Norwegian School of Economics
Bergen, Spring 2020

The complexity of reaching further production growth in the Norwegian salmon farming industry

A two-pronged approach to qualitatively evaluating technological development

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Master thesis, MSc in Economics and Business Administration

Major in Business Analytics, and Strategy and Management

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Abstract

The Norwegian salmon farming industry currently finds itself in a state of radical technological development. Many industry actors have recently undertaken large-scale projects to test the structural and economic feasibility of new operational technologies as a means of replacing the industry's primary production infrastructure. This phenomenon has largely been spurred by the government's institution in 2017 of a developmental licensing scheme intended to promote these initiatives. In this paper, we seek to discover the roles that these alternative production technologies play in the industry's development. We accomplish this through the usage of two complementary qualitative methods: the application of Grounded Theory to transcripts of interviews conducted with decision-makers in the industry ($n = 7$), and the employment of topic modeling using Latent Dirichlet Allocation to industry news articles ($n = 1{,}011$). Our findings indicate that the industry is limited in its production volume outputs, largely as a result of legislation implemented by the government aimed to curb negative production externalities. Additionally, we find that the domestic industry faces an uncertain future with regards to its profitability. This financial metric is expected to be negatively influenced by entrant countries to the global industry. New countries have the potential to become competitive global suppliers upon the construction and operation of local land-based RAS salmon farms to produce salmon of harvest size, constituting a threat to Norway's salmon farmers. In contrast, the usage of land-based RAS salmon farming to produce post-smolts was found to play a supportive role in the domestic industry due to its compatibility with current infrastructure and operational processes. Other alternative production technologies, such as semi-closed containment systems and offshore salmon farming facilities were not determined to play a large or immediate role in the industry's development. Furthermore, our findings suggested that the Norwegian salmon farming industry prefers to utilize and adapt existing processes, rather than to replace them entirely.

Keywords: Norwegian salmon farming · production growth limitations · production technologies · technological development · Grounded Theory · Latent Dirichlet allocation

Acknowledgments

We wish to express our most sincere gratitude to our supervisor, Stein Ivar Steinshamn, for his continual and valuable support during the process of writing this master's thesis. Additionally, we would like to thank Björgólfur Hávarðsson of the NCE Seafood Innovation Cluster, whose passion for the aquaculture industry greatly inspired us throughout this research journey. We recognize that without their unwavering encouragement, much of this work would not have been possible. We also thank all of the individuals who participated in the interviews necessary for deriving the insights as presented in this study. Finally, we would like to convey our deepest appreciation for the support of our families and friends.

Bergen, June 19th, 2020

Shelby Nicole Dennis

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“The empirical basis of objective science has thus nothing ‘absolute’ about it. Science does not rest upon solid bedrock. The bold structure of its theories rises, as it were, above a swamp. It is like a building erected on piles. The piles are driven down from above into the swamp, but not down to any natural or ‘given’ base; and if we stop driving the piles deeper, it is not because we have reached firm ground. We simply stop when we are satisfied that the piles are firm enough to carry the structure, at least for the time being.”

Karl Popper, 1935

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List of Abbreviations

CEO	Chief Executive Officer
CSR	Corporate Social Responsibility
DTM	Document-Term Matrix
EBIT	Earnings Before Interest and Taxes
EU	European Union
FAO	Food and Agriculture Organization (of the United Nations)
GDP	Gross Domestic Product
GT	Grounded Theory
HTML	Hypertext Markup Language
ICES	International Council for the Exploration of the Sea
LDA	Latent Dirichlet Allocation
MAB	Maximum Allowed Biomass
NLP	Natural Language Processing
NNCRE	(The) Norwegian National Committees for Research Ethics
NOK	Norwegian Krone(r)
NPV	Net Present Value
OEC	Observatory of Economic Complexity
R&D	Research and Development
RAS	Recirculating Aquaculture System
RO	Research Objective
RSPCA	Royal Society for the Prevention of Cruelty to Animals
SFI	Salmon Farming Industry
TLS	Traffic Light System
US	United States

1 – Introduction

Aquaculture, which is defined as "the farming of fish and other aquatic organisms" (Davies et al., 2019, p. 1), especially for food, is a central component of the Norwegian economy. Norway's aquaculture and fisheries industry ranked as the country's second most valuable export sector in 2017, surpassed only by the oil and gas industry, which was responsible for generating more than 56% of the Norwegian gross domestic product for the same year (OEC, 2020). Fish products, comprising non-fillet fresh and frozen fish, fish fillets, and processed fish, accounted for approximately 10% of the country's exports by value, bringing in over 90 billion Norwegian kroner to the nation's domestic economy (OEC, 2020; XE.com Inc., 2017). Norway has traditionally had a long-standing history of supplying large volumes of fish by means of wild capture fishing, but upon the country's commercialization of aquaculture in the 1970's, much greater potential to expand the industry was attained (FAO, 2020e). Beginning in the 1990's, the development of value creation within aquaculture began to skyrocket past that of wild capture fisheries, paving the way for a fundamental change to Norway's methods of fish production (Ministry of Trade, Industry and Fisheries, 2015a). Though the Atlantic salmon was never highly sought out for capture in Norway, with its highest annual capture volume in a single year reaching just 520 tonnes in 1992, the species quickly became the frontrunning candidate for Norwegian aquaculture operations (FAO, 2020b). As of 2018, 94.6% of all production volumes of farmed fish in Norway were harvests of Atlantic salmon, while 5.0% were of its salmonid relative, the rainbow trout (FAO, 2020b). During this year, nearly 1.3 million tonnes of Atlantic salmon were produced, valued at over 68 billion Norwegian kroner (FAO, 2020b; XE.com Inc., 2018). This constituted over half of the year's global production volumes of Atlantic salmon, making Norway the world's foremost supplier of this species (FAO, 2020b).

Despite experiencing several decades of steep growth in production outputs, the Norwegian salmon farming industry has struggled since the year 2012 to sustain increases in production volumes (FAO, 2020b). Overcoming stagnant levels of production became even more difficult for Norway's salmon farmers to accomplish since the country's introduction in 2017 of its Traffic Light System regulation, which primarily aims to limit negative effects caused to the environment by industry operations (Ministry of Trade, Industry and Fisheries, 2015a, 2017). To keep the industry's production at a level that is environmentally sustainable, the Traffic Light System periodically determines the upper limit on the maximum allowed biomass of salmon which can be simultaneously held in sea-based open net pens – the primary infrastructure currently used to raise salmon in Norway – within one of the 13 delineated production zones on the Norwegian coast (Ministry of Trade, Industry and Fisheries, 2015a, 2020). More positive for salmon farmers was the initiation in 2015 of legislation with the intent to stimulate investment into research and development of innovative solutions for the challenges posed to or resulting from the Norwegian salmon farming industry, including production space limitations and environmental damage (Directorate of Fisheries, 2020e; Hersoug et al., 2019). This has spurred the application and subsequent implementation of several different production technologies, which have been used as alternatives to traditional open net pen salmon farming (Directorate of Fisheries, 2020b). These alternative production technologies are largely unproven as of the time of writing, but may hold the key to inducing further production growth and advancing the development of the Norwegian salmon farming industry.

1.1 – Research objectives and motivation

In light of recent changes in Norwegian regulation aimed to align industry actions with the country's values of conducting aquaculture operations in an environmentally-conscious manner, while remaining a global leader in Atlantic salmon production, it is tenable that the investment in alternative production technologies is already being discussed to various degrees among producers within the Norwegian salmon farming industry. As researchers, we wish to uncover the influence that these technologies have in the decisions that industry participants are making today to better ensure their companies' production volumes and overall success in future years. To this end, we hoped to better understand these individual decisions, opinions, and expectations, in order to build an aggregated framework which uncovers indicators of the Norwegian salmon farming industry's development.

In this academic work, we aim to provide valuable insight in response to the following research question:

Research Question

What roles do alternative production technologies play in the development of the Norwegian salmon farming industry?

With respect to our research question, it is necessary to first acknowledge that investments made into alternative production technologies are largely long-term, and that there is, therefore, both a present aspect, in which a company decides to allocate current financial resources towards the project, and a future aspect, in which the company is able to realize revenues related to their capital expenditure in future years. However, we note that we are more concerned with how the industry is taking steps today and considering alternative production technologies as a response to current challenges (which are tangentially connected to a future timeframe), than with making predictions on specifics of what the industry landscape will look like over the long term.

Thus, in order to answer our research question, we pursue the two following research objectives:

Research Objectives (RO)

RO1: *Establish a comprehensive understanding of the current state of the Norwegian salmon farming industry.*

RO2: *Analyze proxy indicators for the Norwegian salmon farming industry – interviews with industry representatives, and recent industry news articles – to determine the roles of alternative production technologies in the industry's development.*

It is imperative to provide the reader with a proper theoretical foundation in order to portray the gravity of the current situation and emphasize the need for alternative production solutions within the Norwegian salmon farming industry. To this end, we employ chapter 2 (theory) to accomplish our first research objective and use our findings from chapters 4 (analysis) and 5 (discussion) to shine light on our second research objective.

To our knowledge, there is no current literature which evaluates the salmon farming industry's incorporation of novel production technologies from the industry's own perspective. During the course of our research, we read various academic works on the subjects of the technical feasibility and structural implementation of these technologies, as well as the financial implications for companies which choose to invest in them. The work which we found was most relevant in providing similar insights was the article "Factors Driving Aquaculture Technology Adoption," written by Kumar et al. and published in 2018 in the *Journal of the World Aquaculture Society*. In this article, the authors discussed the various factors which may lead farmers to adopt new technologies as part of their operational activities, and which may further propagate this technological use by others in the industry. The authors' approach to fulfilling their research objective was to conduct an extensive literature review, using sources from as far back as the year 1949, to understand the motivating factors which have historically influenced such adoption decisions. Additionally, the work was meant to draw conclusions from a broad sample of aquaculture activities, in which the cultivation of various species, including tilapia, catfish, shrimp, and salmon, among others, was considered. This also required that the authors investigate aquaculture technology adoption on a largely international scale, and that findings were made based upon a conglomeration of all countries participating in the global aquaculture industry.

In contrast, we wish to explore the specificities of the Norwegian salmon farming industry in exclusive detail. Thus, our work is pioneering in that it empirically seeks to understand the domestic industry's opinions on and implementations of novel aquaculture technologies, given the current industry practices in which the traditional method of open net pen farming is predominantly utilized. Furthermore, we are interested in assessing only the current state and development of the Norwegian salmon farming industry with respect to these alternative production technologies. In this manner, we hope to accurately portray contemporary opinions and concerns of current industry actors for the purpose of answering our research question.

1.2 – Structure of the thesis

The structure of the following chapters of the thesis is given as follows: Chapter 2 gives the theory behind our work, detailing the elements necessary for the reader's comprehensive understanding of the Norwegian salmon farming industry's production processes, challenges, as well as the stimulating and limiting factors for its development. Chapter 3 presents our research design, describes our application of the acquired data, and explicates our two chosen research strategies used for the purpose of drawing insightful conclusions from the data in order to answer our research question. Chapter 4 presents the analyses and results retrieved from each respective research strategy. Chapter 5 discusses our results and how our research helps to illuminate the roles that alternative production technologies play in the development of the Norwegian salmon farming industry. Chapter 6 concludes our work, summarizing our most important findings, presenting the limitations of our work, and citing major areas for future research.

2 – Theory

In order to fulfill our first research objective, we employ chapter 2 to present the reader with the information necessary to establish an understanding of the current state of the Norwegian salmon farming industry (SFI). In this manner, we aim to facilitate the reader's comprehension of the potentially momentous impact that alternative production technologies can cause to the trajectory of the Norwegian SFI's development. Thus, we explicate this foundational material according to the following structure: the life cycle of the Atlantic salmon is given in subchapter 2.1; the prevailing production process used in Norway to cultivate Atlantic salmon is given in subchapter 2.2; the regulatory framework that both supports and confines the domestic industry is given in subchapter 2.3; the projected future developments in the global demand for Atlantic salmon, as well as advancements which can be used to optimize the Atlantic salmon production volumes that Norway is able to supply, are given in their respective subchapters 2.4 and 2.5; followed by a description of the open net pen method of salmon farming, and the significant alternative production technologies which have been proposed as its replacement, as given in subchapter 2.6.

2.1 – The Atlantic salmon life cycle

Salmonids are pilgrims by nature, although they may not be motivated by spiritual reasons and their geographical destinations may not be shrines. The fact that, as long-distance commuters, they spend much of their energy and lifetime migrating between breeding and feeding grounds has given them this unique status. In this subchapter, we first provide a short overview of the commercially important salmonid species, followed by further detail about the Atlantic salmon's life cycle.

Six species of salmonids are considered commercially relevant, all of which naturally are found in the northern hemisphere and are either farmed or caught from the wild (Asche & Bjørndal, 2011). Five of these species are native to the Pacific Ocean, only two of which, the Chinook salmon and the Coho salmon, are cultivated using aquaculture (Asche & Bjørndal, 2011). Over the last ten years, the *Salmo salar* – also referred to as Atlantic salmon – has consistently comprised almost 95% of all farmed fish biomass in Norway, making it the country's most cultivated species of fish (Directorate of Fisheries, 2020a; FAO, 2020a). Therefore, throughout this work, our attention is directed to this specific salmonid species. To ease readability, we hereby refer to this species as "Atlantic salmon," or more simply, "salmon." The Atlantic salmon is endemic to regions with subarctic temperatures (Aas et al., 2010). Consequently, wild populations of the fish can be found in all countries with rivers that flow into the North Atlantic Ocean (Hendry & Cragg-Hine, 2003). Appendix A illustrates the species's global natural habitat, which has been diminishing primarily due to habitat alterations, such as human-made barriers obstructing its migration routes, impairment of water quality, and environmental damage stemming from the SFI (Gross, 1998; Hendry & Cragg-Hine, 2003). The combination of declining wild salmon stocks and a rising biomass of farmed fish over the last five decades have led to the current situation, in which well above 95% of all Atlantic salmon globally reside in commercial fish farms (Forseth et al., 2019; Verspoor et al., 2007).

If not impeded by impassable obstacles, such as waterfalls, Atlantic salmon are *anadromous*, meaning that they hatch in freshwater, migrate to seawater for feeding purposes, and return to the freshwater to spawn (Klemetsen et al., 2003; McCormick et al., 1998). To understand the complexity and challenges involved in cultivating Atlantic salmon, it is vital to shed light on the species's several, distinct stages of life. Table 1 summarizes these stages and their key characteristics. In the following text, we expand upon each stage of life.

Table 1. Overview of the seven stages of life of the Atlantic salmon

Order	Stages of life	Key characteristics
1	Alevins*	Alevins most commonly hatch in the first spring after the breeding season and feed from their yolk sacs.
2	Fry*	Fry feed from microscopic invertebrates and remain in this stage until the end of the first summer.
3	Parr	Parr are highly territorial and stay in this stage of life for one to four years until they start swimming with the current instead of against it.
4	Smolts	During this stage of life, the salmon go through a so-called smoltification process, preparing them for life in the sea.
5	Post-smolts*	Post-smolts live in the sea and remain in this stage until the end of the first winter; many of them struggle to adapt to the new environmental conditions.
6	Grilse	If post-smolts survive the first winter, they become grilse which may return to their home rivers for reproduction purposes.
7	Kelt*	After having spawned in their home rivers, the fish enter their kelt stage of life and return to the sea. Kelt develop a noticeable hooked jaw.

Note. * These stages exhibit exceptionally high mortality rates resulting from their early defenselessness (alevins), scarcity of food sources during spring (fry), adaptation to new food sources and new predators (post-smolts), and loss of body mass caused by an energy-intensive upstream migration (kelt). Adapted from *Atlantic Salmon Ecology*, by Aas et al., 2010, and "Ecology of the Atlantic Salmon," by Hendry & Cragg-Hine, 2003. For the reader's further interest, a collection of photographs of the Atlantic salmon in its various stages of life is provided in Appendix B.

Atlantic salmon spawn in freshwater during autumn or winter, and their fertilized eggs hatch in the subsequent spring (Aas et al., 2010). The timing of hatching strongly depends on the water temperature. Accordingly, fertilized eggs laid in the south, in warmer waters, hatch earlier than those laid in colder, northern regions (Heggberget et al., 1988). For the first three to eight weeks, the freshly hatched *alevins*, which are usually between 15 and 22 millimeters long, gain nourishment from their yolk sacs (Saltveit & Brabrand, 2013). After this highly vulnerable and immobile period that is characterized by the extraordinarily high mortality rate of 99.5%, the alevins develop into *fry*, which feed on microscopic invertebrates such as insect larvae (Asche & Bjørndal, 2011; Hendry & Cragg-Hine, 2003). The fry experience another tough phase in which they are subjected to natural selection, as proper food sources remain scarce during spring (Stradmeyer & Thorpe, 1987). Upon developing vertical camouflaging stripes, the fry turn into highly territorial juveniles, called *parr*, which feed on insects caught from the surface of the water (Hendry & Cragg-Hine, 2003). The parr reside in their native rivers for one to four years, and grow to a size of about 5 centimeters in length (Hendry & Cragg-Hine, 2003).

Approximately 16 months after hatching, at the end of their stage of life as parr, mostly between April and June, the fish start swimming with the river's current instead of against it, and undergo a morphological and physiological transformation process (Asche & Bjørndal, 2011; Marine Institute, 2020). This process is referred to as *smoltification*, in which the parr transform into distinctively silver-colored *smolts*, weighing around 40 grams each. This involves an energy-intensive redesign of the fish's salt-balancing system – taking it from an organism fit for freshwater to one that is resistant to large amounts of salt which previously would have been toxic (Asche & Bjørndal, 2011; McCormick et al., 1998). After having entered marine waters, the fish transition into their *post-smolt* stage of life, in which they remain until the end of their first winter endured (Hendry & Cragg-Hine, 2003). This stage is characterized by exposure to new species of predators and adaptation to unfamiliar forms of food in the sea (Klemetsen et al., 2003). The majority of post-smolts struggle to adapt to their new environmental circumstances, which leads to a high mortality rate of 90 – 99% (ICES, 2018). Due to the abundance of food sources in the sea, post-smolts experience a significant increase in their length to between 10 and 20 centimeters and in their weight to up to 80 grams (Hendry & Cragg-Hine, 2003). After their first winter in the sea, the post-smolts become *grilse*, and may either return to their home rivers to spawn or stay in the sea for another one to three years, before migrating back (Aas et al., 2010). Once the grilse have spawned, they reach the *kelt* stage of life, achieving lengths of between 45 and 135 centimeters, and weighing between 1 and 25 kilograms (Aas et al., 2010).

As opposed to most Pacific salmon species, Atlantic salmon are *iteroparous*, meaning that they are not genetically predisposed to dying after their first return to freshwater for breeding (Verspoor et al., 2007). However, the energy-intensive pilgrimage to their home rivers leads to a reduction of weight by approximately 40% for both female and male fish (Hendry & Cragg-Hine, 2003). As a result of this exhausting feat, only 3 – 6% of the kelt survive a second migration from the sea to freshwater (Hendry & Cragg-Hine, 2003; Mills, 1991).

2.2 – The production process

There are different methods of approaching the presentation of the production process of Atlantic salmon, depending on the purpose of the associated research. In this work's analysis, posed in chapter 4, we seek to build an integrated theoretical framework that explains the roles that alternative production technologies play in the development of the Norwegian SFI. Since these technologies may extensively modify the production process of this species, it is crucial to gain a comprehensive understanding of the individual steps of production involved in the farming of Atlantic salmon. On these grounds, we present the production process chronologically and relate the different steps of production to the fish's associated life cycle stages, as previously described.

Put succinctly, the effective production of salmon is accomplished through human alteration of the fish's life cycle and management of the environmental factors that influence it (Beveridge, 2004). In Norway, a single production cycle takes about three years to complete (RSPCA, 2020). Individual steps within the production process can be classified as either being part of the freshwater production phase, lasting for between 10 and 16 months, or the seawater production phase, lasting for between 12 and 24 months (Mowi, 2019). Figure 1 details the most fundamental steps of production, which we further elaborate on in the following paragraphs, and highlights the freshwater and seawater phases.

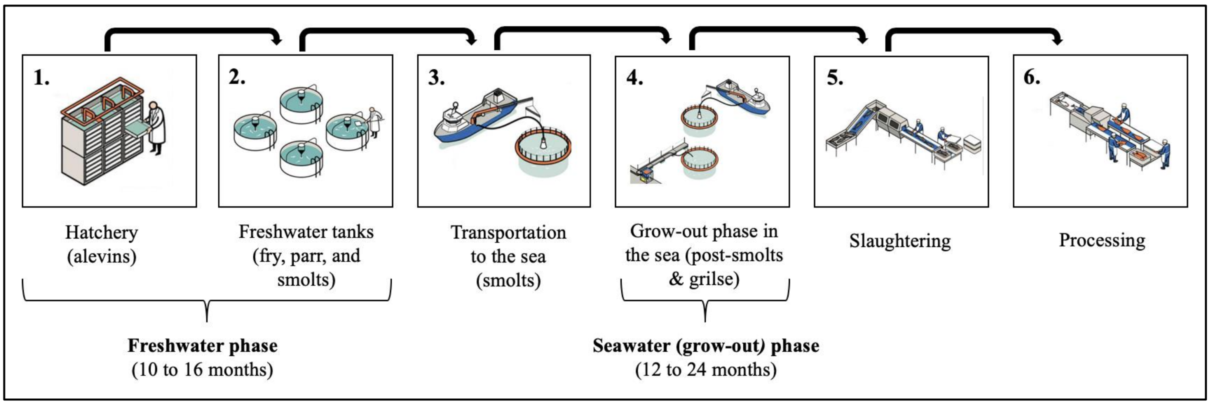

Figure 1. The six fundamental production steps for the farming of Atlantic salmon

Note. The grow-out phase in this illustration rests on the traditional and prevailing production technology: open net pens. The open net pen method of farming is explicated in more detail in subchapter 2.6.1. Concisely explained, open net pen structures are floating enclosures located in seawater near the coast. The net barrier prevents the fish from leaving the enclosure but allows for the exchange of water and other factors, such as salmon lice and nutrient waste, between the facility and the natural environment. Adapted from *Salmon Farming – Industry Handbook*, by Mowi, 2019, and *The Norwegian Aquaculture Analysis 2017*, by Ernst & Young AS, 2017.

Generally, Norwegian salmon farming companies either manage the entire production chain, referred to as *full production*, or specialize in the so-called *grow-out* phase, which takes place in seawater (Lekang, 2013). The first step in the full production process is the fertilization of salmon eggs, necessitating the use of independently raised broodstocks cultivated for the specific needs of aquaculture, such as the need for faster growth rates (Cermaq, 2020). After the eggs have been fertilized, they are transported to hatchery tanks (Asche & Bjørndal, 2011). The incubation period lasts for about two months; subsequently, the fish hatch as alevins and feed from their yolk sacs as they would do in the wild (Asche & Bjørndal, 2011; Mowi, 2019). The time from fertilization of the eggs to hatching is often sped up artificially by heating the water (Viera et al., 2013). By means of human intervention in the Atlantic salmon's life cycle, the mortality rate of the highly vulnerable alevins can be reduced to 30%, in contrast with the 99.5% rate experienced in the wild, still indicating potential room for efficiency improvements for the industry in the future (Asche & Bjørndal, 2011).

