnarsson, 2020). He further adds that the population of the town has increased since. Similar stories are told for other rural towns, as salmon aquaculture has (and has further potential to) increased available jobs – direct and indirect – increased local tax income, population and demand for improved infrastructure and services (Árnason, 2017).

The salmon farming industry, as mentioned in chapter 2.3, accounted for 9,6% of the maritime sector's export earnings in 2019 (Hagstofa Íslands, 2019b). This increase has been sharp, and Steve is optimistic this will eventually reach 30-50%, should the industry be given the chance to grow. However, criticism from Ted and Mark warn that looking at export value as a suggestion of income beneficial for the nation can be misleading as majority share is owned by Norwegian firms. Nevertheless, Steve argues that the industry's tax footprint is large for the local communities. As for economic success of the industry, Greg argues that the government has not provided the industry with the required leeway to start up business. This is mirrored in the SFS (2019a) statements that the government is not doing enough to support the growing industry, as fees are being implemented even during its build-up phase, as untimely fees would decrease Iceland's competitive advantage on foreign markets. As Greg discusses:

> It is difficult having to pay increasing taxes, special tax or increased fees on operations that are in a build-up phase – when every coin is coming from investors of the project – to have to start parting them to the treasury when this is increasing value creation in the country […] it might be a bit early to increase fees on the industry […] competitive advantage is more difficult as a result as – in the beginning – everything is much more expensive. […] we would want to have been given 7-10 years to build up and then we could examine: "wait a minute – is this something that is taxable?"

Furthermore, Paul adds that his company just recently got out of the "red numbers". There is no mention of profit at this point, although the industry is perceived to be generally doing well. Critics such as the biologist Jóhannes Sturlaugsson who worked at the Institute of Freshwater Fisheries but currently runs his own company, Laxfiskar, writes:

> It is intriguing to observe the fact that these firms [salmon aquaculture firms] are treated like start-up companies who are breaking new grounds in innovation instead of the large

established foreign firms which have pursued this field for years. Large firms, which in their home country find it normal to pay full prices for fuel, evaluations, and monitoring, but here there is need to utilise taxpayers' money so that the owners do not lose sleep.

(Author's translation from Icelandic: Sturlaugsson, 2019).

5.3 Sustainable development assessment of the Icelandic industry

One of the objectives of this research was to assess where the industry stands in terms of sustainability. Having provided a brief overview of the current environmental concerns and the industry/government response, the sustainability development status of the industry becomes somewhat clearer. It is impossible to state with confidence that the industry is 'truly' sustainable, as it is still faced with challenges such as the environmental impact of feed and issues with salmon escapes. However, there is a clear *sustainable development* process or path underway, if the regime is examined based on Lozano's (2008) Two Tier Sustainability Equilibrium (TTSE) approach. I have observed that the industry is attempting to progress and evolve and become more sustainable by considering how to mitigate or prevent negative environmental impacts. The TTSE model suggests economic, environmental, and social aspects to be in a dynamic interactive relationship, considering long-, short- and longer-term. The industry has a positive relationship with the adjacent societies, providing jobs and income, while building up its operations. Furthermore, the industry appears to be mindful of its environmental impact, generally perceiving themselves as an industry contributing to sustainable food production. The industry is considering its current and future impact on the communities and environment. However, the industry is not necessarily perceived as sustainable, particularly by actor groups that find their livelihood, or the environment threatened by the industry's activities, questioning that it is alright to expect negative environmental impact for financial gain, "[…] and in this instance, [gain] of foreign firms" as Ted put into words.

"Norway is a normal funding in this. Icelandic funding was not necessarily available when the Icelandic companies started up" claims Rob, emphasising that we must not perceive these as unnatural Norwegian influences. The fish pen aquaculture firms are Icelandic, but majority is owned by foreign firms. However, there are Icelandic ownership in all firms as this has been specially sought after (Sigurður Pétursson, presentation, February 20th, 2020). For Arctic Fish, the firm was established in 2011, but it was not until 2016 that Norway Royal Salmon invested in the firm. As for Ice Fish Farm, founded in 2012, MNH reportedly purchased a 50% share in 2014 and CEO Gíslason stated that it was the next logical step in working towards the company's goals (Hávarðsson, 2015). The situation appears to be more grounded in a mutual interest in aquaculture, where an opportunity presented itself and timing was good for this growth to take place, aided with FDI and knowledge transfer. As Steve remarks: "Aquaculture today is a great knowledge industry." Building the industry requires investing and for the largest salmon farming firms, FDI has played a great role in enabling the expansion. Paul, however, would argue that knowledge and technology has been more important to the industry than investment. As Dicken (2015) discusses, FDI does not necessarily involve knowledge transfer, but as all industry members pointed out, salmon farming relies heavily on skilled labour and therefore knowledge and technology needed to be transferred.