Once the newly-developed fry have consumed their yolk sacs, they are moved to larger freshwater tanks, which are closed production units on land where the salmon are housed during their subsequent stages of life as fry, parr, and smolts (Lekang, 2013; Nordlaks Produkter AS, 2020). Once again, human intervention, including the addition of liquid oxygen as well as the calculated modification of daylight, initiates an earlier occurrence of the smoltification process (Asche et al., 2018; Nordlaks Produkter AS, 2020; Viera et al., 2013). The modification of daylight involves adjusting the amount of light the fish are exposed to, in order to replicate the spring season and trigger the smoltification process after just eight months from initial fertilization of the eggs, whereas this biological progress takes around 16 months in the wild (Abolofia et al., 2017; Nordlaks Produkter AS, 2020). Additionally, genetic alterations of the independently raised broodstocks, induced by focused breeding methods in the industry, lead to a significant increase in the weight of the smolts – from around 40 grams in the wild to 100 – 250 grams in freshwater tanks (Asche & Bjørndal, 2011; Mowi, 2019). The outputs of the freshwater phase, the smolts, can either be used as inputs for the subsequent grow-out phase in seawater or be sold to other salmon farming companies (Mowi, 2019).

Once the Atlantic salmon have successfully completed their morphological and physiological transformation in freshwater tanks, they are equipped for the grow-out phase and are transported in large tanks on vessels to floating open net pens in the sea (Ilknak, 2015). This phase is called the grow-out phase because the fish are grown to their marketable weights of approximately 2 – 8 kilograms (Asche & Bjørndal, 2011). The grow-out phase in seawater lasts for 12 – 24 months, making it the most time-consuming step within the entire production process (Asche & Bjørndal, 2011). For biological reasons, the fish can only be released into seawater during the warmer months, from March until October (Asche & Bjørndal, 2011). Two release cycles are utilized, one in spring and one in autumn, in order to address time-related market needs across the globe (Asche & Bjørndal, 2011). Another important implication of this step of production is the farmers' loss of control over the environment. Asche et al. (2018, p. 452) compared Atlantic salmon farming to chicken production and, inter alia, concluded that, "the control over the production process is still quite limited for salmon," because the grow-out phase most commonly takes place in open net pens that allow surrounding environmental conditions, such as strong currents and storms, to impact the fish's wellbeing (such as by inducing stress and increasing mortality rates).

After 12 – 24 months in seawater, the salmon are removed from the sea pens, either by means of integrated pipe systems that load them onto dedicated harvesting boats or by moving the entire pen closer to the coast, and subsequently transported to slaughter plants (RSPCA, 2020). Although wild Atlantic salmon do not die after breeding, allowing the fish to grow to its kelt stage is not economical because the weight loss associated with this stage of life would require the fish to spend another year at sea before it can be harvested (Asche & Bjørndal, 2011). After slaughtering, which is done either by hand or using machinery, the fish are cooled to 0 degrees Celsius (Viera et al., 2013). In the last step of production, the fish are gutted and, depending on the purchasing company and its customers, either filleted and cold smoked or simply frozen and packaged before they, finally, are transported to various consumer markets (Viera et al., 2013). Only a small fraction of the total Norwegian production volume is intended for the domestic market, as 95% of it is exported (Viera et al., 2013).

Throughout the entire production process, there are numerous ways of stimulating the fish's growth, which can be described as a complex function of well-researched conditions, such as exposure to daylight or the quality of feed (Asche & Bjørndal, 2011). However, since our research objectives do not converge with the optimization of these biological growth criteria, we chose instead to illustrate the cost structure inherent in the production process, which allows the reader to understand which production costs the SFI is most sensitive to. Figure 2 provides a descriptive illustration of recent developments in the cost structure per kilogram of farmed Atlantic salmon in Norway. It shows that feed costs, other operating expenses (associated with fish health and environmental costs), as well as slaughtering and processing costs are the major production costs within the entire production process. While the total cost per kilogram of farmed Atlantic salmon changed only slightly between the years 2016 and 2018 (from NOK 35.45, to NOK 33.78, and then to NOK 33.88), the total cost in 2018 had risen significantly (by 18%) when compared with its 2014 level. The figure also shows that the relative contributions of the production costs to the total cost per kilogram remained rather stable. However, all cost components, except for net financing, experienced considerable surges in absolute terms in the time frame of 2014 – 2018 (as exemplified by slaughtering and processing costs, which rose by 39%).

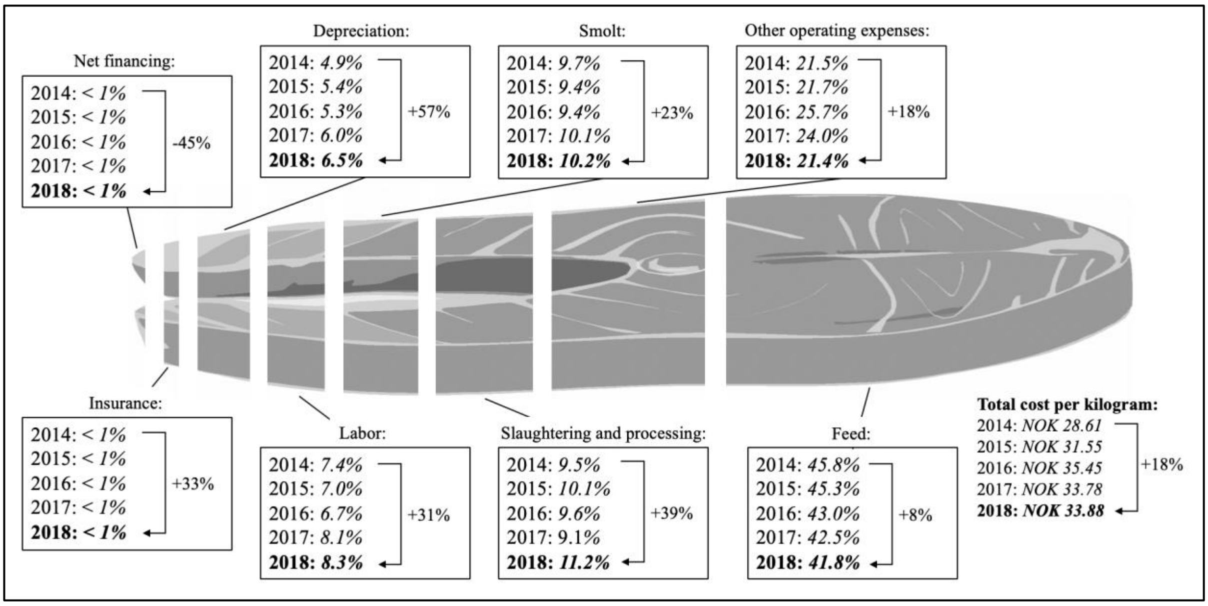

Figure 2. Major production costs per kilogram of farmed Atlantic salmon

Note. The cost data were adjusted for inflation according to inflation rates provided by Norges Bank (2020). The figure comprises data from the years 2014 – 2018 and shows the development of the relative cost distribution per kilogram, as well as the relative changes of the various production costs' absolute costs. Accordingly, the percentage numbers next to the arrows constitute the relative changes of the respective cost components' absolute costs from 2014 – 2018. For example, feed costs rose from NOK 13.10 in 2014 to NOK 14.15 in 2018, constituting a relative change of +8%. Data for the year 2018 are the most recent available data. The production cost for "smolt" comprises all costs related to the production of smolts (in the freshwater phase). Adapted from "Kostnad pr. kg 2008 – 2018," by FAO, 2020c.

In this subchapter, we have outlined the main steps of production and production costs inherent in the farming of Atlantic salmon. It should be noted that Norwegian salmon farmers cannot exclusively consider challenges related to the operational aspects of producing salmon but must also account for environmental challenges experienced throughout the production process. Subchapter 2.2.1 elucidates the two most critical environmental impacts stemming from the SFI. Addressing these impacts is particularly important in order to understand why the industry's production capacity is strictly limited by domestic regulations, and why alternative production technologies can offer an additional avenue for the expansion of the industry's current production output volume.

2.2.1 – Main environmental challenges

The grow-out phase of the Norwegian SFI's production process causes considerable effects to the environment. The issue that has thus far been taken most strongly into consideration when designing regulatory frameworks for the industry is the preservation of wild salmon populations (Ministry of Fisheries and Coastal Affairs, 2009). The term *anthropogenic* refers to alterations of the environment caused directly or indirectly by human activity (Forseth et al., 2017). As nearly 75% of the world's wild Atlantic salmon stocks are found in Norway, the

Norwegian government has recognized its international responsibility to preserve these stocks, and has adjusted its policies in a way that particularly aim to reduce the Norwegian SFI's harmful impacts on the environment (Hindar et al., 2010; Thorstad & Finstad, 2018). Forseth et al. (2017) established an expert-based, two-dimensional classification system, ranking the SFI's anthropogenic factors by their effects on wild salmon stocks and their potential to endanger the species in the future. They found that the increased number of salmon lice and escapements, directly resulting from farming activities, constituted the most serious threats to wild salmon populations (Forseth et al., 2017).

An *externality* is an economic term that refers to a situation in which the activity of one economic agent causes an uncompensated cost (a negative externality) or benefit (a positive externality) for an uninvolved party (Ekins, 2000). *Negative production externalities* arise when an economic agent's production process incurs costs for another party without compensating it for these costs (Saez, 2020). In the following paragraphs, we outline the environmental impacts that the two negative production externalities of increased number of lice and escapements have on wild salmon populations.

Salmon lice, also known by their Latin name *Lepeophtheirus salmonis,* are parasites that attach to the skin of fish, primarily species of salmon, and feed off of their host, causing biological disorders including problems within the salt-balancing system, anemia, weakened growth, and, eventually, premature death in severe cases (Olaussen, 2018; Thorstad & Finstad, 2018). In the industry, salmon lice are commonly categorized as either being mobile, meaning that the parasite resides on the outside of the fish and eats away its skin and flesh, or as being attached, having embedded itself more permanently within its host and gaining nourishment from the fish's blood (Burridge et al., 2010). Without human intervention in their ecosystems, wild Atlantic salmon are not necessarily endangered by natural levels of lice, but as a result of farming activities and the consequently greater number of Atlantic salmon in areas concentrated with farming operations, the numbers of salmon lice have surged (Fjørtoft et al., 2017; Olaussen, 2018). The reason for this is that farming sites in coastal areas increase the density of potential hosts for the parasite, and thereby establish optimal reproduction conditions for it (Heuch et al., 2005). Hosting fewer than 10 salmon lice is not life-threatening to individual Atlantic salmon, but up to 100 lice per wild fish have been documented in regions that exhibit dense farming activities, posing a significant threat to fish health (Revie et al., 2009; Thorstad & Finstad, 2018).

First and foremost, it is wild salmon populations, passing areas dense in farming during their journeys from rivers to offshore marine locations, that are threatened by the anthropogenically increased number of salmon lice (Olaussen, 2018). Because of this negative impact on the environment that can potentially endanger wild salmon populations, with no compensation for any environmental downside, the increased levels of salmon lice resulting from salmon farming can be categorized as a negative production externality. In contrast, naturally occurring levels of salmon lice do not constitute an externality, but a natural phenomenon. The risk posed to wild salmon by the high number of salmon lice caused by dense farming activities was also substantiated by Thorstad and Finstad (2018), who confirmed that there are steady spillover effects of lice from farmed to wild populations of fish. It is impossible to account for the exact number of deaths of wild salmon caused by salmon lice, but it is estimated that 12 – 29% of adult wild salmon in Norway die annually due to the higher levels of salmon lice caused by salmon farming (Thorstad & Finstad, 2018).

It should be noted that the artificially increased numbers of salmon lice do not only harm the environment, but also induce another negative production externality among the producers themselves – an effect referred to as *producer-on-producer externality* (Just et al., 2005). To illustrate this, Jansen et al. (2012) documented a positive relationship between farm density in coastal waters and farm-level parasitic salmon lice infestations, and reasoned that this is because salmon lice also spill over from producer to producer. This producer-on-producer externality can lead to weakened growth rates and increased mortality rates of the farmed salmon (Jansen et al., 2012). Although Abolofia et al. (2017) showed that salmon lice infestations can cause damages amounting to as much as 9% of total farming revenues, governmental regulations mainly aim to restrict the industry's negative production externality on the environment, which may indirectly also mitigate producer-on-producer externalities (Ministry of Fisheries and Coastal Affairs, 2009).

Farmed salmon escapements constitute another negative production externality in the SFI, and its effects can roughly be divided into the two following types: *ecological effects* and *introgression effects*. Ecological effects relate to the way that farmed and wild salmon interact (Forseth et al., 2017). Since farmed Atlantic salmon tend to be territorial and aggressive, escaped fish are able to gain control over natural food sources and river habitats, which can lead to repression or even extinction of native wild stocks (Fjørtoft et al., 2017). Introgression effects, describing the genetic interchange among different Atlantic salmon populations' gene pools, are considered to have a much greater negative impact on wild salmon than ecological effects (Olaussen, 2018). In Norway, Atlantic salmon has been farmed for at least 13 generations (Glover et al., 2017). Consequently, the farmed salmon differ in various characteristics from wild salmon, including their genetic makeup, physiology, behavior, smoltification process, and growth rates (Glover et al., 2017). It has been evidenced that interbreeding between escapees and wild fish lowers the offspring’s stamina, chance of survival, and reproduction rate (Fleming et al., 2000; Glover et al., 2017; Skaala et al., 2012). Karlsson et al. (2016, p. 2488) took representative fish samples from 75% of the spawning locations of wild Atlantic salmon in Norway and found that the majority of rivers hosting Atlantic salmon showed “significant” introgression levels. Although larger investments into more resilient open net pen constructions over the last two decades have helped to decrease the number of escapes caused by storms, attrition, and damage to the nets caused by predators, from 2006 – 2019, the number of annual escapes still ranged from approximately 17,000 to 917,000, with an average of 247,000 (Directorate of Fisheries, 2020c). To put this in perspective, it is estimated that this average number of escapees constitutes around half of the total number of Atlantic salmon which return each year to rivers to breed (Olaussen, 2018).

2.3 – Regulatory framework

The environmental impacts of the Norwegian SFI’s negative production externalities are undoubtedly set to shape the industry’s development, due to their significant influence on the regulatory landscape pertaining to the industry. Since an understanding of these regulations’ domestic effects is a prerequisite for comprehending the reasons behind the industry’s strict production limitations, in this subchapter, we outline the most substantial regulatory interventions and their impact on the development of the industry’s production volumes.

Loayza and Serven (2010, p. 14) defined regulations as arrays of rules designed to intervene in certain efforts made by economic actors, for the purpose of achieving public goals. Motives inducing governments to pass such sanctioning rules can generally be categorized as being based on *market failure* or *justice-based* rationales (Baldwin et al., 2012).

The Norwegian SFI’s associated market failure, in which the environmental costs of negative production externalities are not incorporated in the final market price for processed Atlantic salmon, calls for governmental intervention (Christiansen, 2013). In order to understand how externalities can lead to market failure, it is worthwhile to briefly elaborate on some basic economic concepts. Originally introduced in 1789 and reprinted in 1961, Bentham's social welfare function was intended to measure social welfare as a function of the individual utilities of all people in a society. Thereby, market failure can be seen as a state in which the social welfare function is not fully optimized. Yet, Bentham's (1961) proposition is faced with controversy because it implies subjective value judgments about the ordering of all possible states of the world (Just et al., 2005). The *Pareto criterion* avoids such value judgments and offers an objective way to rank alternative states of the world (Just et al., 2005). According to this criterion, a policy implementation is socially desirable (meaning that welfare is maximized) if at least one person is "better off" after a policy implementation, while no one is disadvantaged by it (Pareto, 1896). If there are no feasible improvements to the current state that comply with the Pareto criterion, the contemporary state is called a *Pareto optimum* (Pareto, 1896). However, the Pareto criterion does not include any statements about justice or distributional states of affairs. These issues are covered by the aforementioned justice-based regulations.

With regard to the Norwegian SFI, a Pareto-optimal state is reached when the utility of some agents, who are affected by the industry's actions, cannot be further optimized without making other agents worse off. In this context, market failure occurs if market mechanisms lead to a state in which the allocation of resources is not Pareto-optimal. If a Pareto optimum is reached by purely competitive forces, whereby consumers act selfishly through maximizing their utilities and producers seek solely to maximize profits, it is referred to as a *first-best optimum* (Just et al., 2005). Accordingly, Smith's (1937) metaphor of the invisible hand, suggesting that overall welfare can be maximized if individuals rationally pursue their own utility maximization, would lead to a first-best optimum. However, a laissez-faire governmental approach to intervention in the SFI could potentially lead to wild salmon populations being put at risk for exposure to negative production externalities (such as high levels of salmon lice exacerbated by production operations, and the escapement of farmed salmon), due to the fact that the preservation of these populations does not explicitly increase the salmon farmers' economic returns. Hence, because the damage to the environment is not incorporated in the final price of Atlantic salmon, this leads to a harmful production output for the environment, as well as market failure (Saez, 2020). This situation calls for governmental intervention and leads to a *second-best optimum*, which implies that if a Pareto optimum cannot be reached, a central planner can still optimize overall welfare by inducing a second-best state (Just et al., 2005). Appendix C abstractly depicts how a disregard for environmental damage, in the form of negative production externalities, can lead to overproduction by the industry, potentially harming the environment. To summarize, the market failure rationale for regulations in the industry is mainly intended to correct the industry's lack of action to mitigate environmental damage, and to generate a second-best optimum by adjusting the industry's production output in order to reach an environmentally bearable state (Ministry of Fisheries and Coastal Affairs, 2009).

As previously mentioned, the Pareto criterion does not incorporate ethical statements, thus requiring an assessment of justice-based regulatory interventions. These regulations aim to ensure justice among competing interest groups within the industry (Just et al., 2005). More precisely, as Hovik and Stokke (2007) posited in their work on the effects of county-level planning strategies on conflicts for coastal zones in Norway, competing claims to the spatial distribution of coastal zones require an independent, justice-based allocation policy. Hereafter, we explicate the Norwegian government's measures with regard to these market failure and justice-based motives for regulations in more detail.

When pioneers in the Norwegian fisheries industry began to shift their commercial focus towards salmon farming in the early 1970's, their efforts initially received substantial backing by the Norwegian government (Liu et al., 2011). The aim was to improve local ownership and employment in rural communities suffering from declining wild fisheries (Aarset, 1998; Liu et al., 2011). Yet, the notable increase in Norwegian production volumes of Atlantic salmon, from 600 tonnes in 1974 to nearly 1.3 million tonnes in 2018, led to an intensified struggle for space, transforming the Norwegian coastline into a "multiple object" (Mol, 2002, p. 5) – a zone that has diverse functions for different interest groups (FAO, 2020b; Young et al., 2019). In addition to the need for justice-based regulations that prevent distributional conflicts among different actors, the risk of market failure, particularly caused by the SFI's negative production externalities, induced policymakers to impose additional regulatory constraints on the industry (Asche & Bjørndal, 2011; Krøvel et al., 2019; Lindland et al., 2019). As a result, the government shifted its regulatory strategy from supporting to constraining the industry's production output.

In 2009, the Norwegian government published the report *Strategy for an Environmnetally Sustainable Norwegian Aquaculture Industry*, which was designed to both set the standard for new regulations, as well as to create amendments to existing ones. The various goals declared in the report exemplified the government's comprehensive focus on safeguarding the industry's environmental sustainability by minimizing its negative production externalities (Taranger et al., 2015). Table 2 summarizes the report's five main environmental goals.

Table 2. The Norwegian government's main environmental concerns and goals for future regulations for the salmon farming industry

Goals	Descriptions	Main Environmental Concerns
Genetic interaction and escapes	Aquaculture will not cause changes in the genetic pools of wild fish stocks.	Crossbreeds of escaped farmed and wild salmon have decreased survival abilities.
Pollution and discharges	Fish farming locations will preserve acceptable environmental conditions and will not generate higher emissions (for example, of organic materials and nutrient salts) than the receiving waters can endure.	Discharges may alter the sea bottom, lead to over-fertilization, and absence of oxygen.
Disease, including parasites	Diseases in fish farms will not have any effects on wild fish stocks while as many farmed fish as possible will grow until they reach their slaughter age with a minimum usage of medical resources.	Especially salmon lice represent a lethal hazard for wild salmon stocks.
Zoning	The aquaculture industry will adhere to a given location structure which limits the risk of uncontrolled spread of infections and other diseases.	Too high production levels within zones foster the spread diseases and parasites.
Feed and feed resources	Raw materials needed for feed in aquaculture farms will be guaranteed without exploiting natural aquatic resources.	Exploiting marine ingredients, such as fish oil, reduces food supply for other creatures and disrupts the food chain ecosystem.

Note. Adapted from *Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry*, by the Norwegian Ministry of Fisheries and Coastal Affairs, 2009, p. 7, 11, 16, 20, and 25 (respectively).

As previously stated, the overarching goal of the industry's market failure-oriented regulations has been to conserve wild Atlantic salmon populations (Ministry of Fisheries and Coastal Affairs, 2009; Serra-Llinares et al., 2014). In accordance with findings from numerous studies that determined that high levels of salmon lice caused by increased farming operations were the SFI's primary threat posed to wild salmon stocks, these regulations largely concentrate on diminishing this threat by restricting the industry's production capacity in certain areas (Bjørndal & Tusvik, 2017; Holen et al., 2018; Osmundsen et al., 2020; Thorstad & Finstad, 2018; Young et al., 2019).

Due to the high number of individual regulations and the lack of cohesion among them, Utne et al. (2017, p. 4) described the regulatory landscape for the Norwegian SFI as being "fragmented." With respect to this circumstance, we organize the following subchapters in a way that emphasizes the three main contemporary regulatory themes (Mowi, 2019). First, we explain the government's approach to hindering spatial conflicts among various interest groups (in subchapter 2.3.1). Thereafter, we explicate the licensing regime which controls the SFI's current production activities and their associated negative production externalities (in subchapter 2.3.2). Finally, we describe the primary control mechanism for guiding the SFI's future output development and environmental sustainability (in subchapter 2.3.3). Rather than detailing the historical development of the regulatory regime, we deliberately chose instead to emphasize the current legislation and its effects on the industry. For a brief presentation, an overview of the most important historical events and turning points are given in Appendix D.

2.3.1 – Coastal zone planning

Approximately 80% of Norway's population inhabits the land area within 10 kilometers of the coast, making the coast a vital component of civil and economic activities (Directorate of Fisheries, 2016; Norwegian Environment Agency, 2020). As previously mentioned, justice-based regulations in the Norwegian SFI aim to deter conflicts that arise from competing claims for the coastal zone. The coastal zone has been defined as the 100-meter belt that covers the land portion of the shore along Norway's coastline (Statistics Norway, 2016). In 2015, approximately 31% of the coastal zone was labeled as already being utilized for various purposes, including agriculture, aquaculture, fishing, housing, and transportation infrastructure (Statistics Norway, 2016). Atlantic salmon farming companies, many of which have transformed from small, family-owned companies into large-scale, multi-national corporations, constitute the largest contenders for areas covered by the coastal zone (Hovik & Stokke, 2007; Tiller et al., 2012). The reason for this is that intensive farming activities during the salmon's grow-out phase require sufficient land for office buildings, feed warehouses, and laboratories in close proximity to the coast (Beveridge, 2004). In 2015, despite more than half of the coastal zone's area remaining unutilized and still potentially accessible for commercial or residential use, accessing and employing the area was difficult (Statistics Norway, 2016). This was reflected by the weak relative change in the utilization of the zone's area over a period of ten years, evolving from 30% in 2005 to just 31% in 2015 (Statistics Norway, 2016). The reason for the difficulty in accessing and using coastal zone areas can be attributed to the Norwegian government's strategy to preserve large portions of it for recreational use and cultural heritage (Ministry of Communities and Modernization, 2011).

Tiller et al. (2012) used Norwegian media coverage data in the period 1984 – 2010 as a proxy to quantitively examine the ongoing conflicts for coastal zones. They attested that there was a significant clash among various agents of differing interests (Tiller et al., 2012). Other, survey-based studies confirmed this finding and voiced the need for a transparent, government-induced allocation policy (Hovik & Stokke, 2007; Røsvik & Sandberg, 2002).

The Planning and Building Act (2008), published by Norway's Ministry of the Environment, constitutes the paramount means for coastal zone planning. This is because it allows single municipalities to independently manage the spatial allocation process for aquaculture sites, while simultaneously aiming to keep the potential for conflict with other interest groups as low as possible (Directorate of Fisheries, 2016). Currently, there are 357 municipalities in total in Norway, of which more than two-thirds have access to the sea (Regjeringen, 2020). The county councils in each of these municipalities are the highest local governing bodies (Store Norske Leksikon, 2019). According to *The Planning and Building Act* (2008), solely the county councils are assigned the power to conduct regional planning; thus, they are authorized to decide which coastal zones can be used for which purposes. In addition to the appraisal of building applications for coastal zones, the county councils' area of responsibility encompasses projects conducted within 1 nautical mile (1.85 kilometers) out from the shore (Kvalvik & Robertsen, 2017). County councils are given supreme jurisdictional authority over regional planning applications for their specific competence on the needs and concerns of each individual municipality (The Planning and Building Act, 2008).

To ensure that conflicts of interest are properly addressed, county councils must consult the general public before deciding for or against a proposal, and must foster active participation by different stakeholder groups in their respective municipalities (Buanes et al., 2005; The Planning and Building Act, 2008). After an application for a salmon farming site is made, members of the county council have four weeks to inform the public, after which point they must also facilitate its collaboration in the decision-making process, identify potential conflicts, and make a final decision (The Aquaculture Act, 2005). *The Planning and Building Act* (2008) prescribes that the evaluation of building applications should be conducted with respect to their long-term economic prospects and the likelihood for potential concerns of different interest groups to arise.

2.3.2 – The licensing system

The Aquaculture Act (2005) constitutes the most important judicial guideline for administering and managing the actions of the Norwegian SFI (FAO, 2020d; Mowi, 2019). *The Aquaculture Act*'s main purpose is to provide transparent criteria for the award and allocation of production licenses (The Aquaculture Act, 2005). As production licenses constitute the government's central mechanism for controlling production capacity and, thereby, minimizing the industry's negative environmental impacts, these criteria mainly aim to preserve sustainable environmental conditions in coastal areas (Asche & Bjørndal, 2011; FAO, 2020d; Mowi, 2019). Further, *The Aquaculture Act* specifies the application process for production licenses (FAO, 2020d; The Aquaculture Act, 2005). The various steps, regulatory frameworks, and authorities involved in the allocation process are summarized in Appendix E.

There are three fundamental requirements that must be fulfilled in order for production licenses to be allocated by the Directorate of Fisheries (FAO, 2020d). First, new production licenses must be released, which has only happened sporadically since 1982 (Mowi, 2019). Due to the causal relationship between a production area's present biomass of farmed salmon and the number of salmon lice which are ultimately able to affect the area's wild salmon stocks, the award of production licenses has been limited (The Aquaculture Act, 2005; Myksvoll et al., 2018; Serra-Llinares et al., 2014). In 2018, for example, the maximum allowed number of production licenses was set to 1,041 and all licenses were utilized (Mowi, 2019). The decision in favor of releasing new production licenses is made if there is at least one coastal region with excess capacity, in terms of the environmentally bearable biomass for farmed salmon (FAO, 2020d). Subchapter 2.3.3 introduces a novel production area regulation that aims to control this environmental requirement within Norway. Second, since the number of firms which apply is usually greater than the number of available licenses, prioritization criteria specify which applicants are favored in the allocation process (FAO, 2020d). The prioritization happens on the basis of *The Aquaculture Act's* (2005) goal to foster future financial growth and innovations which are capable of improving the Norwegian SFI's environmental compatibility (Directorate of Fisheries, 2020b). Third, a license fee must be paid by the applicant in order to obtain a production license (FAO, 2020d). In 2009, the Directorate of Fisheries increased the fee per license from NOK 5 million (excluding for operations within the former county of Finnmark, where the fee was set to NOK 4 million) to NOK 8 million (Bjørndal & Tusvik, 2017; PwC, 2017). Additionally, production licenses can be acquired in open auctions, in which the average price per license may exceed the ordinary fee of NOK 8 million (Olsen, 2018; Undercurrentnews, 2018).

Another avenue for obtaining the right to farm Atlantic salmon in Norway's coastal waters lies in the assignment of development licenses, which are meant to incentivize more significant investments into innovative, environmentally sustainable farming technologies (Directorate of Fisheries, 2020e; Mowi, 2019). These licenses, which were introduced in November 2015, are granted to successful applicants free of charge, giving them the right to produce for 15 years, after which they may be transformed into a commercial license at a lower-than-market expense (Mowi, 2019). The Directorate of Fisheries (2020b) has, as of the time of writing, only approved 19 of the 104 concepts submitted under the development licensing program. The majority of applications vary in their functional interaction with the sea (such as utilizing open versus closed structures) and their distance from the shore (such as utilizing near-shore versus offshore design concepts). The process of awarding development licenses has been criticized for using the extent of research and development (R&D) investment as its main decision metric, which does not necessarily reflect the effectiveness of a novel technological solution (PwC, 2017).

A production license permits its holder to farm Atlantic salmon in Norwegian coastal waters (Mowi, 2019). The so-called *Maximum Allowed Biomass* (MAB) regime took effect in 2005 (Asche et al., 2005). This control measure determines, per license, the upper limit of biomass in tonnes of fish that can simultaneously be held in the sea. The MAB per license is set at 780 tonnes for all counties, except for the county of Troms and Finnmark, where it amounts to 945 tonnes (Mowi, 2019). Further, the MAB regime acts on two tiers: the company tier and the location tier. The company tier encompasses the MAB per company as the product of the number of possessed licenses and the MAB per license (Bjørndal & Tusvik, 2017). The location tier, on the other hand, determines the MAB for each geographical site and depends on the environmentally bearable farming capacity in the respective location (Bjørndal & Tusvik, 2017). Accordingly, the upper limits for each site's MABs are specified to be between 2,340 and 4,680 tonnes (Mowi ASA, 2019). Figure 3 outlines the interplay between the company and location tiers, based on a fictitious example.

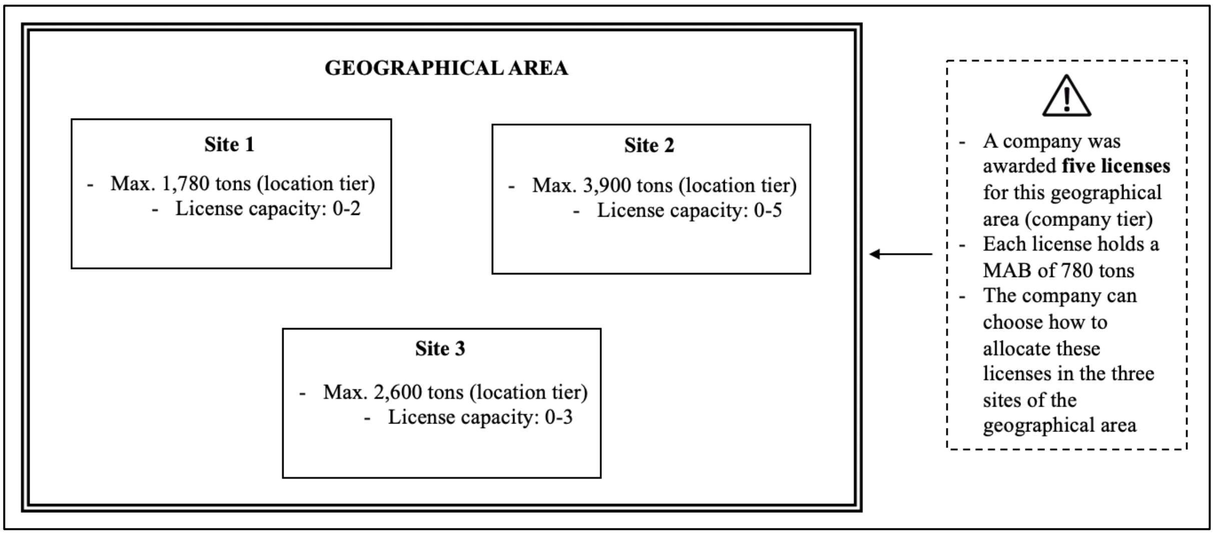

Figure 3. Abstract depiction of license utilization in a hypothetical example

Note. In this example, a company was awarded five licenses for a specific geographical area. Further, the company was assigned three sites within this area, each of which has its own location tier-based biomass limitation (1,780, 3,900, and 2,600 tonnes). The company can now choose how to distribute its entire 3,900 tonnes of company tier-based biomass between its three sites (for example, to utilize two licenses at Site 1 and three at Site 3, or to utilize all five licenses at Site 2). Adapted from *Salmon Farming – Industry Handbook*, by Mowi, 2019.

In addition to these volume limitations, companies must adhere to governmental restrictions instituted in 2013 which limit the maximum allowed number of individual fish per open net pen to 200,000 (Teknologirådet, 2012).

2.3.3 – Traffic Light System

In 2010, the Gullestad Committee, a summoned assembly of industry experts, was convened to accomplish two objectives (Hovland et al., 2014). Initially, the committee was directed to propose ways for the government to guarantee sufficient space within coastal zones for the Norwegian SFI and, thereby, lay the foundation for its further production growth (Hovland et al., 2014). It was then instructed to create a sustainable concept for a new management system that would safeguard wild Atlantic salmon stocks from the Norwegian SFI's negative production externalities (Hovland et al., 2014). Five years later, in 2015, the Ministry of Trade, Industry and Fisheries followed the Gullestad Committee's proposal for a new management system and submitted its white paper number 16, *Predictable and Environmentally Sustainable Growth in Norwegian Salmon and Trout Farms*, to the Norwegian parliament (Ministry of Trade, Industry and Fisheries, 2015a). In essence, the white paper suggested introducing a new management system that would be built on two principles. First, it should emphasize predictability regarding new license allocation rounds which, prior to that point and from the industry's perspective, seemed to occur at random (Ministry of Trade, Industry and Fisheries, 2015a; Mowi, 2019). Second, the system's definition of what constituted environmentallyfriendly production operations should be made comprehensible and transparent (Ministry of Trade, Industry and Fisheries, 2015a). On October 1, 2017, this new management system for growth was authorized and nicknamed the *Traffic Light System* (TLS).

In order to understand what the TLS is and how it works, it is important to clarify its following three facets: production zoning, environmental metrics, and alteration of zones' production capacity (Gullestad et al., 2011).

As for the production zoning facet, the country was divided into 13 areas, as illustrated in Appendix F (Lovdata, 2017). This division was based on an extensive scientific project conducted by the Norwegian Institute of Marine Research (2015). The researchers established a hydrodynamic model of ocean currents and derived a projection for salmon lice transportation between different marine areas (Ådlandsvik, 2015). Based on this model, the researchers ran a cluster analysis and found the best natural borders for production zones that would minimize potential spillover effects of salmon lice between adjacent zones (Ådlandsvik, 2015).

The environmental metrics and alteration of the zones' production capacity are two intertwined facets of the TLS. Depending on the risk imposed on the environment, production zones are classified as *green* (low risk), *yellow* (moderate risk), or *red* (high risk) (Ådlandsvik, 2015). Thus far, the classification of production zones is based on the risks of increased mortality rates that wild salmon populations are exposed to, due to the artificially increased levels of lice that can be exacerbated by farming operations in the area (Myksvoll et al., 2018). The production zone classification is used as the foundation for assessing whether its ecological tolerance can bear an increase in production (a production increase), whether it can only bear the current production output (a production freeze), or whether its ecological tolerance has been already exceeded (a production reduction) (Ernst & Young AS, 2017). Table 3 illustrates the effect that a production classification of environmental risk has on the growth allowance for its respective zone.

Table 3. The effects of the TLS's environmental metrics on the capacities of production zones

	Low risk	Moderate risk	High risk
Environmental metric	The risk of increased wild salmon mortality due to enlarged numbers of salmon lice is estimated to be below 10 percent.	The risk of increased wild salmon mortality due to enlarged numbers of salmon lice is estimated to be between 10% and 30%.	The risk of increased wild salmon mortality due enlarged numbers of salmon lice is estimated to be above 30%.
Consequence	Production increase: The production zone is granted a 6% increase in production capacity.	Production freeze: The production zone will neither be granted an increase, nor will its production capacity need to be decreased.	Production reduction: The production zone's capacity will be decreased by 6%.

Note. The government's announcements about the environmental metrics for the different production zones is planned to be made every other year. The allowance for a 6% increase in production capacity may be partly offered to existing licenses and partly sold in the form of new licenses. Sites that meet two rigorous environmental criteria (First, an average of less than 0.1 salmon lice per fish during the past two years between April 1 and September 30; and second, no more than one medication during the recent production period) are offered an extraordinary 6% of capacity increase. Adapted from *Sustainable growth towards 2050 – PwC Seafood Barometer 2017*, by PwC, 2017.

The most recent announcement about the environmental metrics and its associated updates to the capacities of the production zones were made in the first quarter of 2020 (as presented in Appendix G).

Subchapter 2.4 presents, in the context of growing consumer demand, the foundation for why it is necessary for the Norwegian SFI to navigate its constrictions on domestic production volumes in order to remain a successful and resilient industry on a global scale.

2.4 – Global demand for Atlantic salmon

The global importance of aquaculture is set to grow significantly over the next ten years and further out into the future, and the Norwegian SFI should be poised in the present day to respond to these developments in the market. Changes in the global demography and distribution of wealth, coupled with a growing world population, are anticipated to cause rising demand for food products (Maggio et al., 2019). Not only will this necessitate production scale-ups for food on an aggregate level, but these changes will also shift demand towards more protein-rich sources of food, such as fish (Lem et al., 2014; Ray et al., 2013). The starchy foods that are central to the diets of many populations are expected to be replaced by foods with high nutritional value, resulting in reduced undernourishment especially within the communities of developing nations (Obiero et al., 2019). The elimination of world hunger and establishment of food security is a target highlighted by the United Nations Sustainable Development goals, and continued progress towards its attainment takes a focused effort by all participants within the food supply and value chains (United Nations, 2016). Aquaculture can be a critical component in providing the consumers of the future with a healthy source of protein in a manner that is more efficient and environmentally conscious than current alternatives. As fish products experience a growth in global demand, Norway's Atlantic salmon may also be primed for achieving success in future markets (World Bank, 2013).

An important aspect to consider when anticipating the future development of global demand for Atlantic salmon is that global megatrends may influence consumers' purchasing behaviors (Ferreira et al., 2019). In Kurian's (2013, p. 201) *AMA Dictionary of Business and Management*, a megatrend is defined as a "general and widespread current thinking or paradigm affecting large countries and markets." Maggio et al. (2019) identified five global megatrends which most frequently occur in a sample of literature published between 2012 and 2017 on the topic of food security in the coming years. These were categorized as the following: resource scarcity/availability, economic growth and power, climate change, diet changes/food preferences/values, and demography (Maggio et al., 2019). As these trends are defined by their occurrence over industries globally, all five of these are likely have a direct impact on the future development of the Norwegian SFI, however, it is plausible that the groups "resource scarcity/availability" and "climate change" will primarily affect the supply prospects for Norwegian-raised Atlantic salmon, rather than the demand for the product. With this said, we do acknowledge that consumers have come to increasingly value corporate social responsibility (CSR) and the role that corporations have in protecting natural resources, and may therefore exhibit higher levels of demand for products which fulfill these criteria satisfactorily. Therefore, using a focus on consumer demand, we recategorize the relevant megatrend groups as follows: demography, economic growth and power, diet changes/food preferences, and consumer values. We illustrate the influence that these four megatrends are expected to have on the Norwegian SFI in the succeeding subchapters 2.4.1 through 2.4.4. We also acknowledge that, regardless of production volumes actually demanded by international consumers, foreign political action can potentially disturb or eliminate the flow of goods between countries, which is addressed in subchapter 2.4.5.

2.4.1 – Demography

The global population is projected to rise by over 10% in the coming years, from 7.7 billion people in 2019, to 8.5 billion people in 2030 (United Nations, 2019). This increase will not happen uniformly, however, with countries located in sub-Saharan Africa contributing to a significant portion of world growth, at 334 million people (United Nations, 2019). Countries within Central and Southern Asia are expected to represent a smaller portion of the increase, at 236 million people (United Nations, 2019). The world's two most populous countries, India and China, are expected to grow at slower rates, with India's population projected to surpass China's by 2030 (Lutz & Kc, 2010). The population growth rate in Northern America is expected to remain stable and positive, whereas Europe, in aggregate terms, is projected to experience a decline in population (Lutz & Kc, 2010). In table 4, we present the projected development of populations by region and their representations on a global scale.

Table 4. Projected development of world population, in billions, and distribution by region, to 2030

Region	**2019**	**% World**	**2030**	**% World**
World	7.71		8.55	
Sub-Saharan Africa	*1.07*	*13.8*	*1.40*	*16.4*
Northern Africa and Western Asia	*0.52*	*6.7*	*0.61*	*7.1*
Central and Southern Asia	*1.99*	*25.8*	*2.23*	*26.1*
Eastern and South-Eastern Asia	2.34	30.3	2.43	28.3
Latin America and the Caribbean	0.65	8.4	0.71	8.3
Australia/New Zealand	0.03	0.4	0.03	0.4
Oceania	*0.01*	*0.2*	*0.02*	*0.2*
Europe and Northern America	1.11	14.4	1.13	13.2

Note. Regions which are projected to experience an increase in global representation are italicized. Adapted from *World Population Prospects 2019*, by United Nations, 2019.

In order to anticipate future demand, we can compare expected developments in regional populations with current and recent historical demand for Atlantic salmon in those areas. Sub-Saharan Africa has not traditionally been a large market for Norwegian Atlantic salmon exporters and has even experienced a decline in its imports of all salmon commodity products by nearly 67% over a period of the ten most recent years of available data (from 2008 to 2017) (FAO, 2019). In 2017, the region imported a meager 342 tonnes of salmon (FAO, 2019). Though this area is home to such a large population, it is also the poorest of all regions as defined by the United Nations (Lem et al., 2014; United Nations, 2019). Demand in future years for this area may be influenced significantly by increases in local gross domestic product (GDP) per capita, as discussed in more detail in next subchapter 2.4.2. Due to this, Norwegian salmon companies should not discount future market growth within Sub-Saharan Africa based solely upon its current levels of demand. Southern Asia is also of special interest to the Norwegian SFI, as it is set to grow quite significantly to the year 2030 and has already exhibited increased demand for salmon by well over 200% in the period from 2008 to 2017 (FAO, 2019). Overall, population size is one of the strongest predictors for the total market demand for food products, and the supply of Norwegian-raised Atlantic salmon will be key in feeding the growing communities of the future (FAO, 2017).

Another key change in demography over the coming years will be the aging of the worldwide population. In 2015, the percentage of the world population aged 65 years or older was estimated at around 8.5%, amounting to 617.1 million people (He et al., 2016). It is projected that by the year 2030, this number will jump to 12% of the global population, corresponding to one billion people in absolute terms (He et al., 2016). This trend will be especially profound in the European Union (EU) countries, as well as in North America and Asia. In these regions, the proportions of this older demographic will rise from 2020 levels of 20%, 16%, and 9%, respectively, to 24%, 20%, and 13% in 2030 (Lutz & Kc, 2010). Countries of special interest are China and Japan, both of which are already large markets for Norway's Atlantic salmon exporters (FAO, 2019). It is estimated that China's elderly population comprises 12% of all of its citizens in 2020, and that this figure will grow to 17% in 2030 (Lutz & Kc, 2010). Japan, the country with the world's highest proportion of elderly citizens, is expected to see an increase in this demographic from 28% in 2018, to 32% in 2030 (Tsuya, 2014; World Bank, 2020).

The EU countries, North America, China, Japan, and East/Southeast Asia are all extremely important existing import markets for Atlantic salmon (FAO, 2019). Additionally, the effects of an aging population are expected to further increase demand in these regions. Older people may have a stronger preference for fish over other sources of protein, as fish consumption has been shown in some studies to increase as consumer age increases, however, this may vary by country and culture (Supartini et al., 2018; Verbeke & Vackier, 2005). Higher levels of education have also been shown to be correlated with a greater desire to consume fish, presumably because its benefits are more well-understood and acknowledged (Verbeke & Vackier, 2005). Global access to secondary education is projected to increase in the coming years, and the future's older generation is expected to have fulfilled higher levels of education (Lem et al., 2014). This may lead to more informed decision-making among future consumers concerning dietary choices. As Atlantic salmon is nutrient-rich, the developments in the global demographic composition towards an older and more well-educated society may indicate potential growth in the demand for this commodity.

2.4.2 – Economic growth and power

The income level of a consumer is another strong determinant of the quantity and type of food he or she will demand from producers (FAO, 2017). A consumer's income elasticity of demand portrays the percentage change in the quantity of goods demanded by the consumer when his or her income level changes (Goolsbee et al., 2013). How the demand for a type of food is affected by changes in consumer income is dependent on the good's categorization as an *inferior good*, a *normal good*, or a *luxury good* (Goolsbee et al., 2013). An inferior good experiences an increase in demand when there is a decrease in consumer income, a normal good experiences an increase in demand when there is an increase in consumer income, and a luxury good experiences a more-than-proportional increase in demand when there is an increase in consumer income (Goolsbee et al., 2013). To make projections about the future development of the income of a nation's citizens, we use the country's GDP as a proxy measure for its aggregate income (Lem et al., 2014).

As a household's income increases, the proportion of it which is spent on food decreases, according to *Engel's law* (Deaton & Muellbauer, 1980). Accordingly, poorer households have a higher proportional expenditure on food items than do wealthier households. This is exemplified by the findings made by Muhammad et al. (2015), who concluded that countries categorized as low-income were more likely to spend an additional increment of income on food, whereas high-income countries were more likely to use that money to purchase luxury items. This indicates that low-income countries which begin to see growth in consumer wealth will respond by demanding greater volumes or a higher quality of food. Such an effect may be observed within these countries as a shift away from the consumption of inferior goods, and towards normal goods. A shift in demand of this type has the potential to positively impact export volumes of Atlantic salmon since large-scale farming has brought down its market price over the years, transforming the product from a luxury good to a normal good (Ministry of Trade, Industry and Fisheries, 2015a; Xie, 2008). As incomes in developing countries are projected to rise in the near future, consumers are expected to replace their consumption of energy-dense and processed foods by incorporating healthier options and animal-based proteins in their diets (Ferreira et al., 2019).