We could argue that an industry like salmon farming will never reach or achieve sustainability, as the ecological contradiction suggests; natural environment will keep presenting the industry with obstacles while it strives to reach maximum profits (Irarrázaval & Bustos-Gallardo, 2019). This is appropriate particularly considering the inevitable (predicted and unpredicted) challenges climate change will present the industry with in the future, as well as the increasing global population that will need to be fed. However, it is worth noting that hatcheries in Iceland could be considered among the most sustainable ones in the world as they rely on hydroelectricity and natural geothermal water. Overall, it was clear that the industry member I spoke with set their sight on making Icelandic salmon farming a frontrunner in sustainability. I have little reason to doubt these statements.

6 Turbulence of change: Discussing obstacles and challenges to the industry

Even as the expansion of the Icelandic salmon aquaculture industry is rapidly taking place, there have been significant factors limiting or slowing the industry down. Two key factors have been identified as *obstacles* to the development of the industry: legitimacy and institutions (much like Young et al. (2019) pointed out); while three main factors have been identified as *challenges* to the industry: spatial differentiations, place and environmental issues. Obstacles are defined here as hinderances to the continued development and establishment of the aquaculture regime in Iceland, while challenges are understood as environmental or geographical (landscape) factors that can impact the value of the product/ecological contradictions which the regime needs to overcome and can lead to particular development pathways.

6.1 Legitimacy

From Fuenfschilling and Binz's (2018) discussion it becomes apparent that engaging in institutional work requires not only authority, but legitimacy. Legitimacy can be challenged by various sources – ranging from individuals to large organisations – but is necessary for a firm's survival as it can e.g. impact stakeholder support or financing (Deephouse et al., 2017)

The following groups and organisations have expressed their concerns over suggested legislative changes to aid the expansion of sea based salmon farming, primarily related to issues of escapes and impact on wild salmon populations/rivers: Federation of Icelandic River Owners (LV), Veiðifélag Langdalsár, Hvannadalsár and Þverár (Fishing Association of Hvannadalsá and Þverá), Ungir umhverfissinnar (Young Environmentalists), Íslenski náttúruverndarsjóðurinn (the Icelanic Wildlife Fund), Verndarsjóður villtra laxastofna (North Atlantic Salmon Fund) og Náttúruverndarsamtök Íslands (Iceland Nature Conservation Asociation) (Kolbeinsson, 2020). This relates directly to the private ownership of aquatic spaces issue Young et al. (2019) discussed, which has perhaps been the most predominant one in the aquaculture debate in Iceland, as many salmon rivers are owned by individuals – such as farmers. Ted stresses the value of these rivers should not be overlooked.

Informants from the industry – as well as researchers – complain the media and public discussion has been somewhat hysterical, saturated with misinformation and propaganda. The Strandbúnaður conference is scheduled to be held at Grand Hótel Reykjavík in October 26.-

27.[6], where one of the topics for discussion will be counterfactuals and their impact on the salmon aquaculture debate (Strandbúnaður, 2020). This would suggest that misinformation and where it is coming from is a cause for concern for the industry, as it can decrease political and public support and therefore hinder its progress. News and blog articles like *Destiny of Icelandic salmon species are now in the hands of congressmen* (Sturlaugsson, 2019), *Many negative reviews on aquaculture regulations* (Kolbeinsson, 2020)[7] clearly demonstrate the current lack of trust in the industry and government to follow through on accountability.

Paul firmly states that the media has on occasions published misinformation which they then refuse to remove. He remarks that publishing a correction has been considered enough but as the original article remains online, it keeps circulating. Steve sighs as I ask him about this:

> It is one thing to have an objective debate about the build-up of any industry… but having to sit under, answering… The opposition decides to appeal to people's emotions: salmon rivers are going to be destroyed, [we are] pumping sewage, everything is bulldozing over the country. [Pause.] It is an endless process to thread the government's needle eye. It is made to appear completely different [from how it is]. It is maybe just a little bit difficult to deal with this under these pretences.

Indeed, articles have been published, discussing organic waste from sea-based aquaculture as sewage (Guðnason, 2020; IWF, 2020), which further supports a negative public debate built on misinformation with the public, as the article *What will remain in Iceland* (Frostason, 2020, author's translation) suggests. Organic waste from aquaculture is a well understood issue (see chapters 2.4.1and 5.1) which is being successfully managed, as John states, and should not be compared to sewage[8]. These articles are representative of the public discussion taking place – information appears to be blown out of proportions within actor groups or individuals opposed to the industry, relying on dramatic words and statements. However, an important point is brought up by Frostason (2020), which was briefly discussed in chapter 5.2: how much of the export value remains in Iceland, if majority share of companies is owned by Norwegian firms? Insofar, the industry frequently brings up the importance of export value (see: Guðfinnsson, 2018; Reynisson, 2020; SFS, 2019a), and as numbers from Hagstofa Íslands (2019a) suggest,

[6] The COVID-19 pandemic resulted in the conference being postponed from March until October.

[7] Translated from Icelandic

[8] Sewage is generally considered to be untreated domestic or industrial wastewater, containing various chemical, potentially resulting in a potentially dangerous concoction (Gee, Rockett, & Rumsby, 2015). Furthermore, legislations suggest oceans can be considered as less-sensitive regions if release of sewage does not have harmful impact on the environment (Reglugerð um fráveitur og skólp, 1999). There is little reason to compare organic waste of salmon farming to that of sewage and John points out collecting the waste would simply result in new, possibly more complex problems.

export has become significant. However, this question has not yet been fully answered and Mark remarks that this is rather similar to the strategy of industry critics.

Speaking with Ted it became apparent that the main concern of many opposing actor groups is primarily the escaped salmon and that there is little trust present towards institutions responsible for monitoring the industry – such as MAST. Ted points out that there are not just environmental concerns related to aquaculture, but threats to the livelihood and culture of river fishing. He discusses:

> We have centuries old wild Icelandic salmon population and a rich fishing culture which, I believe, is at risk if aquaculture has the negative impact it is feared to have. […] People have discussed setting up river monitoring systems in two rivers in Ísafjarðardjúp […] which can analyse if the salmon is farmed or wild […] which will remove the [farmed] salmon and allow access to the wild one. Fishermen don't find this particularly romantic – that every salmon that enters the river can't just enter on its own accord. It changes the culture of the fishing – that it is controlled by machinery and not streams and natural factors.

As Young et al. (2019) discussed, private ownership of rivers is extremely important for this debate, as the livelihood of these people is perceived to be threatened. Furthermore, Ted, Chris and Mark brought up a point that there are signs of favouritism between the aquaculture industry, certain monitoring institutions and congress members, although they did not want to make any statement that this truly were the case, only that there are reasonable concerns. Indeed, Gunnarsson (2019) points out that, in his experience, legislations appear biased against new interested actors. Actor alliances are considered to be an important factor when analysing factors that enable (or disable) sustainability transitions (Markard et al., 2012), therefore it concerning for future development of the industry and its regulatory framework should alliances be forming during the build-up phase.

Zukauskaite and Moodysson (2016) discussed that the response to incentive structures and actors' response to incentives – or the possible influence they might have – is dependent on the underlying knowledge base. This is relevant for different social or interest groups and demonstrates the importance of what information is presented to them. Thus, there is no wonder that different reactions and opinions should emerge within and between regions when the varied impact salmon farming can have on these groups is considered. Industry members and Ned claimed that the regions where aquaculture industry was present were generally positive towards the industry. As Paul discussed: "there is a difference in proximity – the people who see first-hand how this looks like [are generally more positive]". Gallup published data in 2018 which suggest there is – in fact – a regional difference in the approval rate of salmon farming.

Regions which are more likely to benefit from salmon farming, as compared to regions that do not experience these benefits, generally had more positive responses when asked about their attitude towards the salmon farming industry. However, the data suggests that the approval rate is rather high, whereas disapproval was at 26,6% as suggested in Figure 11 below.

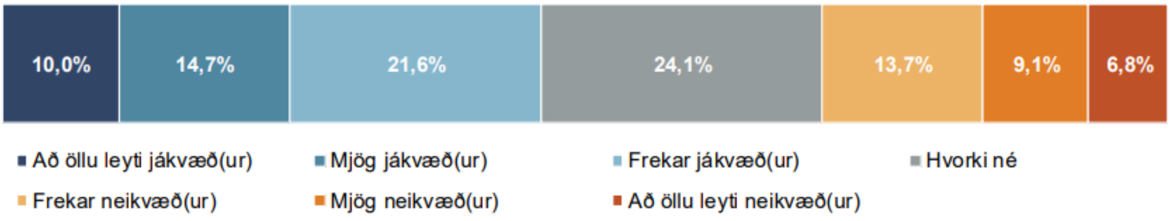

Figure 11. Attitude research made by Gallup on aquaculture in the Westfjords 2018 with 729 respondents. The question was: how positive are you towards aquaculture in the Western fjords? From left to right: positive in every way, very positive, rather positive, neither/nor, rather negative, very negative, in every way negative. 46,3% are positive towards sea-based aquaculture operations. Retrieved from: (Gallup, 2018).

As informants from the aquaculture industry mentioned, the media discussion and apparent fear of the negative environmental impact has resulted in a careful political response (although some argued the response has been too favourable, reflected in the articles written by critics). This is largely attributed to taxes and fees on the industry which some informants complained about – as establishing the industry is costly – in addition to what could be observed as "conservative regulations" or conservative attitudes within institutions like MFRI, as Mark mentioned. As Jóhannsdóttir (2016) discussed, legislation "[…] reflects a diverse preventive and precautionary approach and, to a certain extent, an ecological approach" (p. 266). Here Mark largely refers to fear of genetic mixing with wild salmon and how this is reflected within these institutions – which he views as positive, whereas attempting to make rapid changes to appeal to the industry could have dire consequences. Furthermore, Paul discusses that aquaculture only recently became approached as a critical industry for the Icelandic economy and food production: "this is the first cabinet now that mentions aquaculture. We made our mark". It is important to note that informants were not opposed to taxes and fees, in fact, Greg states that they are happy to pay for the utilisation of natural resources, just as soon as the industry has settled down.