Looking to evolutions in future GDP, we see that countries classified as having emerging and developing economies are projected to grow at a rate nearly twice as fast as countries considered to have mature economies, in the period from 2020 to 2029, as projected by The Conference Board (2020). The GDP for the United States (US) is expected to grow at a 2%

rate for every year in this period, with Japan's GDP slightly lower at approximately 1.9%, and Europe's GDP coming in at around 1.5%. Conversely, China's GDP is projected to grow by around 3.5% for each year to 2029, while India's is set to increase by around 5.5% annually. Other Asian countries with developing economies may see annual growths of around 4.4% over the coming years. A more detailed representation of projected global GDP development is presented in table 5 below.

Table 5. Projected development of GDP growth rates (measured by average annual percentage change), by region, in the period from 2020 to 2029

Region	2020	2020 - 2024	2025 - 2029
US	2.1	2.0	2.0
Europe	1.5	1.5	1.4
Japan	-0.2	1.8	1.9
Other Mature Economies*	2.0	2.7	2.5
All Mature Economies	**1.6**	**1.9**	**1.8**
China	*2.8*	*3.4*	*3.6*
India	*5.6*	*5.9*	*5.4*
Other Developing Asian Economies†	*4.4*	*4.5*	*4.3*
Latin America	0.5	1.7	1.6
Middle East and North Africa	2.2	2.7	2.6
Sub-Saharan Africa	*2.9*	*3.4*	*3.6*
Russia, Central Asia, and Southeast Europe	2.0	1.7	1.9
All Emerging Markets and Developing Economies	***3.0***	***3.5***	***3.5***
World	**2.4**	**2.8**	**2.7**

Note. The rate of GDP growth for 2020 is forecasted, while the rates for the years beyond this, to 2029, are projected. Economies which are set to outpace the overall world growth rate are italicized. Adapted from "The Conference Board Global Economic Outlook," by The Conference Board, 2020.
* Includes Australia, Canada, Hong Kong, Israel, New Zealand, Singapore, South Korea, and Taiwan
† Includes Indonesia, Malaysia, Pakistan, Philippines, Thailand, and Vietnam

By the year 2030, GDP per capita in all regions globally is expected to experience an increase, resulting in positive effects on consumer income (Ferreira et al., 2019). This, thereby, is expected to increase total consumption for all product categories, including food (Lem et al., 2014). The change in consumer purchases is expected to be especially profound in regions which currently have lower levels of disposable income, such as developing Asia and Africa (Lem et al., 2014). It will become increasingly practicable for low-income households in these continents to shift their purchasing behavior towards food items categorized as normal goods, containing higher contents of important nutrients such as protein (Lem et al., 2014). The aggregate rise in income should cause inexpensive and innutritious food items, constituting inferior goods, to be purchased to a declining degree. For the many households within Asia which are soon entering the middle- and upper-middle classes, expenditures on luxury food items will become more common (Lem et al., 2014).

Additionally, because food is a necessary part of a household's consumption bundle, consumers with lower incomes are more heavily impacted by changes in the price of food. This means that a consumer may be more enticed to buy a product if the price is reduced, and more hesitant to buy a product if the price is increased, constituting a product's price elasticity of demand (Goolsbee et al., 2013). Products which experience more responsive changes in demand when prices are adjusted are considered elastic, whereas those which have more resilient levels of demand in response to price changes are considered inelastic (Goolsbee et al., 2013). Consumer demand for certain categories of food is more inelastic to price changes than for other categories of food, depending on their level of substitutability. In terms of the price elasticity of demand for Atlantic salmon, this has been found to be both elastic and inelastic, depending on the market and time period measured (Brækkan & Thyholdt, 2014). Salmon has traditionally been consumed to a large extent by high-income purchasers, and less so by lower-earning households (Brækkan & Thyholdt, 2014). However, market trends have indicated that emerging markets have exhibited much faster growth in demand for salmon than have established markets for the product (Brækkan & Thyholdt, 2014). This could be a positive sign that Atlantic salmon is a food product that is well-marketable in the developing economies of the near future.

2.4.3 – Diet changes and food preferences

In a world which is currently experiencing extremely high levels of obesity, while at the same time attempting to fend off hunger and malnutrition, increasing public attention has been directed towards providing populations with access to vitamin-rich sources of food. In many developed countries, governmental institutions have implemented educational programs meant to encourage citizens to incorporate a balanced diet into their lifestyle (K. Chan & Tsang, 2011; Mikkelsen & Trolle, 2004; Obama, 2012). Additionally, economic incentives have been put in place in countries such as Norway to discourage the consumption of products containing refined sugar, and to encourage the purchase of fruits and vegetables (Gustavsen & Rickertsen, 2013; Reitangruppen, 2020). These campaigns to raise awareness concerning public health, together with a higher educational attainment in future populations, can help to shift consumer purchase decisions of food items towards healthy alternatives. This trend may ultimately benefit companies who produce nutritious foods. Atlantic salmon is very high in omega-3 polyunsaturated fatty acids, the consumption of which has been shown to reduce an individual's likelihood of suffering from heart-related ailments such as heart disease, hypertension, and cardiac arrhythmia (Sidhu, 2003). Fish in general also provides high amounts of protein, minerals (including calcium and iron), and various essential vitamins (Sidhu, 2003). Therefore, demand for Atlantic salmon may be positively affected in the future as consumers become more conscious of the impact that their nutritional decisions make on their physical health and wellbeing.

2.4.4 – Environmental concern and consumer values

Aspects such as a company's CSR and environmental footprint are conjectured to make a bigger impact on present-day consumers' purchasing decisions than has previously been observed within the market. Deng and Xu (2017) found that when companies took strong actions in CSR that were perceived favorably by consumers, purchase intention was positively affected to a significant degree. The authors posited that this behavior occurred when there was a strong relationship created between the company and the consumer, in which the consumer could closely identify personally with the business's values. It has also been demonstrated that many consumers are willing to pay a premium to companies which implement environmentally sustainable measures in their operations (Olesen et al., 2010; Parsa et al., 2015). Therefore, it may be possible to both increase demand for a product as well as its price if the producer can demonstrate sustainable business practices.

Within the salmon farming industry, there have been concerns raised in recent years by stakeholders regarding the impact that production operations have on the natural ecosystem (Olesen et al., 2011). By making environmentally conscious efforts within the value chain and clearly communicating these steps to consumers, the Norwegian SFI is likely to observe positive responses in the market. Additionally, studies have indicated that Norwegian consumers believe that sufficient welfare provided to farmed salmon is important to consider when making purchasing decisions, and that much of the responsibility for proper care of the fish rests with the producers (Grimsrud et al., 2013). The adoption of higher standards for production, resulting in better fish welfare and environmental outcomes, has been shown to elicit a 15% higher price than for salmon of comparable quality only raised according to the industry standard (Olesen et al., 2010). The caveat here is that producers must strike a balance between adhering to high levels of fish welfare and generating excessive extra costs, as international consumers may not be as willing as domestic consumers to subsidize better standards of care for the salmon (Ellingsen et al., 2015). Overall, Norwegian salmon farmers can capitalize on today’s changing consumer values by implementing ethical practices and remaining transparent and forthcoming with the information they convey to consumers.

2.4.5 – International trade restrictions

Norwegian farmed salmon has, over the last decade, proven to be vulnerable to international trade restrictions. Import restrictions imposed by other nations can result in a decline in the volume of Norwegian farmed salmon permitted for sale to foreign consumers. In December 2010, political tensions between Norway and China escalated after the Norwegian Nobel Committee awarded the year’s Nobel Peace Prize to Liu Xiaobo, a Chinese dissident (S. Chan, 2016). Chen and Garcia (2016) studied China’s subsequent response, which culminated in an initiative in 2011 intended to disrupt the flow of trade between the country’s domestic market and Norway. They found that this was carried out covertly by means of continual delays in necessary sanitation inspections upon the entry of Norwegian farmed salmon into the country. Prior to this partial boycott of Norwegian farmed salmon, all inspections were conducted on the same day as the salmon’s arrival into China. However, starting in 2011, these procedures could take as long as 20 days to complete. Because fresh and chilled salmon retains the best quality when consumed within 15 days from the fish’s harvest date, its quality could be significantly degraded by the time it reached the market. Salmon imported from other countries were not subjected to the same treatment, and due to the lack of any officially-declared sanction against salmon produced in Norway, importers began to employ other pathways of providing the Chinese market with their product. This sanctions-busting activity was shown to largely incorporate transshipment, in which Norwegian salmon was routed through countries such as Hong Kong and Vietnam before reaching its eventual destination in China. China’s tactics have since been assessed as highly ineffective in accomplishing its desired outcome, as even several years after the restrictions commenced and were still ongoing, Chinese representatives of Norwegian salmon importers estimated that 50 – 70% of the fresh and chilled salmon sold in the Chinese market was of Norwegian origin. However, any formal sanctions levied by the country in the future could result in a more significant outcome for the Norwegian SFI’s international export volumes.

An example of stricter international trade constraints is that of the economic sanctions imposed on Russia subsequent to the country’s annexation of Crimea in March 2014 (Myers & Barry, 2014). This political action resulted in the EU initiating a total ban on the import of goods originating from the regions of Crimea and Sevastopol, and a restriction against Russia’s use of EU capital markets, among other measures (Council of the European Union, 2020). Russia responded by prohibiting imports of many food products exported both by EU nations as well as by countries which supported the sanctions, including Norway (Fritz et al., 2017). In 2013, prior to Russia's ban on imports of Norwegian seafood, Norway was Russia's primary trade partner for supplying their consumers with salmon, with salmon of Norwegian origin constituting 40% of the country's salmon market by value (Bjørkman, 2016). Before sanctions were enacted, Norway provided the Russian market with over NOK 4 billion worth of farmed salmon, comprising approximately 8% of all salmon consumed globally during the course of that year (Bjørkman, 2016). Thus, Russia was formerly an important market for Norway's seafood industry, but political tensions have interrupted the natural development of its significant and growing market share. Regardless of any lingering consumer demand stemming from a preference for Norwegian farmed salmon over substitute goods, foreign policy has been shown to have the potential to constrict or eliminate the production volumes that the Norwegian SFI is able to export to the international market.

It is worth ending this subchapter 2.4 with a note that there are always *black swans*, or unpredictable events with significant consequences, which are capable of affecting a market at any time (Taleb, 2007). We have seen that the global struggles with the 2019 novel coronavirus have caused massive decreases in seafood demand in several markets (Furuset, 2020b; Mutter, 2020c). Though there are reliable indicators which can hint at market changes in the coming years, ultimately, it is not possible to know precisely to what degree these variables will affect demand, or what other unexpected scenarios will come to light in the future.

2.5 – Norwegian Atlantic salmon supply

Norway has experienced an enormous surge in its production levels of Atlantic salmon over the last half-century. Harvests have skyrocketed from a meager few hundred tonnes in the early seventies, to well over one million tonnes in recent years (FAO, 2020b). Presently, Norway is the world's foremost supplier of Atlantic salmon and accounted for over half of the species's global production by weight in 2018 (FAO, 2020b). In looking to the future, the Norwegian government has acknowledged the opportunity of providing for the growing global demand for fish products. By the year 2050, the government strives to reach the ambitious goal of annually supplying the market with five million tonnes of Norwegian-raised, sustainably produced salmon and trout (Olafsen et al., 2012). However, industry experts from PwC (2017) have forecasted that even in the best-case scenario, wherein all production zones in the TLS maintain green lights over the next three decades, this goal for production volumes is hardly achievable.

The struggles to increase the country's production levels have already been observed within recent years, exemplified by the stagnation depicted in figure 4.

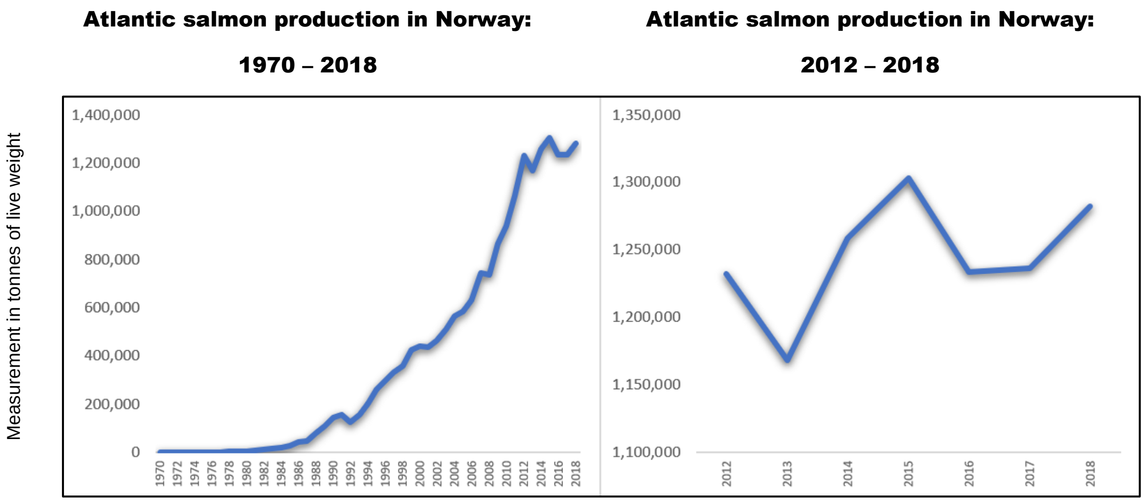

Figure 4. Norwegian Atlantic salmon production output between the years 1970 and 2018, and 2012 and 2018, in tonnes

Note. Adapted from *FishStatJ – Software for Fishery and Aquaculture Statistical Time Series*, by FAO, 2020b.

There are several obstacles to overcome on the path to further, future gains in production volumes. These obstacles include domestic regulations which attempt to mitigate the negative environmental impact of industry operations, thereby limiting potential for additional production allowances, as well as biological challenges which constrain salmon farmers' ability to fully optimize the MAB they already hold licenses for (Osmundsen et al., 2020). In order to expand or optimize Atlantic salmon production in Norway, taking the spatial limitations set by current regulations as given, we consider that salmon farmers have two options: to look to non-conventional methods of salmon production, using alternative production technologies, as detailed within subchapter 2.6, or to improve upon current production practices within the highly-used open net pen salmon farms, which we discuss in this subchapter 2.5. We examine three methods of operational improvement which may stand to maximize production volumes for the Norwegian SFI in the near future: an improved treatment of salmon lice, an improved mix of ingredients in fish feed, and an increased utilization of existing production licenses.

2.5.1 – Improved treatment of salmon lice

The problem of salmon lice is arguably the biggest challenge facing the Norwegian SFI today (Holen et al., 2018). Due to increased levels of salmon lice as a result of salmon farming operations, this parasite has become the sole metric for setting and maintaining government-induced caps on production levels, and thereby indirectly limits domestic supply (Osmundsen et al., 2020). It is also a harmful nuisance inherent in the production process of farmed salmon that significantly increases the mortality rates of fish stocks, reducing production efficiency (Liu & vanhauwaer Bjelland, 2014). For the sake of ensuring optimal production volumes of farmed salmon, measures must be taken by companies to utilize treatments to rid their stocks of salmon lice. Such measures both help to account for the lice affecting individual pens, as well as to contribute to the limitation of lice spread from site to site. Unfortunately, the methods that currently exist can result in more robust populations of treatment-resistant lice and are becoming increasingly inefficient at assuaging the issue (Overton et al., 2019).

The most common modern lice treatment measures can generally be grouped into three types: chemical treatments, thermal treatments, and mechanical treatments (Overton et al., 2019). Chemical treatments consist of substances including organophosphates, pyrethroids, and hydrogen peroxide, and are released into the water in which the salmon reside (Torrissen et al., 2013). The advantage to using this type of treatment is that it is effective in removing both mobile lice as well as attached lice from the fish (Burridge et al., 2010). However, the downside to utilizing any chemical delousing method is that lice populations have been observed to build up resistance to these measures within a short time frame (Aaen et al., 2015). Additionally, it is thought that the chemical compounds have negative effects on the surrounding environment (Burridge et al., 2010). Even hydrogen peroxide, widely considered to be more innocuous than other chemical treatments, may harm populations of unintended species such as shrimp (Burridge et al., 2010; Fagereng, 2016).

Much of the usage of chemical delousing treatments has been phased out in recent years in favor of thermal and mechanical treatments (Overton et al., 2019). Thermal treatments involve transporting the fish to a treatment chamber in which they are exposed to higher temperatures of seawater, rendering lice impaired and forcing them to remove themselves from the body of the salmon (Holan et al., 2017). Though up to 100% of mobile lice may be removed from the salmon stock at the higher end of the salmon's temperature tolerance, this method has been shown to be ineffective at ridding the fish of attached lice (Grøntvedt et al., 2015). Furthermore, thermal delousing has been shown to produce the highest mortality rates of all modern treatment types, in part due to the increase in stress and immunosuppression experienced by the fish (Overton et al., 2019). In contrast, mechanical treatments consist of pumping the fish into an enclosed system in which pressurized water is used to force lice away from the salmon (Gismervik et al., 2017). These methods can result in the removal of up to 100% of mobile lice and up to 70% of attached lice (Gismervik et al., 2017). However, the abrasive nature of the treatment can result in scale loss, gill damage, and eventual mortalities (Hjeltnes et al., 2018).

The delousing methods currently in use not only can be harmful to fish welfare, but they are also losing their efficacy in alleviating the problem of salmon lice, as evidenced by trends in the frequency of necessary lice treatments over recent years (Overton et al., 2019). Overton et al. (2019) found that the number of lice treatments applied to fish stocks from 2012 to 2017 increased by 40%, even though the production volumes were nearly identical in these two years. More effective delousing methods may be gamechangers in ensuring the future success of the Norwegian SFI, both in working to solve the ecological issues that governmental regulations attempt to address by limiting production volumes, as well as to decrease the number of farmed fish lost to lice-related mortalities. New experimental lice-removal methods that have been proposed include the emission of ultrasound waves and the implementation of robots which utilize laser beams controlled by artificial intelligence (Qviller & Grøntvedt, 2016; Stranden, 2019).

Ultrasound has already been applied in operations to control outbreaks of algae in targeted areas, and entrepreneurs now want to bring their expertise to salmon farms (LG Sonic, 2018). Proponents of the technology claim that if it is shown to be effective, the emission of ultrasonic waves could provide a method of eradicating salmon lice from farming enclosures without applying chemicals or impacting the health of the fish (LG Sonic, 2020). Continued R&D efforts are being conducted in this undertaking to determine the effectiveness of this technology (LG Sonic, 2020; Skjelvareid et al., 2016). Another technique which combines a high-precision laser with advanced imaging software is able to recognize the presence of lice on individual salmon and deliver a pulse of energy directed at the parasite (Stingray Marine Solutions AS, 2020). Though this method proves fatal to the louse, it reflects off the scales of the fish, leaving it undisturbed (Stingray Marine Solutions AS, 2020). This technology can work continually and autonomously, as opposed to needing to be distributed manually at regular intervals, and is thereby able to handle lice infestations as they happen in real-time (Stingray Marine Solutions AS, 2020). As of the time of writing, no studies exist that document this method in practical usage, but if it becomes a viable alternative to traditional lice treatments, optical delousing could revolutionize the way salmon farming operations are conducted.

2.5.2 – Improved mix of ingredients in fish feed

Current trends in the evolution of the fisheries sector indicate that aquaculture companies may need to modify the mix of ingredients in their fish feed in order to sustain stable production volumes of salmon over the coming years. As time progresses, it will become increasingly necessary for components such as fish meal and fish oil to be swapped out with alternative sources of proteins, fats, and other nutrients. This is due to the fact that the primary source for this feed input is small pelagic fish which are not typically farmed, but rather wild-caught (Ryder et al., 2012). Feed is a variable input used in the process of farming salmon, meaning that the amount employed in production must be increased as greater production volumes are attained, in contrast with fixed costs which must be allocated regardless of production levels (Goolsbee et al., 2013). Thus, a certain paradox exists which requires that as aquaculture activities of species such as Atlantic salmon increase, the demand for certain species of captured fish grows proportionally (Lem et al., 2014). This increases the danger that these fish stocks will become overexploited and will no longer be able to replenish themselves at a sufficient rate, resulting in strengthened regulatory controls and introducing uncertainty into the market for this commodity (Deutsch et al., 2007; Ryder et al., 2012). Because feed is the industry's primary variable input, it is vital that producers acknowledge their vulnerability and utilize alternative sources when catch volumes of pelagic fish become volatile (Lem et al., 2014). In the current market, other sources of feed components are being considered as supplements or replacements for the nutrients which fish-based feeds provide (R. L. Olsen & Hasan, 2012).

The rapid increase in aquaculture production volumes, combined with stagnant levels of wild-caught fish, has coerced the industry over the last two decades into using diminishing portions of fish meal in its aquaculture feed. Instead, ingredients such as soymeal, wheat, and corn gluten have become substitutes in providing fish with the protein content necessary in their diets (Torstensen et al., 2008). The caveat of using these crops is that they lack important amino acids and the feed must instead be enhanced with these compounds, ultimately resulting in lower growth rates in the fish (Espe et al., 2006). In attempts to address this, recent discoveries have been made while studying the effects of replacing fish meal and fish oil with insect meal and insect oil, revealing surprisingly successful results (Belghit et al., 2018). Insects can be grown on the organic waste that is already generated by the food industry, as has been attempted with larvae of the black soldier fly (*Hermetia illucens*) (Belghit et al., 2019). A substitution in fish feed with the oil and meal generated from this species provides a high-quality source of protein and fat and contains similar amino acid contents to those found in fish meal (Belghit et al., 2019). In scientific studies to this point, the Atlantic salmon's feed intake and growth has remained unaffected by the replacement of fish meal and fish oil by their insect equivalents (Belghit et al., 2019). This indicates great promise for future trends towards a sustainable and potentially more reliable source of vital nutrients in farmed Atlantic salmon feed and can reduce the industry's dependency on turbulent supplies of wild fish stocks, ultimately helping to secure future production outputs.

2.5.3 – Increased utilization of current licenses

The licenses owned by a company for a specific region dictate the MAB that the company is permitted to rear simultaneously within their production sites in that region (Ministry of Trade, Industry and Fisheries, 2015a). In 2018, the average utilization for all Atlantic salmon farming companies operating within Norway was estimated to be around 85% of full allowance, indicating room for optimization (Mowi, 2019). MAB is closest to full utilization between October and November because the salmon's growth rate is higher than the harvest rate during this period, however, production capacity does not seem to reach its full potential as permitted by the licenses at any point in time during the year (Mowi, 2019). There is a very careful balance of factors that salmon farmers must consider with regard to maintaining the total biomass present within a farm at a single time, including the total volume of smolts introduced into the system, the growth rate of the fish, the expected mortalities within the stock due to salmon lice infestation and disease, and the removal of fish ready for harvest (Mcconnell, 2018). Due to the fact that Atlantic salmon is a biological product, and its production success is based upon a number of complex, interrelated and at times unpredictable conditions, the ideal of full utilization of the MAB regime has not yet been reached within the industry.