As Zukauskaite and Moodysson (2016) discussed, various reaction to incentives within sectors, suggests that this can result in varying paths of development for sectors in different countries or regions. What remains clear from this is the salmon farming industry still needs to prove itself to critics in terms of negative environmental impact and value for the national economy. In this sense, lack of legitimacy is not necessarily an obstacle to the industry, but an important landscape pressure as understood by the MLP (Geels, 2011; Geels & Schot, 2007), pushing the industry to transform its practices towards sustainability. As Steve remarks: "The best response of the industry is to do its best, show what it is capable of and that all of this – everything that is being claimed – is not true. […]. It puts strong demands on the industry to approach this work meticulously and be careful". As mentioned in chapter 5, Icelandic salmon aquaculture firms have strived towards international certifications to showcase responsible farming methods are being used, largely to increase their products value on a global market, but this also demonstrate their strife to establish themselves as an industry in Iceland.

6.2 Institutions

Discussing regulatory changes and monitoring frameworks with industry members, some things became apparent: it is still their perception that institutions remain a limiting factor in the expansion of the industry, partially due to impact on legitimacy. Institutions are critical for this discussion, particularly as the regime is argued to represent "the dominant institutional rationality" of a socio-technical system (Fuenfschilling & Binz, 2018, p. 736). Furthermore, institutions can become enablers or obstructers of change (Hodgson, 2006). Looking over transcripts from the 78th parliamentary meeting during legislative session 149 on March 11th 2019, where aquaculture legislations were discussed, it became apparent that there is support from congress to create a strong and sustainable industry, but some disagreement regarding *how* to build a decent environmental monitoring framework were apparent (Alþingi, 2018). As Young et al. (2019) discussed, the rapid expansion in salmon farming caught Icelandic regulatory and monitoring bodies off guard. Here I illustrate the impact of this unpreparedness on the industry and its reactions to it.

Critics of the aquaculture industry are not overly pleased with the status of critical monitoring bodies such as MAST, as mentioned in previous chapter section. The lack of faith in monitoring institutions has a direct impact on trust in the industry itself, as an incident earlier this year illustrates; High volumes of salmon died at Arnarlax due to injury caused by extremely harsh weather condition, resulting in salmon rubbing against other salmon and equipment. The firm in question originally reported that approximately 100 tonnes died, which later turned out to be 470 tonnes. As this example made apparent, according to the reporter, MAST relies heavily on reports from the industry, giving the impression the industry has the power to control discussion about itself (Vilhjálmsson, 2020). Furthermore, recent regulations suggest that the responsibility is increasingly being transferred to the industry itself, but as Steve remarked, the industry has been diligent in reporting any issues as monitoring bodies find themselves uncapable to due to what informants generally referred to as lack of funding, manpower, poor structural frameworks or even lack of knowledge on the industry amongst policymakers.

What the example above and remarks from informants suggest, institutions are (still) not developed enough to respond to the industries demands, particularly as Steve discusses:

> [The government] has put many obligations and monitoring duties on these institutions and within these institutions falls not just the aquaculture, but various food production. The National Planning Agency does not only deal with aquaculture, there are also environmental evaluations for road construction […] they don't have the manpower to take care of monitoring and dealing with licensing. They have delayed this for many years [licensing]. Still, they do their monitoring well.

Legislative changes have directly impacted Icelandic aquaculture firms, both land and sea-based firms, as their timing or lack of clarity has resulted in several licensing applications to fall through due to new changes in regulations, or revocation of operating licenses (Hilmarsdóttir, 2018). Paul addresses this issue, stating that these rapid changes in legislations have made the framework difficult. Indeed, if institutions form stability for expectations and behaviours (Hodgson, 2006), their instability prevents stability in the regime, making it difficult to establish appropriate (sustainable) practices. Steve discussed that he does not think the institutions are uncapable of handling their role. The lack of manpower within these institutions has simply resulted in license application being processed too slowly, resulting in them falling through as was the case for Steve and Chris, and insofar, Chris has been unable to enter the Icelandic market. However, as Mark discusses, recent regulatory changes made in 2019 might help clarify some of previous issues, potentially resulting in more stable institutional frameworks, which would help establish the regime and improve the application process, but as (Young et al., 2019) discussed, this remains to be seen. As for land-based aquaculture, Frank discusses there are different demands and requirements so regulations relevant for sea-cage farming do not necessarily apply, but as the salmon farming expands, this has negatively impacted the land-based aquaculture industry due to slower responses, suggesting a need to reconsider the structure of the monitoring bodies.

The response from the industry to these issues has been somewhat limited. There is not necessarily much industry members can do in the face of legislative changes except engage in discourse about the needs of the industry with policy makers and criticise the current state of affairs, much like the opposition. However, industry members discussed that the new legislative changes might – indeed – have fixed some issues that were present in the framework, although they cannot be certain how things will play out. Some interesting suggestions were made to how the monitoring could be improved, one which was to move operations of monitoring closer to the industry – as currently it is centralized in Reykjavík whereas operations largely take place in the Eastern- and Western fjords of the country. Furthermore, industry members pointed out that the industry could benefit from an institution specialized in aquaculture, which would only service/monitor the aquaculture industry. This is perhaps only realistic once the industry starts to pay full taxes and fees, creating financial space for expanding the government's institutional framework.

As it stands, the institutions remain a limiting factor due to e.g. lack of funding and manpower, further attributing to lack of trust from the public/critics. The frequent structural changes being made around the time aquaculture expansion began, suggest a lack of streamlining or inexperienced structure for monitoring or handling aquaculture production of the current scale. Slow response and poorly defined/structured institutions are not just a hindrance for industry expansion, it can be an issue for the environment, society, and economy. As soon as these institutions are firmly in place, and people have gained confidence in their capability, the socio-technical regime should be established and can move forward with focus on innovation and sustainability transition perspectives. The industry could then be more capable of following through on environmental regulations, regions would benefit from jobs, and innovation could start blooming. Furthermore, a profitable industry could be taxed accordingly.

6.3 Challenges

What past experience has demonstrated, and with insight from the MLP and territorial sensitivity addition (see: T. Hansen & Coenen, 2015; Irarrázaval & Bustos-Gallardo, 2019), three key challenges for the industry could be identified. Informants discussed certain environmental factors that set Iceland apart from Norway which has served as a frame of reference to legislations. However, as industry members remarked, there is a need to adapt equipment to Icelandic situations. Additionally, Iceland is confronted with the issue of place, i.e. its geographical location in terms of distance to markets. Furthermore, there are several possible long-, short- or longer-term future environmental challenges the industry might have to prepare for and overcome. Therefore, I have defined the three key challenges to be: spatial differentiation, place, and environmental factors.

6.3.1 Spatial differentiation

When the institutions of a socio-technical regime gain validity beyond their national borders, it can be considered a global socio-technical regime. Furthermore, in a field where uncertainty and complexity is high, actors are inclined to copy what are considered legitimate institutional templates (Fuenfschilling & Binz, 2018). As can be observed from chapter 2 and 3.3, the reach of the Norwegian regime is significant and has understandably influenced the Icelandic regime as majority share is owned by Norwegian firms (see Table 1). This is suggested by congress' 78th meeting, 149th legislative session in 2018 – where it was suggested to model the Icelandic aquaculture legislations and regulations on Norwegian rules (Alþingi, 2018) – and the adaptation of the NS 9415 standard (Reglugerð um fiskeldi, 2015), pointing to it being a global regime based on Fuenfschilling & Binz's (2018) discussion. However, spatial differentiation, which takes into consideration the regional variations of niches, regimes and landscapes, needs to be considered when observing the industry's development (Raven et al., 2012). Variations between Iceland and Norway are a challenge as the industry needs to adapt equipment and regulations to Icelandic requirements, as informants suggested. Spatial differentiation is especially relevant for resource-based industries like aquaculture, as interaction between nature and firm plays a key role in forming the organisational web of the spatial production network (or the socio-technical regime) and impacts value creation (Irarrázaval & Bustos-Gallardo, 2019).

Bjarne and Leif recognise that establishing an industry in Iceland takes time as there is need to build specialised competences. Furthermore, they add that environmental impact must be taken seriously, and they believe Norway's 40 plus years of experience will be of great value in assisting Iceland with building a sustainable industry. It is therefore interesting to consider John's discussion on the earlier aquaculture guideline suggestions for Iceland from Norway that suggested using "leppefisk" (wrasse) to fight salmon lice. That fish is not present in Icelandic waters, and therefore not suitable. He discusses: "people do not always think before transferring standards". Legislations are still being adjusted to suit Icelandic requirements, as the examples in chapter 3.3.2 demonstrates, with some suggestions being made to model the Icelandic regulatory system on the Norwegian 'traffic light model'. However, arguments were made against relying too much on Norwegian (or foreign) legislations and frameworks (Alþingi, 2018). Informants suggested looking at the Faroe Islands, where knowledge was (and is) largely gained from Norway, but after setbacks due to viral disease outbreaks, search for knowledge is now refocused on a global scale (Hersoug et al., 2017). Furthermore, geographical landscape in the Faroe Islands is different from Norway. The deep Norwegian fjords generally reduce the potential environmental impact of organic waste, as it becomes diffused and less likely to collect on the bottom (P. K. Hansen et al., 2001). In the Faroe Islands, however, impact on the benthic layer has been an issue and Iceland has learned a lot from their research, discusses John. Indeed, the recent example with fish dying at Arnarlax, traced to rough weather conditions (Vilhjálmsson, 2020), suggests NS 9415 as an equipment standard might not be sufficient; spatial differentiation must be accounted for.