A target for the industry in the coming years may be to develop ways to reduce the unused portion of the licenses that companies already have access to. Mcconnell (2018) identified two ways that companies can potentially increase the proportion utilized of their MAB, and thus raise production levels: by introducing larger smolts into the sea phase of production, and by introducing the juvenile fish into the sea at more regular intervals. By using larger smolts which are produced in freshwater tanks on land, the length of time that the salmon are exposed to risk in the open net pens while reaching harvest size is reduced, resulting in fewer mortalities and creating more reliable predictions of fluctuations in biomass in the grow-out stage of production. The growth of large smolts on land is not constricted by MAB regulations, allowing farmers to decrease the amount of time the fish spend in open net pens by moving part of the production process out of the sea, and thus generating quicker turnover of salmon grown to harvest size in the pens. Additionally, allowing smolts to enter the sea in more frequent intervals keeps the biomass in operation areas at consistently high levels, and alleviates some of the seasonality of the production process. There are some practical obstacles that stand in the way of full incorporation of these suggestions, such as governmental regulation on smolt rearing and the need for new practices within the industry. Clear guidelines on such an intricate issue are hard to give, but it is tenable that an industry as innovative as salmon farming will work to solve these challenges in time.

2.6 – Aquaculture technologies

An unrelenting drive towards success under uncertain circumstances is a characteristic that uniquely describes the development of Norwegian aquaculture over the last several decades. Now, in a landscape of strengthening regulations and a shift towards environmental consciousness, the industry must again adapt to retain its global foothold. Key innovations into new and alternative methods of production may be a viable avenue of achieving this goal. Though these novel technologies may require higher initial fixed costs, producers which utilize alternative production methods may experience lower variable costs in the long term, such as for lice treatments and the restocking of smolts to replace fish lost to mortalities. Producers may ensure their highest levels of profitability by assessing various investment options, and choosing to invest in those ventures that generate the greatest present value of expected future cash flows (Cornelius et al., 2005; Eklund, 2013). The economic metric of net present value (NPV) compares the current value of the cash to be invested in a project (outflows) with the current value of the cash expected to be generated by that project (inflows), when assessed over the project's operational horizon (Remer & Nieto, 1995). Discounting these cashflows to a single point in time makes them comparable even if they accrue at different times (Remer & Nieto, 1995). When the NPV of cash inflows is greater than that of cash outflows, and the metric therefore manifests itself as a positive value, the project may be considered a worthwhile investment (Liu et al., 2016). In the application of NPV as an investment indicator for alternative production technologies, a salmon farmer is considered to have made a good financial investment when the NPV of the project is a positive value, when evaluating with respect to the period of time for which the technology is to be utilized.

Further explicating the cost side of a producer's profitability equation, a key assumption made of any firm's production behavior is that "the firm's goal is to minimize the cost of producing whatever quantity it chooses to make" (Goolsbee et al., 2013, p. 217). One of the ways that a firm can accomplish this is by undergoing technological change, in which total factor productivity growth is achieved (Goolsbee et al., 2013). This means that a firm can reach higher levels of production output with the same amount of input, or seen from another angle, the same amount of production output using a lesser amount of input (Goolsbee et al., 2013). In the case of the Norwegian SFI, advancements in production technologies may allow salmon farmers to produce harvestable salmon using fewer variable costs associated with alleviating the problems posed by salmon lice.

In this subchapter, we briefly describe the history and development of open net pen farming within Norway (in subchapter 2.6.1), followed by an illumination of the most recent and significant developments in alternative production technologies for farmed Atlantic salmon (in subchapters 2.6.2, 2.6.3, and 2.6.4).

2.6.1 – Traditional salmon farming – open net pens

The use of open net pens is currently the prevailing method of production within the Norwegian SFI (Bjørndal & Tusvik, 2017). This method of farming has persisted in Norway since its initial commercial establishment in the early 1970's, and has gone through several technological developments since this time (FAO, 2020e). The floating enclosures used during the early era of Norwegian salmonid farming (comprising rearing of both the Atlantic salmon and the brown trout) were of various designs and sizes, spanning a depth of from two to eight meters, and holding an average of around 200 m^3 in total volume (Braaten & Sætre, 1973). These enclosures were constructed of nylon nets suspended from a floatation device, usually made from either cork or Styrofoam, and rested on the surface of the water (Fiskeriøkonomisk Institutt ved NHH, 1971). The net pens were fastened in place using an anchor to either the sea floor or a stationary structure on land (Fiskeriøkonomisk Institutt ved NHH, 1971). Units would be installed in groups of two to six, in order to better utilize the production potential within a single coastal area (Fiskeriøkonomisk Institutt ved NHH, 1971). At this point in time, potential farming locations were limited by the quality and attributes of their waters, the local population's willingness to participate in the industry, and the robustness of nearby transportation infrastructure (Fiskeriøkonomisk Institutt ved NHH, 1971). Due to these limitations and the novelty of the industry, production quantities of salmon farmed within Norway were comparatively low during this early period (Statens forvaltningstjeneste, 1999).

Since this point in time, the open net pen technology utilized in the industry has been further developed with the goal of maximizing production volume (Food Safety Authority &

Directorate of Fisheries, 2010). The design of the floating rings has been scaled up since initial prototypes, and sturdier materials such as plastic and steel have replaced earlier infrastructure (Food Safety Authority & Directorate of Fisheries, 2010). The maximum circumference of the circular pens has steadily increased over the decades, from around 60 meters in the earlier days of farming, to nearly 160 meters in more recent years (Teknologirådet, 2012). To give a representation of the persistent trend towards larger net pens, we refer to a 2010 report published by the Directorate of Fisheries in collaboration with Norway's Food Safety Authority. This report showed that there was a 530% increase in the number of "large" net pens (19,500m^3 – 38,999m^3), accompanied by a drastic decrease in the number of "small" net pens (< 8,999 m^3), between the years 2005 and 2009 (Food Safety Authority & Directorate of Fisheries, 2010). The change in the size of enclosures used within the Norwegian SFI allowed the industry to grow by nearly double over this time period (Food Safety Authority & Directorate of Fisheries, 2010). A few years later, in 2013, it was not uncommon to achieve a farming volume of 100,000m^3 in a single pen (Iversen et al., 2013).

There are some biological and environmental challenges that currently, and will continue to, constrain the amount of production possible in Norwegian fjords using open net pens (Taranger et al., 2015). Establishing open net pens in an area introduces the opportunity for the farmed fish stock to pass on parasites and disease to wild fish (Taranger et al., 2015). Because the net structure is permeable by nature, salmon lice and nutrient waste generated by the farmed fish can pass through to other nearby areas (Bjørndal & Tusvik, 2017). The Norwegian government has instituted a number of laws to address these negative production externalities largely by restricting production volumes, as discussed in subchapter 2.3. In light of this, however, the Norwegian government has also initiated regulation which allows Norwegian aquaculture companies to apply for development licenses. This is intended to encourage the innovation of technological solutions to the industry's environmental challenges and lack of sufficient production space (Ministry of Trade, Industry and Fisheries, 2015b). Hereafter, we discuss some of the most significant types of full production methods which are being developed under these concessions.

2.6.2 – Semi-closed containment systems

One solution proposed by the SFI in an attempt to solve some of the challenges it faces is to utilize semi-closed containment systems. The Centre for Research-Based Innovation in Closed-Containment Aquaculture (CtrlAQUA) defines this type of system as one which pumps deep sea water (from twenty to fifty meters below the surface) through the production unit, in an attempt to “secure stable water quality and to avoid pathogens and parasites located near the surface” (CtrlAQUA, 2020, para. 9). Like traditional, open net pens for farming, semi-closed containment systems are able to utilize some of the natural conditions of the environment (Midt-Norsk Havbruk AS, 2020). However, the barriers which contain the fish stock may be constructed in an alternative manner, so that the flow of water in and out of the system can be controlled (Haaland, 2017). Incoming water is treated to ensure the desired temperature and oxygen levels, and to reduce pathogenic material and parasites such as salmon lice to a sufficiently low level (Haaland, 2017). Depending on the type of system, it may also have the capability of ensuring a lower number of fish escapes, and of purifying waste produced by the fish and fish feed (Haaland, 2017). Utilizing a semi-closed system allows the operator to make continuous adjustments to keep the aquatic conditions within a range which is optimal for the fish stock.

Implementing a semi-closed containment system can give the fish farmer more, but still limited, control over the environment their fish are raised in. This can limit the stock’s risk of escape and of its exposure to salmon lice, diseases, and suboptimal water conditions (Salaks AS, 2020). This advantage does not occur in open net pen farming, where the welfare of the fish stock is remarkably vulnerable to deteriorations in the water quality of the area in which they are located (Taranger et al., 2015). A growth in the local population of salmon lice or a lack of sufficient water exchange can have notable effects on the production quality and volume of the salmon raised in that location’s open net pens (Beveridge, 2004). Semi-closed systems are able to utilize the natural waterways, while mitigating for some of the negative effects experienced in the traditional farming method (Midt-Norsk Havbruk AS, 2020). Additionally, it is also worth mentioning that a semi-closed system can reduce the number of lice affecting the fish stocks in a geographical area, but it cannot eliminate the parasite completely in an environment where there is still some level of dependence on the natural water conditions.

One clear disadvantage that using a semi-closed containment enclosure presents when compared against open net pens is that it is more expensive to implement more substantial barrier materials and maintain additional operational systems within the farming infrastructure (Iversen et al., 2013). The use of semi-closed containment systems also necessitates energy to operate processes such as pumping new seawater into the system, and using various methods of filtration (Haaland, 2017). Due to the high capital expenditure and operational costs necessitated, semi-closed containment systems may not be optimally used when rearing salmon completely to harvest size. This type of technology may be better suited towards raising post-smolts, which are later to be transferred to a different type of enclosure (Calabrese et al., 2017).

2.6.3 – Land-based, recirculating aquaculture systems

Another technology which has been developed as an alternative to salmon farming's traditional open net pens is that of closed containment systems. This method utilizes an impermeable wall which creates a clear separation between the rearing environment of the farmed salmon and the natural aquatic ecosystem (CtrlAQUA, 2020). When the facility is located onshore, it is referred to as a land-based aquaculture system. Though land-based methods of farming have existed in Norway for several decades, significant technological advancements have been made in recent years, popularizing the use of recirculating aquaculture systems (RAS) in today's industry (Bjørndal & Tusvik, 2017). As with semi-closed containment systems, closed containment systems also pump water through the production unit, however, there is minimal to no exchange of water between the facility and the natural environment (CtrlAQUA, 2020). As much as 99.9% of the water recirculates through the system during operation and is continuously treated and recycled to maintain proper quality (CtrlAQUA, 2020).

Utilizing a land-based RAS system allows a salmon farming company to have nearly complete control over the aquatic environment in which its salmon are growing (Bjørndal & Tusvik, 2017). One major advantage to this is that a salmon farming company can virtually eliminate the problem of salmon lice affecting their stock within an RAS facility (Davidson et al., 2016). Significant costs associated with salmon lice treatments, as well as with the loss of stock due to mortalities caused by lice outbreaks, are averted (Abolofia et al., 2017). Since the quality of the water can be more easily controlled in production using RAS, some of the costs of establishing and operating this type of facility are offset by the reduction in production costs for salmon lice treatments (Bjørndal & Tusvik, 2017).

The health and welfare of the salmon can also be maintained more easily within a land-based RAS facility than within an open net pen. Because RAS technology allows the conditions of the water to be controlled as necessary, the fish stock benefits from having a more stable environment, notably in terms of a consistent temperature and level of oxygen (Bjørndal & Tusvik, 2017). This allows the salmon to thrive, improving their uptake of feed, positively impacting their rate of growth, and ultimately creating a healthier fish of higher quality (Bjørndal & Tusvik, 2017). Increasing the salmon's rate of growth by optimizing feed consumption reduces the amount of time the salmon must spend in production before they reach harvest size, which may in turn increase the turnover of fish being reared within the land-based RAS facility, and thereby helping to maximize production volumes.

Another unique aspect experienced by utilizing a land-based RAS facility in lieu of sea-based open net pens is that there is the possibility to establish the operations at a location that is closer to the end-consumer, reducing high transportation costs (Bjørndal & Tusvik, 2017). Because an artificial environment optimal for salmon rearing is created within the confines of a man-made structure, a facility of this type can be established independent of any natural conditions necessitated by traditional farming sites. Norway retains a distinct competitive advantage in salmon farming compared with many other countries, due to its extensive, sheltered coastline, which has contributed in large part to the domestic industry's success (Osmundsen et al., 2020). This specific natural landscape is not required to operate a land-based RAS salmon farm, meaning that other countries can become potential competitors in the global supply market. For these reasons, this technology can be seen as an advantage to the Norwegian salmon farming company looking to expand production, but also as a potential disruptor within the industry on a global scale.

One of the most notable disadvantages to this technology is the sheer capital expenditure associated with building the facility, and the operational costs of utilizing it for production. Whereas Iversen et al. in 2013 estimated the investment cost of an open net pen in-shore to be 220 NOK per m^3, and that of a semi-closed containment system to be 2,500 NOK per m^3, the report also concluded that land-based RAS facilities required an estimated investment of 10,000 NOK per m^3. The high cost of land-based farming operations may also financially restrict producers from being able to raise their salmon to slaughter size in these facilities, and at current costs, it may instead only be feasible to use land-based RAS for post-smolt salmon grown as inputs to be placed within open net pens (Bjørndal & Tusvik, 2017). There is also some discussion in the industry concerning the salmon produced in land-based RAS facilities as having a taste that is perceived as poor quality (Sapin, 2020b). This may be a characteristic of the end product which is not acceptable to consumers, resulting in a reduction of demand in salmon produced using this technology.

2.6.4 – Offshore salmon farming

As biological challenges contribute to the limitation of potential space to utilize for aquaculture within Norwegian coastal waters, salmon farmers are incentivized to think outside of traditional areas of production. Land-based RAS facilities comprise one response to this phenomenon, whereas offshore aquaculture offers another approach. Offshore salmon farming presents many unique challenges in regard to technological requirements, the structural integrity of the infrastructure, and the assurance of the farmed fish's welfare.

There is no consensus in the industry of what defines an area as being "offshore" for use in aquaculture, in terms of distance from the shore and depth of the operating waters (Froehlich et al., 2017). In a report issued in 2019 by the Norwegian government, offshore aquaculture infrastructure is described only as "aquaculture installations which can be used further out than what is usual in today's aquaculture activities" (Ministry of Trade, Industry and Fisheries, 2018, p. 8) Such a loose definition may be a source of legal contention surrounding this type of production in the future, as current regulations for production activity vary based upon the distance out into the sea in which it occurs (Ministry of Trade, Industry and Fisheries, 2018). Therefore, offshore aquaculture is currently a concept still based mostly in theory, and future industry developments may give a clearer depiction of what this type of technology actually encompasses.

The idea of offshore fish farming has come to fruition only very recently, and its potential therefore holds a considerably more uncertain outlook than that of other methods. Due to its novelty, there is as of yet very limited knowledge on what type of technologies and equipment the optimal offshore farm would need to utilize in order to be feasible, scalable, and profitable (Shainee et al., 2013). It is well-established that the structure of such a farm must be sturdy enough to withstand heavy storms and extreme environmental conditions in the open sea (Shainee et al., 2013). The current Norwegian regulation regarding the longevity of a single floating aquaculture pen requires that the pen's construction allows the infrastructure to hold up in the worst storm it can be expected to encounter over a fifty-year period, however, suggestions have been made to hold offshore aquaculture installations to the hundred-year standard of oil and gas platforms (Ministry of Trade, Industry and Fisheries, 2018). Accomplishing this feat may call for a combination both of the competencies built up in the Norwegian oil and gas sector over recent decades, and of the knowledge-base of the country's aquaculture industry (Shainee et al., 2013).

One of the primary challenges that offshore aquaculture attempts to resolve concerns the limitations on operating space and production output within Norwegian coastal waters (Shainee et al., 2013). As explained in subchapter 2.3, governmental regulations have effectively capped traditional production in Norway's fjords to a large degree, but they have not established maximum levels of capacity generated by offshore installations. One of the appeals of offshore salmon farming is that it may not be covered by the TLS if the structure is located at a sufficient distance away from the coasts, and does not fall under the current legislation which constrains production volumes (Ministry of Trade, Industry and Fisheries, 2018). SalMar ASA's Ocean Farm 1 offshore salmon farming production facility has shown to be capable of holding 1.5 million fish, and the company aims to double this number with their future Smart Fish Farm offshore facility (Popescu, 2018). If offshore technology is a feasible answer to the industry's lack of operating space and restrictions on production outputs, this opens up notable possibilities for these companies to produce large volumes of fish in a single operation.

Offshore salmon farming can also more easily mitigate the accumulation of fish waste in the area of operation. It is in aquaculture companies' best interest to ensure low levels of waste build-up, as a deterioration of the surrounding water quality can lead to reduced growth of the salmon stock, as well as augmented levels of disease and mortality (Asche & Bjørndal, 2011). Maintaining good water quality adequate for salmon to thrive in is not always an easy goal to achieve in the coastal areas of Norway. A strong current needs to be present in the area of operation in order to supply the water with enough oxygen to allow for a sufficiently fast rate of organic waste decomposition (Bjørndal & Tusvik, 2017). This is an advantage that offshore aquaculture affords, providing better water exchange and enhanced transportation and dispersion of fish waste (Hvas et al., 2019).

There is significant uncertainty surrounding the degree to which offshore salmon farming manages the growth and distribution of salmon lice populations (Iversen et al., 2013). A report authored by Ådlandsvik and published by the Institute of Marine Research (2019) concluded that salmon farms operating 20 – 30 nautical miles (37 – 56 kilometers) from the coast present a risk of salmon lice spread to coastal waters. If these findings hold up in practice, this could mean that offshore salmon farms may also be subjected to regulation limiting production levels or requiring a minimum distance from shore for operation. This should be taken into account in future legislation posed by governments and considered in future investment decisions made by aquaculture companies.

Maintaining proper fish welfare in an offshore farming operation is a significant technological hurdle that the industry must work to solve effectively. Due to a stark difference between the salmon's natural environment and that of the open sea, care needs to be taken to ensure that the salmon do not experience stress caused by powerful currents or suboptimal sea temperatures (Shainee et al., 2013). Salmon residing offshore and near the water's surface can experience such negative effects as seasickness during storms, causing the fish to dive to the bottom of the enclosure to avoid discomfort (Shainee et al., 2013). The salmon's aversion to the impact of waves is so strong that it can override their natural behavior of seeking a suitable temperature and level of light, both impacting the welfare of the fish stock as well as reducing the effective volume of the enclosure (Shainee et al., 2013). Furthermore, a decline in fish welfare can cause increased mortality rates, decreasing the number of harvestable fish at the end of a season, and thereby decreasing a farmer's total production output (Taranger et al., 2015).

3 – Research design

Our research design is intended to present the comprehensive and coherent framework that guided us in empirically answering the stated research question and to reflect the scientific quality of this work.

In order to provide the reader with a thorough understanding of the research design employed, we begin by explaining this study's underlying research philosophy and purpose (in subchapter 3.1). Subsequently, we specify the types of data which were gathered and analyzed (in subchapter 3.2), followed by a description of the time horizon used (in subchapter 3.3). Lastly, we expand our two chosen research strategies (in subchapter 3.4), and present the necessary ethical considerations that accompanied our data collection and analysis (in subchapter 3.5).

3.1 – Research philosophy and purpose

In answering our research question, it was necessary to make some assumptions about the individual realities we examined, their relationships to one another, and the ways in which data were to be gathered and analyzed. These assumptions were targeted towards the end goal of inferring unique insights about the development of the Norwegian SFI, with respect to alternative production technologies.

Saunders et al. (2008) defined research philosophies as belief and assumption systems inherent in the process of knowledge development in a particular field of study. In line with this definition, we hereby briefly illuminate the underlying research philosophy of this work, as it significantly influenced the choice of research strategies (Symon & Cassell, 2012). Moreover, the process of discovering and acknowledging our research philosophy allowed us to develop the competence of reflexivity, which enabled us to critically challenge our methodological choices (Miles et al., 2014).

Saunders et al. (2016) differentiated among five major research philosophies: *critical realism, interpretivism, positivism*, *postmodernism*, and *pragmatism.* For the sake of conciseness, we describe only the philosophy that is applicable to this work, namely, interpretivism. This philosophy stems from the assumption that human beings, due to their ability to construct meanings from their experiences, are intrinsically distinct from natural phenomena, and that, "therefore social sciences research needs to be different from natural sciences research rather than trying to emulate the latter" (Saunders et al., 2016, p. 140). Thus, interpretivist assumptions are particularly appropriate for empirical research that seeks to build deep understandings of organizations or industries by means of qualitative data (Saunders et al., 2016). In contrast to positivists, who seek to determine categorical laws that apply to humans collectively, interpretivists hold the opinion that meaningful knowledge about humankind would be ignored if its complexity was abstracted to principle-based generalizations (Stern, 2004). The main practical challenge for interpretivists is to consciously exclude subjective expectations of possible research outcomes, which is achieved through the deliberate and systematic extraction from the dataset of socially constructed meanings (Saunders et al., 2016).

To the best of our knowledge, current qualitative studies on decision-making behavior within the Norwegian SFI remain scarce, especially when considered in the narrower scope of the industry's development as contingent on alternative production technologies. Given this methodological and thematic gap in existing literature, it was impracticable to scan any existing literature on this topic to derive hypotheses for potential validation or falsification with regard to our research question. Instead, we presented this work's chapter 2 as a basis for providing the reader with industry-specific knowledge necessary for the comprehension of our results in terms of socially constructed meanings and their contexts. While *deduction* describes the process of testing general hypotheses for specific cases, *induction* is geared towards generating comprehensive conclusions from specific cases (Saunders et al., 2016). In aiming to deduce novel, holistic insights for the Norwegian SFI's development based on interviews with decision-makers from Norwegian salmon farming companies, as well as garnering a further understanding from industry-specific news articles, we followed an inductive approach to theory development. Figure 5 depicts a model about the interplay between this work's chapter 2 and our approach to theory development.

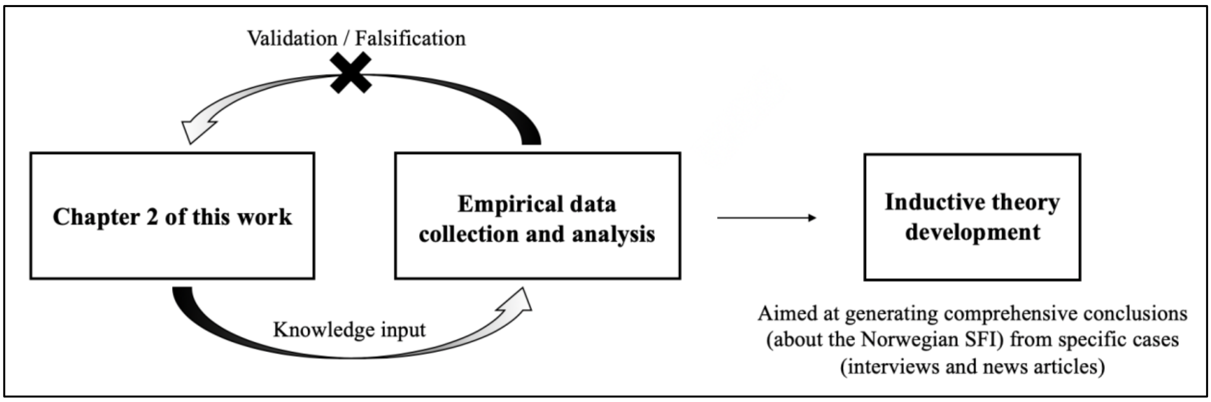

Figure 5. Model about the approach to theory development

Exploratory studies aim to illuminate topics of unclear nature and are used as a basis for further research (Given, 2008). Due to the pioneering nature of our research question and its deeprooted objective to systematically explore an uncharted issue, this work can be classified as an exploratory study. In order to ensure an unbiased process of data collection and analysis, exploratory research questions posed should leave the investigators enough scope to discover the unexpected, by means of open-ended formulation, for example, by introducing the questions with the words “what” or “why” (Saunders et al., 2016). Srnka (2007) regarded this form of inquiry as a cornerstone of science and as an important source of knowledge for further work in a research domain. Furthermore, this study constitutes applied research, meaning that it aims to generate empirical findings that are of practical relevance to both decision-makers and policymakers in the Norwegian SFI (Saunders et al., 2016).