6.3.2 Place

The working group established by the government in 2016, which had the purpose of creating condition for growth in the aquaculture industry, support responsible industry and secure the wild salmon stocks, assessed that Iceland would never become a lead producer in salmon production, but could potentially focus on high quality and therefore higher value (Erlingsson et al., 2017). This is partly because of Iceland’s competitive disadvantage: distance to markets. (This can also be attributed to limits to production volumes, as suitable areas for farming are limited due to harsh conditions along the southern cost and legislations restricting available areas, as seen in Figure 10). This is discussed by Irarrázaval and Bustos-Gallardo (2019) as a critical factor for the salmon industry. Furthermore, as Rob informed, labour cost, feed, etc. is cheaper in Iceland compared to Norway, but as soon as export is factored in, there is a sharp rise in costs. As production costs increase in Norway and its competing countries, this becomes an increasing concern. Looking at Faroe Islands, they used to exceed Norway in quality, however, today this competitive advantage is somewhat lost while production costs are higher (Nofima, 2019).

Potential solutions could be focusing on increased volumes, but cost would probably remain high. Still, increasing volumes has been discussed to provide the opportunity to open for flight transport from the Easter fjords (Reynisson, 2020), securing more rapid access to markets. Furthermore, as Steve discusses, this would also enable secondary processing in Iceland (Figure 9), adding value to the product. Still, the best response of the industry at this point is to maintain high standards during production which, as Paul discussed, is a primary concern at his company.

6.3.3 Environmental factors

Mentioning environmental (landscape) factors specifically may seem repetitive, especially having already addressed spatial differentiation and place, as this essentially suggests adjusting to the Icelandic environment. However, the main emphasis here is on the future challenges that need to be overcome by the entire socio-technical regime, as the industry strives to develop sustainably while simultaneously utilising natural resources (marine spaces, land and marine protein sources for feed) to generate profit – an ecological contradiction (Irarrázaval & Bustos-Gallardo, 2019). These challenges are – but not limited to – lice, viral diseases, climate change impacts, unpredicted impact on the environment as the industry progresses, and accidental escapes. These challenges are the same as those in neighbouring salmon farming countries, suggesting international cooperation and knowledge sharing will continue to play a key role (see discussion in chapter 2.1). This will be an especially critical factor for Iceland to consider, as the informants claim high production standard of the salmon farmed in Iceland is what will determine its value and set it apart from the rest of the world due to disadvantage in market proximity.

6.4 Opportunities and future paths

As production is intensified in Iceland, a decision must be made: is Iceland to learn from the mistakes of other nations, including Norway, or are we to follow similar paths? What the discussions above suggest is the Icelandic aquaculture regime is not yet fully stable. A stable regime – or as Geels (2002) discusses, socio-technical systems – is formed as activity between different actor groups lead to interconnectedness between their various elements.

Considering the Norwegian salmon industry from Geels' (2002) example of the car, the industry's knowledge base is extensive, with fish health specialists and engineers who design cages, boats, and feed systems. Additionally, industry structures are diverse (see e.g.: Lusedata, AKVA Group, Laks.no display centres) as the result of cooperation strategies between salmon farmers and their suppliers. Monitoring structures are developed with decades of experience, and policymakers prioritise the industry as important for the nation, pushing for expansion which requires innovative solutions (Misund & Tveterås, 2019). In society, the salmon has been established as a frequently consumed food; a common sight at the '17 Mai' breakfast table and always present at the farmers market, where each farmer claims theirs is the best. Furthermore, news sites such as iLaks.no exist, focusing on news of the industry. Comparatively, as informants suggested, Iceland is still working towards building its industry, relevant expertise, and governing bodies. There had been little consistent or stable activity in salmon sea cage aquaculture, as the industry had been unable to gain solid footing or withstand difficult economic and environmental challenges as introduced in chapter 2.3. This would suggest a *reproduction process* prior to the sudden landscape pressure that was Norwegian investment, triggering a *transformation path*. This is suggested as niche innovation is not yet (strongly) present and, according to Geels and Schot (2007), outsiders serve an important role in pointing out negative externalities. Furthermore, various social groups are active in voicing protests, mobilise public opinion and lobby for tougher regulations. Scientists also play a critical role in criticising technical details and suggest changes to adjust technology and practices. A key point here is: “The demonstration of viable alternatives may change perceptions of regime insiders and lead to reorientations of (innovation) activities” (p. 406).

Greg discussed:

> There is no servicing industry around this [sea cage farming of salmon] so we have had to do everything on our own. […] What we see happening now is there are more parties to this which are considering helping, new firms that are servicing the aquaculture.

Many informants mentioned distance to foreign markets as a concern for the Icelandic industry. However, informants also mentioned the strong innovative environment of the Icelandic maritime industry – particularly in processing and storage technology – and discussed that there is limited reason to believe this would not happen for aquaculture if the industry is given the chance to bloom. After all, “[…] we are frontrunners in processing of fish”. The distance can therefore be perceived as a landscape pressure for the salmon farming industry, having encouraged innovation in methods of preserving freshness of the product such as Skaginn’s 3X’s SUB CHILLING™ technology (Skaginn 3X, 2018), which Greg discussed has extended the fish’s freshness period, eliminating issues they had earlier on with distance to markets and quality. Still, if the production quality of fish were to decline due to environmental factors, the gains from improved freezing technology would be limited. This has the potential to put pressure on the industry to keep production quality at a high standard, create a lively niche environment, allow firms that show great promise in farming techniques to enter the market, and focusing on building a positive reputation as a sustainable fish farming industry.

As for lack of legitimacy discussed in chapter 6.2, this could be viewed as an opportunity to creating an incentive to allow new actors with focus on closed or offshore sea-cage farming systems access to Icelandic waters, as this has the potential to aid in establishing the industry as legitimate amongst several critics and possibly increase trust in the government’s decision making towards aquaculture, as it could suggest willingness to seek solutions to the underlying key problem – salmon escapes – as moving the industry entirely to land is currently an unfeasible option albeit a very desirable alternative as viewed by critics such as Ted.

Aarset and Jakobsen (2015) researched how salmon aquaculture became the dominant aquaculture industry in Norway through self-reinforcing processes, as salmon firms, authorities and public actors have fine-tuned the institutions to its needs. They also found the momentum of salmon farming to limit expansion for other aquaculture species, as the industry has become *too* catered to its own needs, decreasing knowledge transfer opportunities for other emerging or existing aquaculture (and non-aquaculture) industries. This might suggest a risk for 'monoculture' or the stagnation of a diverse aquaculture industry, should this continue.

As suggested above, informants were optimistic that an increase in aquaculture would benefit the innovation environment in Iceland. However, if this will come at a cost to other aquaculture species, or if this will pressure other industries – like land-based aquaculture – to move towards salmon farming, remains to be seen. Currently, Iceland has some way to go before reaching the state where salmon aquaculture has developed into a stable regime but the example above suggest Iceland should encourage innovation in other aquaculture fields, even as salmon farming continues to expand. Therefore, it is a bit concerning to listen to Chris' story on how his company – which specialises in closed sea cages – has insofar been unable to enter the market despite their attempts for several years. He is concerned that there is limited interest in something "new and innovative", or perhaps that the issue lies in lobbying.

It is impossible to predict the future, but as Iceland remains a frontrunner in Arctic char production (Samherji, 2019), nurturing that industry, as well as experimenting with other species, could potentially be of great value in the unforeseeable future. Considering Samherji's recent licenses to further expand production (MAST, 2019c), I consider it unlikely that sea-based salmon farming will come at a cost for other industries and Frank is optimistic in terms of his company's expansion. Furthermore, it has been my observation that Icelandic businesses are eager to find ways in which they can set themselves apart on global markets. Hjaltason (2020) discusses that according to company owners, Icelanders are particularly well fit for innovation work – in parts thanks to the "þetta reddast[9]" attitude. Looking forward, the gradually increasing political (and public) support suggests aquaculture is establishing itself as an industry in Iceland. While actor groups and the various challenges continue to apply pressure on the industry to solve key concerns, there is limited reason to predict the industry will lose its focus on sustainable practices. However, should the environmental challenges or societal pressures ever overwhelm the industry, it is important that it considers nurturing a strong niche environment to rise to these challenges.

[9] Roughly translates to "things will work (themselves) out", suggesting everything will be figured out eventually.

7 Conclusion

The aim of this research was to study the recent expansion of the salmon aquaculture industry in Iceland. The objective was to answer how the industry is perceived, how it perceives itself and where it stands in terms of sustainability; which obstacles and challenges the industry is facing, which opportunities these present, and what the industry's response has been? For this, theories on sustainable development and the multi-level perspective were used, with insights from geography. To answer the questions, interviews with several aquaculture industry actors and an opposing actor group member were conducted. Secondary data was also used to provide credibility and critically analyse interview data.

As it stands, the Icelandic salmon aquaculture industry perceives itself as a strong (possible) contender for sustainable development on all three levels: environment, society, and economics, and its activities and contribution to society suggests the industry is working with focus on sustainable development. However, the scientific consensus remains that there is much to be done to decrease the environmental impact of salmon farming. Furthermore, there is still scepticism amongst several actor groups which is not predicted to change while sea cages carry the risk of breaking. This remains a key obstacle for further expansion, lack of legitimacy, as it has resulted in caution amongst policymakers and a conservatism approach towards licensing and requirements within monitoring bodies. However, lack of legitimacy has also put pressure on the industry to focus on sustainable practices. Other key obstacles to the industry are (still) institutional, as they have been unable to keep up with and respond to the rapid expansion and requirements of the industry and insofar failed to establish trust amongst critics. However, legislations were recently changed and their impact remains to be seen.