3.2 – Use of data

This work can be categorized as using *mixed methods* research, with a *concurrent triangulation* design. Mixed methods research involves the use of both qualitative and quantitative data collection and analysis procedures, while concurrent triangulation refers to using various, independent data sources and/or research strategies with the aim of crosschecking findings and developing a more complete understanding of phenomena (Saunders et al., 2008).

We utilized both qualitative and quantitative elements in order to answer our research question, though a stronger emphasis was placed on the qualitative aspects of our data. Our study primarily makes use of purely qualitative elements, namely, interviews and news articles, which are comprised of textual rather than numerical data. Furthermore, these items were analyzed through the lens of the researchers’ interpretations, with precautions in place to ensure relative objectivity, in order to derive meaning from the opinions and events surrounding the Norwegian SFI in regard to alternative production technologies. Two methodological approaches were applied as mutual supports, in order to both broaden and deepen our understanding of the industry. Through the application of triangulation, we aimed to increase the diversity of our data by employing news articles while utilizing conducted personal interviews to garner a more substantial explication of the industry’s implementations of alternative production technologies. Data was collected concurrently, allowing the researchers to independently draw conclusions from each data type and to crosscheck findings across the gathered data. It should be noted that our study contains some quantitative characteristics, as our method of grouping the news articles for categorization and inspection relies on probabilistic modeling algorithms to generate distinct topics of interest. Additionally, this data is presented in a manner that highlights topic distribution over the sample, as well as the proportions of each researcher-identified theme discovered within the relevant topics.

However, our ultimate goal for this work is to present the reader with a qualitative description of the roles of alternative production technologies within the Norwegian SFI's development. To this end, we utilized some quantitative means to come to a conclusion which can be understood qualitatively, in a theoretical perspective.

3.3 – Time horizon

For the purpose of accomplishing our second research objective, we chose to pursue a cross-sectional study, as opposed to one which was longitudinal. This is because our goal in this research endeavor is to utilize current, relevant proxy indicators to shed light on the roles that alternative production technologies, as used in companies' farming operations, play in the development of the Norwegian SFI. To this end, we believed that conducting interviews over a short time period would be suitable in attempting to gain insights into the perceptions industry actors had on these alternative technologies, thereby indicating developmental trends. Our discussions with industry decision-makers were therefore focused on deriving opinions about current practices and expectations of industry development. These interviews were conducted between the dates of February 17th, 2020, and March 20th, 2020.

After holding several discussions with industry representatives, we began to understand the importance of central information hubs capable of relaying current events and developments between participants on the supplier's side of the Norwegian SFI. This led us to implement a second aspect within our analysis, in the form of articles retrieved from the industry news website IntraFish. We chose to extend our time period to one year for the retrieval and assessment of industry news articles in order to derive the most meaningful findings, and we hold that this still remains reflective both of current industry practices while containing key perceptions that are capable of indicating the industry's developmental state. Our purpose in doing this is to increase our sample size of articles with the goal of gaining a broad perspective of how the Norwegian SFI is portrayed through industry media, while still ensuring that articles are relevant for portraying the industry's current and developing themes. Furthermore, we make no attempts to analyze or discuss how the articles trend over the sample period, but rather focus on recurrent themes that appear when considering the documents as representative of a relatively brief moment of time in the context of the Norwegian SFI's fifty-year history. These articles were published between the dates of April 22nd, 2019 and April 22nd, 2020, and were retrieved from the web on April 23rd, 2020.

3.4 – Research strategies

Research strategies are organized and conclusive plans of action for fulfilling the research objectives and constitute the logical link between the underlying research philosophy and the methods employed to gather and analyze data (Saunders et al., 2008).

The following presents this work's research strategies and the reasons for choosing them (in subchapters 3.4.1 and 3.4.2). In addition, each of these two sections contains a subchapter that describes how these research strategies were employed in practice, aiming to ensure the highest possible transparency and replicability of this work (in subchapters 3.4.1.1 and 3.4.2.1).

3.4.1 – Grounded Theory

Grounded Theory (GT) was established by the two American academics Glaser and Strauss (1967) and offers a systematic agenda for the generation of novel theory. The name of this research strategy is meant to emphasize its aim to establish new theory that is grounded in the research participants' behavior, words, or actions (Glaser & Strauss, 1967). Though GT was initially intended to unveil patterns in social behavior, its descriptive and interpretative strength for theory generation has increasingly been recognized and utilized by business researchers, who aim to understand organizational decision making and its impacts on industrial developments, as well (Ng & Hase, 2008; O'Reilly et al., 2012). Strauss and Corbin (1994) defined a theory as a collection of conceptual relationships that offers a valid explanation for a phenomenon of interest. The central academic aspiration of GT is to enhance future studies by offering a strong qualitative foundation (Bryant, 2017). In practical terms, Glaser and Strauss (1967) observed the pattern in which many scholars tested hypotheses from theories that they had barely begun to understand. Consequently, the research of these scholars was often conducted on the basis of theoretical foundations which were too abstract and led to vague hypotheses (Goulding, 2002). This notion of GT resonates with this work's underlying interpretivist research philosophy and exploratory research purpose, intending to build new theory in a research domain where little is known, as opposed to testing hypotheses in a well-researched field of interest.

The practical implication that is most characteristic of GT is that relevant concepts needed for theory development emerge just throughout the empirical phase of the research endeavor, meaning that they are an outcome of repeated interactions between gathering and analyzing data (Bryant, 2017). Thereby, concepts in the realm of GT can be seen as the abstract explanation of meaningful pieces of data (Goulding, 2002). This fundamental aspect within

GT ensures that as few preconceptions of potential research outcomes as possible manifest within the researcher before the collection and analysis of data have commenced (Goulding, 2002). The quality criterion of *reliability* evaluates scientific work for its transparency and its potential to be replicated (Saunders et al., 2016). Hence, if other researchers can mirror a given study using the same research design and retrieve the same insights, the study would be classified as being highly reliable (Saunders et al., 2016). Ensuring that concepts arise just throughout the collection and analysis of data strengthens the reliability of GT studies because researcher biases, which induce preconceptions within the researcher of the participants' realities, can be minimized (Goulding, 2002).

To achieve this, practitioners of GT offer a variety of practice-oriented recommendations. Since the initial publication by Glaser and Strauss (1967) exhibits a strong emphasis on the philosophical notions of the theory, in the following two paragraphs, we refer to two textbooks that offer a stronger focus on explaining the practical application of the theory (Charmaz, 2006; Goulding, 2002). Figure 6 aims to familiarize the reader with the most important activities and artifacts involved in a GT study.

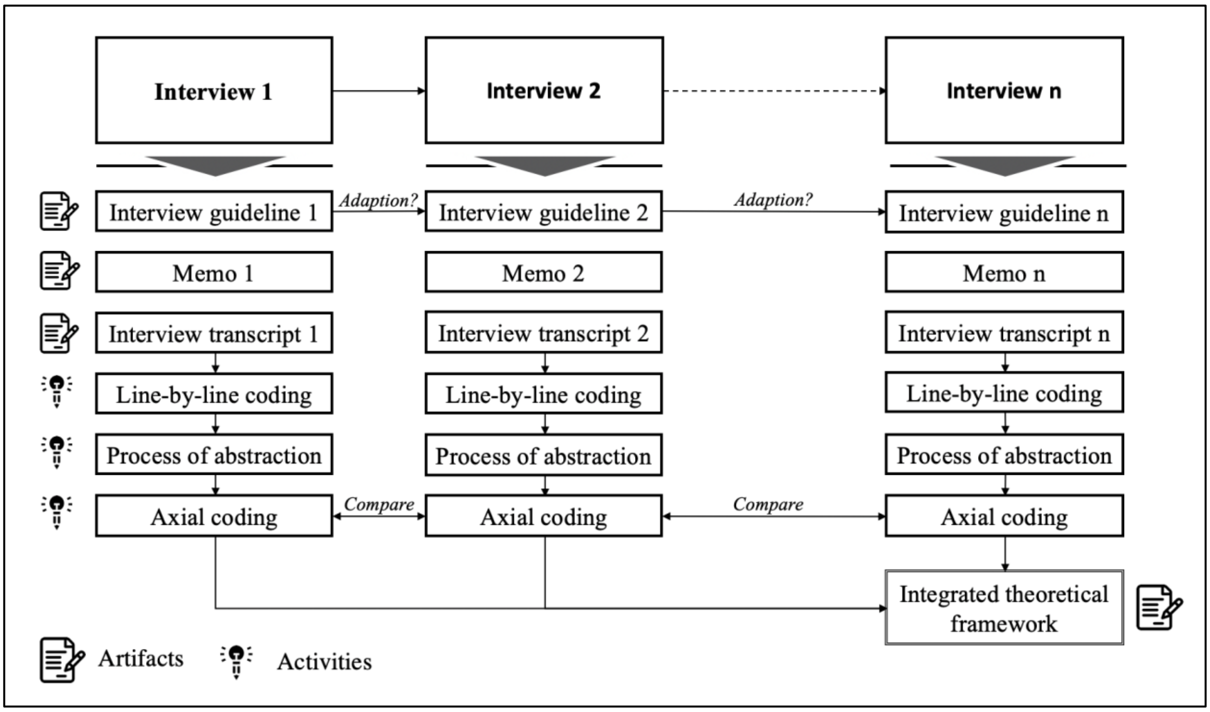

Figure 6. Most important activities and artifacts involved in a GT study

Note. The question of adaptation refers to the possibility to adapt interview guidelines according to concepts that have emerged in previous interviews. Hence, concepts that emerge throughout the analysis of interviews can affect the data collection process in subsequent interviews (repeated interaction). Axial coding involves the comparison of interview transcripts in order to be able to acknowledge complex conceptual interrelationships across the data. Adapted from *Grounded Theory: A Practical Guide for Management, Business and Market Researchers*, by Goulding, 2002.

It is recommended that the researcher commences the research project by designing an interview guideline incorporating open-ended, broad, and non-judgmental questions, which entice the interviewee to lead the conversation. Throughout the first interviews, it is important that questions are not colored by preconceptions, but instead take a naïve stance towards possible guiding themes within the conversations. However, as the research progresses, the interview guideline can be adjusted in accordance with emerging concepts that originated from concrete statements made in previous interviews (resulting in repeated iterations between collecting and analyzing data). The use of *memos* is vital for capturing initial ideas for concepts. Throughout the research journey, memos should be written immediately after each interview in order to create an idea repository which the researcher can revisit at any time. There are no formal criteria in terms of size or medium for memos. Yet, they play an indispensable role in GT because they ensure that initial ideas do not become forgotten or prematurely abandoned. In addition, memos are a useful means of abstraction and the ideas they encapsulate should be phrased conceptually rather than in the words of the research participants.

Subsequent to the creation of memos, the next step in the process of theory development is to apply hierarchical methods of coding to the data of interest. This step aims to subdivide interviews into specific entities of meaning. Given the great amount of verbal data, it is necessary to first transcribe interviews, thereby transforming them into textual data. Establishing entities of meaning starts with *line-by-line coding*, in which the researcher reads through every line of the transcribed interviews and labels portions of the data with descriptions in order to create data summaries and enhance the feasibility of further analytical steps. These preliminary labels, or *codes*, are not related to one another and do not constitute concepts. In the following step of coding, the analysis of the transcribed interviews requires the *process of abstraction*, allowing the researcher to visualize data on a more abstract layer of meaning – moving from simple, descriptive codes to concepts that offer explanations for observations in the data. That is, the researcher labels parts of the transcribed interviews with emerging concepts that are suitable for explaining the realities portrayed by the research participants. This is largely done on the basis of the codes that have resulted from the line-by-line coding in order to keep the work manageable. After having identified and highlighted concepts in the interview transcript, the process of analyzing the data involves a final method of coding, called *axial coding.* Axial coding is intended to move the analysis from a collection of concepts to an integrated theoretical framework. This framework refers to a structure of empirically grounded findings meant to support the research study's underlying objectives and, in the context of this work, is presented in our discussion in chapter 5 (Abend, 2008). An integrated theoretical framework is created through the acknowledgment of concepts with respect to their complex interrelationships within and across interview transcripts and data in general. It requires that concepts are examined in-depth and coherently, leading to the formation of theoretical *categories*, which can be thought of as storage for related concepts. Categories should, if applicable, combine the related concepts with the researcher's scholarly knowledge, meaning that extant theory should be employed to elaborate further upon categories and to facilitate the generation of a well-informed novel theory. The inclusion of extant theory should be based on a process called *introspection*, by which category-based, existing theories arise from the researcher's own knowledge base. Still, reading new literature remains a crucial part of the researcher's responsibilities and should not be neglected, as it helps one to reflect critically upon known theories and to encounter new ones.

Glaser and Strauss (1967) differentiated between two kinds of theories. While *formal theories* aim to explain general phenomena across industries, organizations, or individuals, *substantive theories'* explanatory power remains within one particular field of study. Since we strive to gain a better understanding of the Norwegian SFI in particular, the resulting theory is of substantive nature.

To conclude, we consider GT a suitable research strategy primarily for the following three reasons. First, as mentioned, GT places strong emphasis on the connectedness between data collection and analysis, facilitating the creation of unbiased outcomes and resulting in enhanced reliability. Second, its strategies of coding offer a feasible and effective framework for researchers to exhaustively and systematically answer qualitative research questions, without reducing the complexity of the research participants' realities to the vague judgment of the researcher. Finally, GT's open stance towards possible research outcomes and its aspiration to incorporate existing theories into the process of theory generation make it particularly suitable for thoroughly studying research domains about which little is known.

3.4.1.1 – Application: Data collection and processing

The practical implementation of GT was highly conditional on the participation of relevant decision-makers from the Norwegian SFI. Hence, receiving a positive response from these individuals to participate in interviews constituted the most critical challenge in the process of collecting data. To overcome this obstacle, we started first by defining the target population according to the following two dimensions: the individuals' functions within their respective organizations, and the size of the organization with which they were employed. In terms of their functions, we specified that they should play an active part in the decision-making process for the investment into alternative production technologies. The reasoning behind this criterion was that these decision-makers would presumably be best able to provide us with an accurate, first-hand account of the roles that alternative production technologies play in the development of their respective firms. Regarding the size of the company, we limited the target population to the 10 largest companies, in terms of annual production capacities, operating within the Norwegian SFI (Ministry of Trade, Industry and Fisheries, 2018). According to data provided by the (Directorate of Fisheries, 2020d), these companies have consistently comprised around two-thirds of the industry's total annual sales volume in the years from 2014 to 2018 and, thus, can function as suitable proxies for indicating developments in the Norwegian SFI. Appendix H presents the distribution of the Norwegian SFI's total production capacity and the historical development of the largest companies' share of the industry's yearly total sales volume. The choice for the largest 10 companies, in terms of annual production capacities, was made to create the most representative portrayal of the industry with the limited time and capacity we had while conducting this research.

After having defined the target population, we applied a *quota sampling* technique, whereby we approached pre-selected individuals from a list of subgroups we had derived from the target population (Saunders et al., 2008). However, subsequent to contacting these individuals, we experienced a relatively low positive response rate. In fact, only two of the five chosen potential interview participants agreed to participate in our study. In response to this obstacle, we modified our sampling technique to include *volunteer sampling*, meaning that we sought out potential interview participants who would both fall into our predefined target population, as well as volunteer to be a participant in our study (Saunders et al., 2008). This sampling technique involves asking participants in initial interviews for contacts who may be willing to engage in subsequent interviews – a concept also referred to as *snowball sampling* (Saunders et al., 2008). It is worth mentioning that we deliberately discarded theoretical sampling as a potential method, though it is recommended by some GT practitioners and implies aligning the sample in accordance with emerging theoretical categories, because we placed greater emphasis on the representativeness of our sample and argued that our target population would be competent and capable of providing information on a wide array of categories related to our research topic.

To reach further potential interview participants and to increase the number of initial interviews, we applied a method known as *pyramiding*. In essence, this method is built on the assumption that sought-after individuals with rare attributes in large populations can effectively be reached through tertiary levels of the researcher's own networks (von Hippel et al., 2009). Pyramiding involves "moving up the pyramid" (von Hippel et al., 2009, p. 1398) from a broader population at the bottom to the target population at the top. In accordance with this method, we employed our professional and personal networks in Norway and asked colleagues, friends, and family if they knew potential willing participants who work in the Norwegian SFI. By means of using the pyramiding method, we succeeded in conducting another three interviews with individuals in our target population. During the interviews, we applied snowball sampling and were able to identify five additional potential participants that fulfilled the criteria for our target population, of which two agreed to participate in our study. In line with the suggestions of Glaser and Strauss (1967), we ended the sampling process when we realized that emerging concepts saturated and no new ones arose, which happened after the seventh interview. Figure 7 summarizes the conducted interviews.

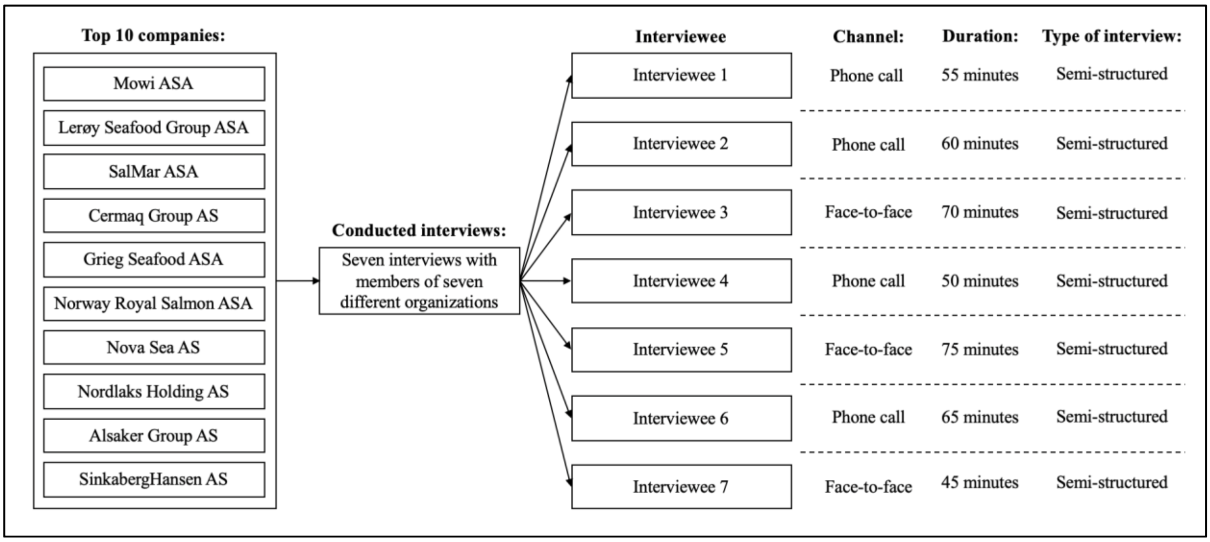

Figure 7. Overview of the conducted interviews

Note. Interviews conducted via phone calls had similar depths and lengths as face-to-face interviews and helped to increase the individuals' willingness and ability to participate.

Since GT holds that relevant concepts needed for theory development should not be determined before the data collection and analysis process has begun, but rather are allowed to emerge throughout the process, we conducted semi-structured interviews. Accordingly, we prepared an array of broad themes and key questions for the interviewees. Depending on the flow and focus of a conversation, we would consult our interview guideline to steer the interview towards relevant topics or use follow-up questions to seek clarification of unclear statements.

This interview technique allowed us to remain flexible during the conversations and to expand upon emerging concepts. To further illuminate these concepts, we considered marginally adapting our interview guideline prior to each successive interview. Appendix I presents the three interview guidelines utilized in chronological order. In addition to the guidelines we used for our own, internal purposes, we sent less descriptive, external interview guidelines to the participants. These were distributed prior to the interviews to ensure that the participants had enough time to prepare for the interviews, in order to elicit richer information. Appendix J provides the reader with an example of an external interview guideline.

After each interview, we discussed initial ideas among ourselves which could be used for concepts, and exercised the aforementioned process of introspection. Immediately after these debriefing sessions, we captured our initial ideas in memos (we refer the reader to Appendix K for a representative example of a memo). In order to develop these memos with ideas for possible theoretical explanations, we would continuously refer to concepts with which we were already familiar, as well as seek out further relevant literature in academic domains such as managerial decision-making and strategic management theory, in order to foster a coherent, theory-based understanding of the concepts encountered in interviews. All interviews were audio-recorded and subsequently transcribed verbatim. In order to apply the various methods of coding, we used a software called Atlas.ti to conduct a computer-assisted qualitative data analysis. Friese (2016) described this software as being particularly useful when a researcher manages large amounts of interview data, as it enables one to methodically attach codes to relevant sections of textual data to assist in visualization. We used Atlas.ti for line-by-line coding and the process of abstraction, resulting in descriptive codes and abstract concepts that explained meaningful observations in the data. A representative screenshot of the use of Atlas.ti is provided for the reader in Appendix L. For axial coding, we employed a traditional pen and paper approach as we realized that this was the best method in practice for summarizing the complex interrelationships among the concepts identified, and then relating them to extant theory. We drafted interrelationships among various concepts, compared relevant existing theory to the newly established categories, discussed our findings, and validated them with explicit statements from interviews.

Throughout the collection and analysis of data, we implemented a broad range of measures aimed at ensuring a high scientific quality of this study. Appendix M explicates these measures and clarifies how they were employed to deal with common threats to reliability and validity.

3.4.2 – Documentary Research

As we continued to engage in conversations with our interview participants, one common theme we noticed throughout their responses was that companies tended to attentively follow industry developments. Central hubs for industry news were noted to be of great interest to decision-makers, due to their conveyance of information relayed by other professionals operating within the Norwegian SFI. We deem that such sources have great potential to reliably portray contemporary themes in the industry with regard to alternative production technologies. Therefore, we found it valuable, in the process of conducting our research, to implement an analysis on articles recently published by the industry news source IntraFish. In addition to being referred to as "the world's leading seafood and aquaculture news source," this website was repeatedly cited by respondents as being useful in keeping a pulse on developments within the Norwegian SFI (IntraFish, 2020, para. 1). By incorporating this aspect in our research, we hoped to balance our personal discussions with industry experts with a source that may better reflect the voice of the industry on an aggregate level.

To accomplish our research objective in this manner, we engaged in documentary research. This type of research strategy encompasses a great deal of potential sources which can be utilized for investigative purposes, including textual, visual, and audio depictions of information (Saunders et al., 2016). For our usage, we considered textual data, in the form of online articles, most relevant in building a framework for how the Norwegian SFI is developing with respect to alternative production technologies. Documentary research has been acknowledged in academic circles as a good complement to GT, as the combination of both strategies can provide more coverage than either would be capable of on its own, allowing for both breadth and depth into the research subject of interest (Baumer et al., 2017; Saunders et al., 2016). In particular, the method of *topic modeling* can be of great assistance to the qualitative researcher who wishes to efficiently and effectively derive meaning from large datasets (Eickhoff & Wieneke, 2018). Both GT and topic modeling work in similar ways, in that they rely on the researcher's interpretation of recurrent themes to come to conclusions about the overall dataset, however, topic modeling's strength lies in its usage of algorithms to identify groups of related documents within datasets, with a very high upper limit on the amount of data which is feasible to analyze (Baumer et al., 2017; Boyd-Graber et al., 2017).

Topic modeling is an approach to clustering data that utilizes unsupervised machine learning (Bakharia et al., 2016). This means that the model is left to detect hidden structures within the dataset without being provided with additional information, such as topic labels, by the researcher (Jeong et al., 2019; Pröllochs & Feuerriegel, 2020). The goal of topic modeling is to take a number of documents as input, containing the texts for evaluation, and as output, produce a probabilistic estimate of each document as belonging to each individual topic in the set of *K* total topics, where *K* is specified by the user prior to initialization of the model (Boyd-Graber et al., 2017). Each unique document is assigned a probability of belonging to each topic *k*, where the sum of the probabilities of a single document belonging to all individual topics *k* is equal to one (Blei et al., 2003). This representation of every document as a mix of all possible topics in the model allows for some flexibility in the interpretation of the resulting probabilities in this study, as news articles can encompass a number of different topics within a single text.

The method we use to conduct our topic analysis of industry news articles is that of *Latent Dirichlet Allocation* (LDA) topic modeling using *Gibbs sampling*. LDA was introduced in 2003 by Blei et al. in their paper "Latent Dirichlet Allocation," which we hereafter explain concisely. This model is a generative model that uses joint probability to determine which topic a document is likely to belong to, given the probability distributions of existing data in the model. To initialize the process of LDA, a number of documents is passed as input to the algorithm. To explain the algorithm most simply, one can think of LDA as first beginning with a blank document to which it can add words at random. The algorithm then attempts to generate a new document with the highest probability of replicating the existing document of consideration, which has already been provided to the model as input. In order to accomplish this, the LDA model uses certain parameters, which provide information about the words and topics, to maximize this likelihood. Four components are of special importance in determining the success of replication.

The first component (as represented by α in figure 8) is a Dirichlet distribution which provides a geometric location of documents within the simplex of topics, where each vertex of the simplex represents a single topic. As previously stated, each document is assigned a value representing its probability of consisting of a certain topic, where the sum of all probabilities across all topics equals one. These probabilities are passed to a multinomial distribution, which determines the probabilities of each word generated to compose the new document as stemming from any one topic. In this manner, the topic composition of all of the words in the document is chosen according to this multinomial distribution, which comprises the second component of the model (as represented by θ). The third component (as represented by β) is another Dirichlet distribution which locates topics inside a simplex of words, where each vertex of this simplex represents a single word. The closer the geometric location of a topic is to a vertex of a word, the higher the probability for that word to be chosen to represent that topic. From this, to construct the fourth and final component (as represented by φ), another multinomial distribution can be derived which uses the probabilities of the words generated in the third component to choose the specific words which will represent the decided topics in the new document. The plate notation for this model is presented in figure 8.

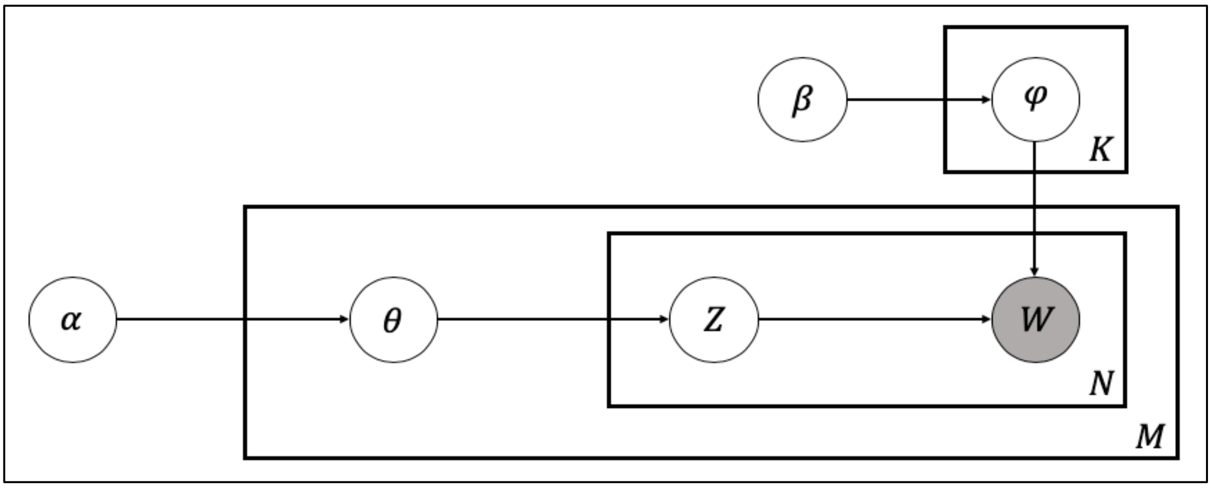

Figure 8. Plate notation for LDA, with Dirichlet-distributed topic-word distributions

Note. In this notation, Z represents the list of topics generated for the model. This list Z is combined with the previously-mentioned fourth algorithm component φ to obtain W, which is a list of words in which one word is generated per topic. The list of topics Z, combined with each word in W, are concatenated to make up a collection of words N, representing a single document. The documents, combined with the second algorithm component θ, make up the group of all documents in the dataset M, also referred to as the corpus. The variable W is shaded because it is the only variable in the model that is observable, and all other variables are considered latent. Adapted from *Analysing Russian Trolls via NLP Tools*, by Kong, 2019.

The result is that the algorithm generates a new reference document which utilizes both words and topics according to the probabilities drawn from the model. This document is compared against the original document of consideration, and the probability of the model having created its replication is calculated. The simplex locations created in the second and fourth components are initially randomized, so further models are computed and compared until a stable point has been realized wherein the probability of creating the replication does not increase (significantly). Ultimately, LDA should produce a final model which provides the researcher with the probabilities of topics existing within documents, and of words existing within topics. Naturally, the highest probabilities of these two groups are likely to be of most interest to the researcher, as they should most exemplify the topics defined. A review of the representative words and documents should allow for enough coherence and interpretability for the researcher to either make insights about what latent themes the collection of documents consists of or to adjust the number of topics K in an attempt to make better inferences from the dataset.

Gibbs sampling is a sampling-based algorithm used to estimate the parameters within the LDA model; its usage may result in the expenditure of less computational effort to generate non-ambiguous topics which encompass the hidden semantic structures within the documents (Binkley et al., 2013; Nikolenko et al., 2015). Once topic assignments have been made for all words over the entire corpus of all documents, Gibbs sampling employs an algorithm that individually re-evaluates the topic of each instance of a word, while taking into consideration two existing aspects present within the model: each document's affinity for certain topics, and each topic's affinity for certain words. These two factors influence the conditional probability distribution with which a word is assigned to a specific topic. For example, the greater the number of times the document which contains the word being evaluated uses a certain topic, the higher the chance that word will be assigned to that topic. Additionally, the topic assignment is also dependent on the number of times that word has been assigned to that topic across all other documents in the corpus. Combining these two metrics together provides a probability distribution for which the word of consideration will be assigned to a specific topic within the group of all topics *K*. This algorithm continues the process over all words in the corpus. The conditional probability distribution for each word in each document provided by Gibbs sampling is represented by the following formula:

$$p\left(z_{d,n} = k \middle| \vec{z}_{-d,n}, \vec{w}, \alpha, \beta\right) = \frac{n_{d,k} + \alpha_k}{\sum_i^K n_{d,i} + \alpha_i} \frac{v_{k,w_{d,n}} + \beta_{w_{d,n}}}{\sum_i v_{k,i} + \beta_i}$$

where $n_{d,k}$ represents the number of times that document *d* uses topic *k*; $v_{k,w_{d,n}}$ represents the number of times topic *k* uses word type $w_{d,n}$; a_k represents the Dirichlet parameter for the multinomial distribution over topics for each document, previously referred to as the first component of LDA, applied to topic *k*; and $\beta_{w_{d,n}}$ represents the Dirichlet parameter for the multinomial distribution over words for each topic, previously referred to as the third component of LDA, applied to type $w_{d,n}$. The first term on the righthand side of the equation comprises the affinity that document *d* has for topic *k*, whereas the second term on the righthand side of the equation comprises the affinity that topic *k* has for word type $w_{d,n}$.

3.4.2.1 – Application: Data collection and processing

The data used for our industry assessment guided by topic modeling consisted of online news articles published on IntraFish's English website over a one-year time period. As IntraFish is a news source that publishes recent developments in the markets for several species produced within the seafood industry, as opposed to focusing only on Atlantic salmon, we found that not all of the website's articles published within this time period would be valuable or relevant to our research. Therefore, by using IntraFish's search page, we narrowed down our sample of the website's articles to only those which returned a positive result after searching for the keyword "salmon." This provided us with a total of 1,858 articles fitting both our time and subject criteria. The HTML for each article's webpage was loaded into RStudio and cleaned so that only the article's contents were retained.

Within RStudio, the articles were filtered to maximize their relevance to our research purpose, enhancing internal validity by generating findings that truly corresponded with our research question (Saunders et al., 2016). After manual inspection of the data, we removed some articles from the dataset that did not provide useful information about the industry, but rather contained only advertisements for IntraFish's weekly podcasts. We also removed any other sentences contained within relevant articles that promoted IntraFish's services, to eliminate the influence of these phrases on the algorithm's grouping of the articles. In order to limit the scope of our analysis, we further filtered for only articles which contained the words "Norway," "Norwegian," or any of the names of companies which were listed as one of Norway's top 10 salmon farming companies by total production capacity held in the year 2017 (Ministry of Trade, Industry and Fisheries, 2018). In doing this, we hoped to capture all articles which would be of significance in portraying the roles of alternative production technologies in the development of the Norwegian SFI. This produced a final collection of documents containing 1,011 news articles.

Further steps taken to prepare the texts for analysis with LDA were made using the *tm* package within RStudio (Feinerer & Hornik, 2019). After determining the final document sample, we constructed a corpus which contained information about all of the individual words present in the documents, along with frequency counts of their total number of occurrences across all documents. Using this corpus, we built a *document-term matrix* (DTM), which is a two-dimensional matrix in which each row represents each unique document in the sample, and each column represents each unique word occurring in the corpus. The value of each cell in the matrix, where a single row and column intersect, represents the number of times the column's corresponding word occurs in the row's corresponding document. In the construction of the DTM, we once again applied filtering methods to the dataset in an attempt to maximize our chances of eliciting valuable insights from the LDA results. These measures consisted of removing all punctuation from the texts, as well as removing numbers, to reduce the amount of noise in the resultant model. All words were reverted to lowercase so that the model would not distinguish between a word beginning a sentence (for example, "*Production* is expected to pick up pace…") and the same word occurring elsewhere in a sentence (for example, "The company will build up *production* volumes…"). Additionally, all *stop words,* which are commonly used words without much informative value, were removed from the DTM, according to the standard list of English stop words defined within R's *tm* package. As a final step, a few of our own custom stop words were added to this list of disregarded words. Since the words "salmon," and "Norway," or "Norwegian" were already ensured to exist within each document according to prior steps, these were not included in the model's consideration of the topic groupings. Lastly, the word "IntraFish" was also removed from potential grouping influence. The completed DTM resulted in a matrix which contained a total of 1,011 documents and 13,785 unique words. Upon finalization of the DTM, the LDA could be constructed to produce a model from which we could analyze and make deductions about the development of the Norwegian SFI with respect to alternative production technologies.

3.5 – Ethical considerations

In order to comply with necessary ethical considerations, we consulted the *General Guidelines for Research Ethics* developed by The Norwegian National Committees for Research Ethics (NNCRE) (NNCRE, 2014). In accordance with these guidelines, we sought to implement the following four fundamental principles into our research plan: respect, good consequences, fairness, and integrity. These principles constituted the foundation for our codes of behavior that guided us both in upholding the rights of interview participants and in handling the news articles from IntraFish. We hereby present the most significant practical procedures used to ensure that these principles were met.

The ethical principle of respect requires researchers to treat everyone who engages in the research with sincere admiration (NNCRE, 2014). In all correspondence with interviewees, we maintained professionalism and gratitude for the individuals' time and participation. Additionally, we made clear that the participant could refuse to answer any question asked and could end the interview at any time. We also asked each interviewee if he or she had any questions or concerns before commencement of the interview (see the interview guidelines in Appendix I).

Furthermore, we incorporated the principles of good consequences and fairness in our research design. Good consequences of the research ensure that the study produces outcomes that offer the possibility to lead to an improvement of the status quo (NNCRE, 2014). The open-ended and exploratory purpose of our research is intended to portray an accurate picture of the Norwegian SFI's development and to offer relevant decision-makers, as well as policy-makers and scholars, the possibility to recognize potential opportunities for improvement within the industry. Fairness relates to the equal treatment of research participants, which we upheld in conducting each interview (NNCRE, 2014).

Due to the significant amount of sensitive company information expressed to us throughout the interviews with participants, we believe that the principle of integrity was most crucial to fulfill during this endeavor. We therefore had to conduct our actions honestly and responsibly with regard to this information (NNCRE, 2014). The adherence to this principal can be divided into three phases: collecting, storing, and reporting data. In terms of collecting data, we ensured that interviewee's names, employers, and any identifiable information were anonymized subsequent to interview completion. Regarding the storage of data, we used a dedicated voice-recording device (Sony ICD-PX370) to record conversations, which was not connected to the internet, ensuring that we had complete control over access to the information. The audio files contained on this device were deleted upon completion of their analysis and submission of the research. In our reporting of the data, we have ensured complete anonymization and utilized aggregate data, where applicable, in our final presentation of the work.

Finally, we note that our use of the news articles published by IntraFish is purely for academic purposes and is not intended to redistribute the website's contents. The goal of our research is to provide an overview of industry trends, rather than to re-package very detailed information from individual news articles. A valid digital subscription was purchased during the period of analysis.

4 – Analysis

Using this work's chapter 2, we fulfilled our first research objective by providing the reader with a comprehensive understanding of the current state of the Norwegian SFI. In order to fulfill our second research objective, we use chapter 4 to expand upon this previously-presented knowledge. In this chapter, we hereby explicate how the Norwegian SFI is in a state of development for the purpose of overcoming contemporary challenges, and present how companies may assess various alternative production technologies, by choosing either to implement these technologies, or to dismiss them as investment opportunities, in order to respond to current industry limitations. As described in chapter 3, we analyze proxy indicators for the Norwegian SFI in order to discover what roles these alternative production technologies play in the industry's development, fulfilling our second research objective, and thus answering our research question to its full extent. One form of these proxy indicators comprises interviews with industry decision-makers, which are analyzed in subchapter 4.1. An overview of the results is given in subchapter 4.1.1, and the resultant five categories identified in the analysis are presented in their respective subchapters 4.1.2 through 4.1.6. Additionally, proxy indicators in the form of IntraFish news articles are analyzed in subchapter 4.2. An overview of the results for this analysis is given in subchapter 4.2.1, and the resultant five topics identified in the analysis are presented in their respective subchapters 4.2.2 through 4.2.6. A summary and comparison of the findings from the two complementary analyses is given in our discussion in chapter 5.

4.1 – Analysis – Grounded Theory

This subchapter presents the results and analysis of the seven interviews which were conducted with decision-makers from the predefined target population. The subchapters 4.1.1 through 4.1.6 constitute the identified categories in line with the research strategy of GT, logically build upon one another, and contribute to our objective to generate a theoretical framework about the roles of alternative production technologies in the development of the Norwegian SFI.

It should be emphasized that findings in the aforementioned subchapters, referring to the Norwegian SFI as a whole, are exclusively based on interview statements that did not conflict with other interview statements. Divergent findings in the interviews are explicitly highlighted by citing single or groups of mutually supportive interview statements. Furthermore, the analyses of categories presented in the subchapters 4.1.2 through 4.1.6 incorporate specific interview statements intended to more concretely express the "voice" of the Norwegian SFI.

For our approach to presenting results and the analyses of the categories identified, we consulted Goulding's (2002) work, *Grounded Theory: A Practical Guide for Management, Business and Market Researchers*, which provides an illustrative application of a GT study.

In the following subchapter 4.1.1, we provide a brief overview of the results discovered through the application of GT. This depiction of the results is followed by subchapters 4.1.2 – 4.1.6, in which these findings are examined in further detail.

4.1.1 – Overview of the results: categories and extant theories identified in the interviews

The process of axial coding is intended to move the analysis from a collection of concepts to an integrated theoretical framework. This was accomplished through the acknowledgment of concepts with respect to their complex interrelationships within and across interview transcripts. The following table summarizes the categories and related extant theories as identified from the interviews.

Table 6. Overview of the identified categories and extant theoretical concepts from interviews with decision-makers from the Norwegian SFI

Category	Categories	Extant theories
1	The industry's central challenges	- *True uncertainty* (Knight, 1921) - *Corporate social responsibility* (van Marrewijk, 2003)
2	The industry's strategic orientation	- *Corporate strategy* (Foss, 1997; Kenyon & Mathur, 1993) - *Lean manufacturing* (Carreira, 2005) - *Incremental process innovation* (Ireland et al., 2003) - *Resource-based view* (Barney, 1991)
3	Land-based RAS systems used as a complementary farming technology	- *Diversification* (Silverman, 2002) - *Technological diversification* (Cantwell et al., 2004) - *Full capacity utilization* (Corrado & Mattey, 1997) - *Production bottleneck* (Wallace, 2020)
4	Land-based RAS systems seen as a threat to the Norwegian SFI	- *Strategic sensemaking* (Dutton & Duncan, 1987) - *Creative destruction* (Schumpeter, 1911) - *Technological discontinuities* (Tushman & Anderson, 1986)
5	The Norwegian SFI's approach to alternative production technologies	- *Standard model* (Hill & Rothaermel, 2003) - *Absorptive capacity* (Cohen & Levinthal, 1990) - *Real options* (Kogut & Kulatilaka, 2001) - *Coopetition* (Brandenburger & Nalebuff, 1997)

4.1.2 – Category 1 – The industry's central challenges

The category of industry-wide challenges manifested itself in all conducted interviews and transpired to be a suitable point of departure for the construction of a conclusive theory about the Norwegian SFI. This is because, throughout the process of collecting and analyzing data, it became apparent that the industry's challenges profoundly shaped the salmon farmers' perception of which specific strategic objectives should be pursued, and the roles of alternative production technologies turned out to be greatly affected by these challenges and strategic objectives. Therefore, we began the analytical process of theory development by illuminating the industry's central challenges.

In response to the question of the current state of the Norwegian SFI, one externally given circumstance that was repeatedly mentioned was the limitation on the industry's production capacity. Some research participants cited the high number of lice, propagated by industry operations, as the cause for this circumstance. These individuals argued that if the industry did not manage to actively and sufficiently mitigate the harmful effects of the parasite on farmed salmon, production capacity would remain limited, as mortality rates intensified by artificially increased salmon lice levels would inhibit the industry from generating more output. Alternative environmental challenges, such as farmed salmon escapements, were not mentioned as causes for the fixed domestic supply. The omission of other environmental challenges in this context hints to the conclusion that containing levels of salmon lice was the primary point of interest for these participants' companies, while other environmental challenges were not as focused upon. The larger share of interviewees, in contrast, built their perception of the industry's challenges around domestic regulations. More precisely, the TLS was cited as being the main output-restricting regulatory framework in this regard. As detailed in subchapter 2.3.3, the TLS constitutes the government's primary control mechanism for ensuring the Norwegian SFI's environmental sustainability by keeping the anthropogenically increased number of salmon lice at an environmentally bearable level (Bjørndal & Tusvik, 2017). Interestingly, the research participants who identified the TLS as the cause of the limited production output did not refer to salmon lice as an industry-wide challenge, but rather regarded the regulation as a barrier to further production growth. As a result of both of these mentioned causes (high levels of lice and the TLS), participants declared the "Norwegian SFI's limited production volume growth" to be a central challenge facing the industry. It is worth

> On production growth:
> *We haven't really had any growth in the production, mainly because the government has put on restrictions.*
> (Interviewee 2, in-person conversation, February 24, 2020)

Figure 9. Interview statement on production growth

noting that while the market failure rationale for regulations appeared to be of paramount concern, justice-based regulations, such as coastal zone planning policies, were at no point declared as a type of restriction that adversely affected the industry's production volume growth.

Another central challenge for the Norwegian SFI resulted from the combination of the limited production capacity within Norway and the increasing global demand for Atlantic salmon. These two circumstances were seen as being capable of potentially initiating a conceivable causal chain, leading to the challenge of the "Norwegian SFI's uncertain future profitability." The first consequence, stemming from the biologically and regulatorily fixed domestic supply and the increasing global demand, was the "fantastic" (Interviewee 1, in-person conversation, February 17, 2020) market price of Atlantic salmon that had, on average, been rising for the past eight years. However, this seemingly favorable market outcome was described as being highly fragile and, thus, was considered a double-edged sword, as it held the detrimental potential to attract new market entrants from comparatively unregulated countries, eventually expanding global supply and, in turn, causing decreasing market prices in the long run. Volatile production costs that had exhibited major upswings and downturns, especially prior to the year 2015, were regarded as a condition that amplified the aspect of uncertainty inherent in this challenge. It is worthwhile to shed more light on the notion of uncertainty as it constitutes a core aspect of the challenge of the Norwegian SFI's uncertain future profitability.

On new market entrants:
We are in a non-sustainable development where we are kept alive because of the very high salmon prices. At the moment, other countries, such as Chile, Canada, and the US, are allowed to grow and fill the market demand. It's a game over for us.
(Interviewee 1, in-person conversation, February 17, 2020)

Figure 10. Interview statement on new market entrants

Knight's (1921) landmark work *Risk, Uncertainty and Profit* has been acknowledged as the foundation for describing the role of uncertainty in managerial decision making and highlights the difficulty of dealing with scenarios that cannot be captured by purely probabilistic data (Sarasvathy & Kotha, 2001). Knight (1921) distinguished among the following three fundamental forms of uncertainty: *risk* (when probabilities of potential future draws/scenarios are known), *uncertainty* (when probabilities of potential future draws/scenarios are unknown, but can be determined by examining draws from a longer time frame), and *true uncertainty* (when probabilities of potential future draws/scenarios are not only unknown, but unknowable). With regard to the challenge of the industry's uncertain future profitability, there is valid basis for the assumption that potential future outcomes for the industry's profitability cannot be classified by a plausible set of probabilities. Although it may be feasible to label some factors that influence the industry's future profitability with probability distributions, such as the global demand for Atlantic salmon, other factors that impact profitability remain of highly irregular and sporadic nature. For example, on the cost side of the equation for the industry's profitability, feed accounted for 41.8% of total costs per kilogram of farmed salmon in 2018, but little is known about how the availability of wild-caught pelagic fish and the usage of alternative feed sources will develop in the future, let alone the estimation of probabilities for different possible scenarios (Deutsch et al., 2007; FAO, 2020c).