Key challenges to the industry were identified as: spatial differentiation, as the industry needs to adapt Norwegian equipment standards to Icelandic situations; place, as distance to markets becomes a critical cost factor, limiting market advantage; and environmental challenges which refers to any future predictable and unpredictable challenges which will potentially impact the market value of Icelandic salmon. These factors, along with lack of legitimacy, can be considered key landscape factors, pressuring the Icelandic aquaculture regime to uphold strict environmental standards to increase value creation and public support, eventually leading to the regime's stabilisation.

The drive to maintain Icelandic aquaculture at a high environmental standard is extremely critical as this is the only market advantage of the industry. Should the industry fail here, it could be in danger. Therefore I believe the industry will not lose sight of its current goal of working towards sustainability and responsible practices, and suggest that the industry and policy makers nurture innovation and enable actors with promising solutions to environmental problems access to the market. More importantly, there is a need to strengthen the institutional framework, particularly focusing on supporting the monitoring institutions by increasing manpower and competencies, as the informants reported their responses had been slow. This will be costly, but as the industry grows, so should income from tax and fees.

Iceland's example can provide valuable insight and understanding into other developing and/or emerging agro-industries relying on FDI and knowledge transfer, suggesting that it is important to consider spatial differentiation and understanding (potential) actor relationships and dynamics. Furthermore, building a competent and transparent monitoring and legislative framework to rise to any (environmental) challenges is critical in supporting the industry's legitimacy.

As the report on legislative flaws by Gunnarsson (2019) might suggest, I have merely scratched the surface of the complex dynamics between the industry, relevant institutions, critics, and critical landscape pressures impacting its legitimacy and development. This will have to be critically examined in the near future to establish faith in the regime. Unfortunately, the industry is already facing its first unexpected challenge, the COVID-19 pandemic. How this will impact the industry in the long- and longer-term remains to be seen, but industry members are calm and optimistic. It appears despite all its obstacles and challenges that aquaculture is – indeed – here to stay.

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Appendix

Interview guide

Translated from Icelandic

Quick self-introduction

I am writing a master thesis in Globalisation and Sustainable Development on the Icelandic aquaculture expansion. I want to look at the sustainability status of the industry – considering environment, society and economics – and look at how the industry is perceived and how it perceives itself. I would also like to explore where the industry is meeting obstacles, challenges, or opportunities in its expansion. Ask for permission to record, inform them they will be anonymous, data will be deleted at completion and they have the right to withdraw statements and/or participation at any point. Ask any questions informants might have about their participation or my project.

Background

Tell me about your work related to aquaculture.

Tell me about your company/organisation.

The industry

How would you describe the development of the aquaculture industry in recent years (since 2011/12)?

What have the main changes been?

What have the main challenges been?

What role has foreign investment played for the industry?

Institutions

What changes have there been in monitoring?

How has your organisation/firm experienced the legislative framework? What has the impact been?

(If unhappy): can you give me any examples of how this has impacted you?

Environment

What are the main environmental challenges?

Are there any specific challenges (or benefits) Iceland brings? Please elaborate.

What actions has the industry taken to work on these challenges?

- Ask about: escapes, lice, disease.

Society and economy

How has the industry impacted society?

Direct and indirect jobs: examples?

(Is there/will there be outsourcing?)

Where does the industry stand economically? (export value, generating profit? Paying taxes and fees?)

Legitimacy

What is your perception on public support of the industry?

- If mention of misinformation: how has this impacted the industry?
- If not: how has discussion on the media been? How has this impacted you?

What is your perception on political support?

- Follow up questions such as: what could be done to assist the industry during its build-up phase?

Challenges/obstacles for the industry (related to society and economy)?

Innovation/niche development

Can you name examples of innovation related to the salmon aquaculture industry?

Where do you see options for niche development?

Special questions for critics:

What comes to the top of your mind when expansion of salmon aquaculture is discussed?

What do you think of the actions the industry has taken to prevent (what you would consider to be) key environmental challenges?

- Are they satisfactory? Why/why not?

What do you think of the current monitoring of the industry?

- Do you trust the monitoring bodies? Please explain why/why not?

What is your experience of political/public support of the industry?

What does the industry need to do to gain approval (e.g. under what circumstances would you consider it acceptable to expand/continue salmon farming at sea)?

Closing off

How do you picture the development of the industry? (realistic vision/dream vision)

Is there anything you would like to add, that I did not ask about?

Remember to be aware of 30-minute limit and inform when they have passed.