Another future outcome that cannot be estimated with probabilistic means is the occurrence of new industry entrants from comparatively unregulated countries. These entrants could employ alternative production technologies, which hold the potential to make salmon farming feasible and profitable in other countries that do not have a sheltered shoreline as does Norway. For example, land-based RAS systems are located onshore and could potentially weaken the natural advantage associated with the sheltered Norwegian fjords. Yet, there are still several obstacles to overcome in relation to the profitability of such alternative production technologies, including the high capital expenditure required to build these facilities or an undesirable taste of the resulting product (Bjørndal & Tusvik, 2017; Sapin, 2020b). Tushman and Anderson (1986) analyzed the impact of technological change on competitive conditions and highlighted that major technological advancements are often based on erratic flashes of insight that can hardly be predicted. In line with this argumentation, it can be reasoned that it is not foreseeable if and when alternative production technologies will reach a state of profitability that could attract new entrants from comparatively unregulated countries which, in turn, could adversely and significantly affect the Norwegian SFI's future profitability. To conclude, the challenge of the industry's uncertain future profitability rests on Knight's (1921) concept of true uncertainty.

One interview in particular exhibited a strong emphasis on the industry's social compatibility, as the interviewee stated that the industry had to change in order to establish legitimacy within society. The interviewee expressed that the Norwegian SFI was strongly focusing on being profitable, but not enough on ensuring ethical considerations that were not regulated by the government. More precisely, the interviewee stressed that the mortality rates in the industry had been addressed insufficiently over the recent six to eight years, and that this was due to the lack of economic incentives for fostering improvements in this regard. As a result of the neglect to utilize more resources on the issue of fish welfare, the industry conveyed to society an image of disregarding fish health, which could ultimately lower the industry's attractiveness for environmentally conscious young and experienced professionals to enter the workforce.

On society:
I've seen for many, many years that the industry has not responded to its challenges with sufficient strength and energy, and it really annoys me. I think we reached a period of time where the society is trying to find a way to interfere, because they can see that the business itself runs the development more than the sustainability.
(Interviewee 4, in-person conversation, March 6, 2020)

Figure 11. Interview statement on society

The resulting challenge identified was labeled as "perceived lack of the Norwegian SFI's ethical responsibility in society," which is closely related to the theoretical concept of CSR. Van Marrewijk (2003, p. 102) provided an overview of the different common definitions of CSR and concluded that "in general, corporate sustainability and CSR refer to company activities – voluntary by definition – demonstrating the inclusion of social and environmental concerns in business operations and in interactions with stakeholders." Relating this definition to the interviewee's perception, it can be interpreted that there had been a lack of voluntary inclusion of social concerns in the industry's activities, resulting in the industry's non-compliance with ethical social demands. Several studies on CSR activities and employer attractiveness showed the gravity of this challenge by demonstrating how the lack of inclusion of social concerns can impair a company's ability to attract new workforce members (Klimkiewicz & Oltra, 2017; Puncheva-Michelotti, Hudson, & Jin, 2018).

Other challenges mentioned throughout the interviews were either of peripheral nature, meaning that they neither affected the industry's strategic orientation nor the roles of alternative production technologies in the Norwegian SFI's development, or were disputed by other interview participants. Therefore, these challenges were not classified as being central. Appendix N summarizes the aforementioned three central challenges and their relations to the different circumstances described by the research participants.

4.1.3 – Category 2 – The industry's strategic orientation

To capture the strategic orientation of the Norwegian SFI and to, thereby, be able to more comprehensively understand the roles of alternative production technologies in the industry's development, we asked each interview participant the following question: "What is [company name]'s strategy for the future?" To clarify how this question illuminated the strategic orientation of the industry, it is of value to call closer attention to the meaning of strategy. A *corporate strategy* comprises the design of decisions in an organization that determine its overarching objectives and that constructs the major policies and plans for accomplishing these objectives (Foss, 1997). Further, Kenyon and Mathur (1993) discussed the linguistic meaning behind the word "strategy" in corporate environments and argued that a strategy is a set of theories formulated to achieve major, large scale objectives, and postulated that the outcomes of these objectives are of central importance for the entire organization. Exploring the corporate strategy of our interview participants' organizations led us to the identification of the industry's strategic orientation on the grounds of two notions: the Norwegian SFI's strategic objectives and the main sets of deliberately-formulated theories for achieving these objectives. During the interviews, we did not actively limit the time horizon for these strategies, nor did we provide the interviewees with a formal definition for the term "strategy." Instead, the goal of this open-ended question was to bring to light the participants' spontaneous and most prevalent thoughts on this topic. Accordingly, this subchapter elucidates the industry's main strategic objectives and the most fundamental policies and plans for achieving these objectives, which together form the category identified to be the industry's strategic orientation.

With regard to the strategic objectives, we noticed a strong strategic proclivity across the companies our participants represented towards the creation of improvements to profitability by means of cost reductions. As briefly addressed in the introduction of the previous subchapter, the Norwegian SFI's main strategic objectives turned out to be heavily influenced by its central challenges. In particular, challenge 1 (the Norwegian SFI's limited production volume growth) and challenge 2 (the Norwegian SFI's uncertain future profitability) were described as shaping the industry's focalized strategic objective of pursuing profitability improvements over a long term. Thereby, challenge 1 was seen as an externally given circumstance that prevented most farming companies from formulating their main strategic objective as increasing production volume. Since most participants mentioned governmental regulations as the cause for challenge 1, it can be concluded that, in fact, these regulations did prevent these farming companies from making the strategic objective of production volume growth their primary focus. In light of the government's ambitious goal of annually supplying the market with five million tonnes of Norwegian-raised, sustainably produced salmon and trout, there seemed to be an evident discrepancy between this

> On strategic objectives:
> *The [volume growth] possibilities are limited in Norway due to the authorities that limit the growth of aquaculture in Norway. So, we want to be more efficient.*
> (Interviewee 7, in-person conversation, March 20, 2020)

Figure 12. Interview statement on strategic objectives 1

> On strategic objectives:
> *We are also aware that volume growth might be too costly for being good. So, not that inexpensive.*
> (Interviewee 6, in-person conversation, March 6, 2020)

Figure 13. Interview statement on strategic objectives 2

governmental goal and the effect of governmental regulations on the formulation of strategic objectives in the industry (Olafsen et al., 2012). In other words, while the government aimed to foster production volume growth in the future, regulations prevented farming companies from strategically aligning themselves with this goal. Furthermore, challenge 2 and its underlying uncertainty reinforced the Norwegian SFI's strategic orientation towards ensuring the industry's future profitability.

The strategic focus on profitability improvements was consistently expressed as being pursued on the basis of cost reductions. This observation can be linked to two existing theoretical concepts. First, *lean manufacturing* is a management philosophy that encompasses business practices which aim to improve the efficiency and effectiveness of production processes (Carreira, 2005). Lean manufacturing is particularly well-suited for industries where production processes are repetitive and predictable, and its goals are to reduce unnecessary costs and to increase revenues by optimizing the quality of the end product (Carreira, 2005). The approach's aspiration to create efficiency gains by means of cost reductions is especially analogous to the industry's main strategic focus of profitability improvements. Additionally, the fact that the Atlantic salmon production process is arguably standardized and predictable (as described in subchapter 2.2) can be linked to this management philosophy. Furthermore, it should be stressed that lean manufacturing does not challenge or replace the underlying production method as such, but is solely intended to optimize it, which is also congruent to statements made in the interviews (Carreira, 2005).

> On cost improvements:
> *I think the main focus is to improve on operations. I think that is more or less the same for all of the companies. The focus is to improve on cost, as the cost has been increased by nearly 100% [in recent years]. ... So, we focus very much on taking the traditional open cages and innovating based on them and making them competitive for the future. This means that we are making improvements, so we can allow for better yields.*
> (Interviewee 2, in-person conversation, February 24, 2020)

Figure 14. Interview statement on cost improvements

Second, one can think of the pursuit of these cost improvements as a specific type of innovation. *Incremental process innovations* are applied inventions that can help firms improve internal processes and, thereby, create greater profit margins by exploiting existing competitive advantages more efficiently (Ireland et al., 2003). A competitive advantage is attained when a firm generates a higher rate of economic profit compared to the rate of economic profit which is average in the industry in which the firm is competing (Besanko et al., 2012).

Generally, firms create competitive advantages by carrying out strategies that capitalize on their internal strengths in response to external opportunities, while simultaneously overcoming external threats and minimizing internal weaknesses. Barney's (1991) *resource-based view* defines the sources of sustained competitive advantages and shifts the focus away from environmental factors (opportunities and threats) and towards idiosyncratic, internal resources (strengths and weaknesses). This theory is based on the rationality that within-industry performance differences are caused primarily by varying internal firm characteristics, because environmental factors are expected to remain largely similar for all industry participants (Barney, 1991). The notion of sustained competitive advantage is built on two central assumptions. First, firms possess heterogeneous sets of resources, which can be thought of as assets, capabilities, and competencies controlled and used by a firm to implement different strategies for value creation (Barney, 1991). Second, these resources are not perfectly mobile, meaning that resource heterogeneity can be long-lasting (Barney, 1991). Accordingly, if a firm controls and organizes resources that are valuable (by increasing the customers' willingness-to-pay or decreasing the cost of value creation) and rare (in reference to resource heterogeneity), the firm creates a competitive advantage (Crook et al., 2008). If these resources are, in addition, inimitable (in reference to resource immobility), the firm establishes a sustained competitive advantage (Crook et al., 2008).

With regard to the decision-makers interviewed from the Norwegian SFI, it was not determinable whether competitive advantages were or were not sustained. Yet, interestingly, we were able to identify a consistent use of existing valuable and rare resources; hence, the companies' goals were to strengthen existing competitive advantages as opposed to building new ones. The sources for these existing competitive advantages were described as being twofold. First, most farming companies had had a long-standing history of using commercialized open net pens. Since the early 1970's, the technology used in open net pen farming has gone through several developments. The resulting competencies for producing Atlantic salmon in Norway were commonly seen as a source of a global competitive advantage. Second, participants explained that their organizations' abilities to acquire production licenses and, thereby, gain access to farming sites on the Norwegian sheltered coasts, were another source of their companies' competitive advantages. Given the industry's strategic orientation towards achieving cost reductions by means of exploiting current competitive advantages, the primary industry-wide strategic objective inferred was "profitability improvements through exploiting

On competitive advantage:
If you go back 40 years, [the salmon farmers] didn't know what they were doing. But now, the salmon farming industry, compared to other aquaculture industries, is very industrialized. We want to take control of every single step in the supply chain. So, we have a lot of experience and knowledge.
(Interviewee 5, in-person conversation, March 6, 2020)

Figure 15. Interview statement on competitive advantage 1

currently-held competitive advantages." Since only two interviewees explicitly mentioned that their organizations mainly pursued a production volume growth strategy, and the other participants explained that this objective was subordinate to cost reductions, we defined "production volume growth" as a secondary strategic objective.

On competitive advantage:
[Atlantic salmon] is a cold-water fish, and you have to have access to fjords. This is because the cages have to go pretty deep, probably 50 to 70 meters deep … There are not many places with fjords in the world. For example, Japan wants to farm salmon, but they don't have them.
(Interviewee 5, in-person conversation, March 6, 2020)

Figure 16. Interview statement on competitive advantage 2

The tactics employed to achieve the main strategic objective of profitability improvements through exploiting currently-held competitive advantages were overwhelmingly based on the goal to reduce the mortality rates in open net pens. Participants mentioned three ways to achieve this goal. First, the raising of larger smolts, which are produced in freshwater tanks on land, were cited to reduce the time the fish are exposed to surrounding environmental risks in the open net pens, thus reducing mortality rates. Second, genetic alterations to the independently raised broodstocks were mentioned to result in more robust and resilient fish. Third, the more focused use of surveillance technologies was described as being capable of facilitating the monitoring of fish health, and ultimately providing more information on the causes of mortalities, allowing producers to take timely countermeasures against suboptimal conditions. These measures both had a positive direct effect on the main strategic objective of profitability improvements through the exploitation of currently-held competitive advantages, as well as an indirect effect on the secondary strategic objective of production volume growth. This was because decreasing mortality rates naturally led to a better utilization of the company tier-related MAB and, thus, increased production outputs. Another indirect effect of the main strategic objective of profitability improvements on production outputs was that increased profitability improved a firm's financial ability to acquire costly production licenses. Finally, it can be hypothesized that the industry's concentration on the reduction of fish mortalities could also have an indirect and mitigating effect on challenge 3 (the perceived lack of the Norwegian SFI's ethical responsibility in society).

On mortality rates:
You have long-term solutions, like better work on [salmon] genetics, so that you have a more resilient salmon to put in the sea. It's quite vital to reduce the mortality rates. For example, out of 100 smolts, you end up harvesting about 87 to 90. The rest are dying naturally, or through treatment, or something else.
(Interviewee 4, in-person conversation, March 6, 2020)

Figure 17. Interview statement on mortality rates

Regarding the secondary strategic objective of production volume growth, participants mentioned that this objective could be achieved through two central measures. First, high energy diets, accelerating the fish's growth rate, could optimize the turnover of each of the steps involved in the production of Atlantic salmon and, ultimately, shorten the time of a single production cycle. Second, the use of land-based RAS systems as an intermediate step in the traditional production process was described to reduce the fish's time in open net pens, leading to a better utilization of the company tier-related MAB, which limits the biomass of fish that can be held simultaneously in the open sea cages. In more practical terms, if a company manages to increase the turnover of salmon in open net pens, it can exploit the MAB more efficiently during any given time period and thereby expand its annual production output. Since participants voiced that the latter method involved the use of land-based RAS systems, this phenomenon may be valuable in depicting the roles alternative production technologies in the development of the Norwegian SFI and is, therefore, described in more detail in the following subchapter.

Appendix O builds on the central challenges as previously defined, and complements the model by industry insights from this section, in particular, the industry's strategic objectives and implemented policies for achieving these objectives.

4.1.4 – Category 3 – Land-based RAS systems used as a complementary farming technology

During the conducted interviews, it became evident that salmon farmers within the Norwegian SFI commonly voiced a two-sided opinion about land-based RAS systems. As mentioned previously, the Norwegian SFI exhibited a strong proclivity towards exploiting sources of currently-held competitive advantages. Participants explained that especially the industry's long-standing path dependency on the use of open net pens, which had culminated in several technological developments and minimized production costs, had led to the salmon farmers' currently-held competitive advantages. In accordance with this observed pattern, the interviewees' views on land-based RAS systems were dependent on the systems' interplay with the industry's established technological advantages in open net pens. More precisely, whether land-based RAS systems were regarded as *complements* to or *substitutes* for sea-based farming in open net pens significantly influenced the interviewed decision-makers' attitudes towards this production method. This subchapter elucidates the role of land-based RAS systems used as complements and shows how this farming technology has been employed in combination with

> On land-based RAS systems:
> *Having a closed containment system [on land] is part of the solution, it's not THE solution. It's a niche solution and it will happen in one way or another. But it's not the whole solution. It's not that we just stop doing open cages. I don't believe in that.*
> (Interviewee 4, in-person conversation, March 6, 2020)

Figure 18. Interview statement on land-based RAS systems 1

the widely-used method of open net pen farming. This is in contrast to the following subchapter 4.1.5, which clarifies the industry's concerns about land-based RAS systems used as substitutes for open net pens.

Generally speaking, the term *diversification* refers to a situation in which the variety of an item *X*, which is linked to an item *Y*, is expanded (Silverman, 2002). In business literature, the term largely refers to product diversification, whereby a company seeks to expand the variety of its product portfolio (*X*) to serve an existing or new market (*Y*) (Cantwell et al., 2004). Klein and Lien (2009) shed light on the reasons why firms seek to diversify and argued that efficiency advantages are the primary motivation behind diversification. There are two sources for such efficiency gains. First, in the case of product diversification, perfectly substitutable excess resources, which are needed in the production processes for certain products, could be employed in the production processes for other products (Klein & Lien, 2009). In order for efficiency gains to occur, it is necessary that these excess resources are not perfectly divisible, or "lumpy," implying that they cannot simply be separated and then sold or rented out to third parties (for example, it is clear that half a machine is not half as valuable as an entire, complete machine) (Knecht, 2014). Consequently, undiversified firms will be left with expensive and unused excess resources, while diversified firms can deploy these excess resources internally in the production processes for other products (Knecht, 2014). The existence of excess resources can, for example, stem from learning: with increased production, novel resources are created, and excess resources emerge (Knecht, 2014). However, Klein and Lien (2009) pointed out that even if resources are perfectly divisible, transaction costs, such as accruing from contracting expenses, may in some cases inhibit firms from selling or renting out their divisible excess resources. Second, efficiency gains can result from complementary resources, which can be thought of as mutually supportive resources that do not substitute one another, but rather increase each other's value (for example, the know-how for the production of certain products might complement the know-how for the production of other products) (Klein & Lien, 2009).

In line with this reasoning for diversification, the production of two different products, involving perfectly substitutable or complementary resources, can lead to the situation in which the total cost of their joint production is less than the total cost of their separate productions – that is, that $C(A, B) < C(A) + C(B)$, where C refers to the production costs and A and B refer to two distinct products taking perfectly substitutable or complementary resources as inputs for production. The cost reductions achieved through this type of diversification are commonly referred to as economies of scope (Silverman, 2002).

However, diversification does not have to exclusively take place in the product-market domain. According to Cantwell et al. (2004, p. 30), *technological diversification* comprises firms' activities to "increase the diversity of their technical capabilities over time as a result of exploration of and experimentation with new technologies," which emphasizes that products and services need not only rely on high technology (high tech), but that they can also rest on multiple technologies (multi tech). The notion of technological diversification is applicable to the inclusion of land-based RAS systems as a complement in the traditional production process described in subchapter 2.2. To understand how and why the Norwegian SFI conducts technological diversification, it is worthwhile to describe the two theoretical concepts of *full capacity utilization* and *production bottlenecks* in more detail. Full capacity utilization is reached when a firm produces the most economical level of output by means of its possessed production capacity (Corrado & Mattey, 1997). In other words, the concept of full capacity utilization refers to the situation in which following ratio reaches 100%:

$$\frac{Current\ production\ output}{Maximum\ sustainable\ production\ capacity}$$

A production bottleneck, on the other hand, refers to a process step with restricted capacity which limits the capacity of the whole production process (Wallace, 2020).

In 2018, the average utilization for all Atlantic salmon farming companies operating within Norway was estimated to be around 85% of full allowance, indicating room for optimization (Mowi, 2019). Improving the capacity utilization ratio by raising the current production output (the numerator of the full capacity utilization ratio) was not mentioned as a primary lever to increase production output, but was largely indicated to be a technique used to pursue the industry's primary strategic objective of generating profitability improvements. This was because the current profitability was reasoned to be affected substantially by fish mortalities, which the interviewees' organizations aimed to reduce in order to generate profitability improvements. Hence, improvements in current production output were seen as a means of fostering profitability. The fact that increasing the ratio's numerator, as by reducing mortality rates, would indirectly also enlarge the production output was regarded as an indirect side effect. The maximum sustainable production capacity (the denominator of the full capacity utilization ratio), represented by the company tier-related MAB, on the other hand, was seen as the primary bottleneck for production output growth in the Norwegian SFI. This bottleneck was largely seen to be caused by output-restricting regulations.

Participants explained that land-based RAS systems were employed by the industry to overcome this production bottleneck, in order to expand the denominator of the capacity utilization ratio. That is, instead of moving smolts from the freshwater phase into open net pens, they were moved into land-based facilities which utilize saltwater tanks, in which they were bred to a weight of up to one kilogram. Subsequently, the land-grown post-smolts were transferred to open net pens to fulfill their final part of the grow-out phase in the sea. Because the MAB regime solely dictated how much biomass could simultaneously be held in the pens, decreasing the time the fish spent in open net pens led to a higher production turnover, overcoming the production bottleneck and ultimately increasing the denominator of the capacity utilization ratio (the maximum sustainable production capacity) (Bjørndal & Tusvik, 2017).

> <u>*On land-based RAS systems:*</u>
> *Some have increased [smolt weight] to 200 or 250 grams, and then also have built up factories on land that make what we call post-smolts. … You are able to farm [the post-smolts] up to even a kilo on land. So, in that way, you increase the utilization and can better plan the production in the sea. You can produce much more in the same amount of room.*
> (Interviewee 3, in-person conversation, March 5, 2020)

Figure 19. Interview statement on land-based RAS systems 2

To conceptualize this use of land-based RAS systems more vividly, it is advantageous to portray an exaggerated, yet simplified, hypothetical scenario. One can assume that a farming company has been awarded a production license for a certain geographical site, allowing it to simultaneously hold 780 tonnes of biomass in the pens. If the company conducted only one production cycle at a time and managed to grow all the post-smolts to the point of full capacity utilization, a single cycle would produce 780 tonnes of fish after 16 months, assuming the grow-out phase took precisely this long. Since the cultivation of salmon throughout the freshwater phase does not constitute a threat to wild salmon populations, as this process occurs on land, this phase's production output is not as strictly regulated as is the grow-out phase in seawater (Olaussen, 2018). Accordingly, the company tier-related MAB represents the bottleneck within the entire production process. If the farming company utilized land-based RAS systems as an intermediate step and moved a part of the production process's grow-out phase to seawater-based farming facilities on land, the company would be able to reduce the amount of time the post-smolts spent in open net pens. This is because the post-smolts would have spent a certain share of the total time used for their grow-out phase in land-based RAS systems. Consequently, the company would be able to perform more production cycles in a shorter amount of time. To give a more extreme example, one could conceptualize that the time the fish spent in open net pens was reduced to 10 days. Assuming a non-restricted use of land-based RAS systems and a linear array of production cycles, the farming company would be able to finish one full production cycle every 10 days.

Bjørndal and Tusvik (2017) showed that the use of land-based RAS systems as an intermediate step in the traditional production process leads to significantly increased production costs per kilogram of farmed salmon. Though land-based RAS systems offer the advantage of better control over production, in 2017, the inflation-adjusted total cost per kilogram of farmed salmon produced by means of land-based RAS systems used as a complementary production step was estimated to range between NOK 51.87 and NOK 58.80 (Bjørndal & Tusvik, 2017). These higher production costs were largely driven by the significant capital expenditure associated with building the facilities and the operational costs of utilizing them in the production of salmon (Bjørndal & Tusvik, 2017). The increased costs hint at a rather counterintuitive conclusion. In contrast with the general assumption that diversification efforts are intended to pursue profitability improvements, the Norwegian SFI's practice of technologically diversifying by employing land-based RAS systems as an intermediate step in raising larger post-smolts on land is likely to increase the total cost per kilogram of farmed salmon. Though the nature of our interviews did not allow for expansion upon the exact trade-off between increased production outputs and profitability, it is tenable to assume that the decreased profit margins per kilogram of farmed salmon caused by this industry practice simultaneously led to a lower return on capital. In spite of these decreased profit margins, the increased production outputs might have generated higher total profits compared to open net pens as standalone solutions, thereby justifying the industry's efforts towards technological diversification. The exact quantitative extent to which firms in the Norwegian SFI are willing to trade production output increases for better profit margins per kilogram of farmed Atlantic salmon remained unclear and could eventually constitute a call for further, future studies which employ economic analyses to uncover this metric.

On land-based RAS systems: *The cheapest way to produce salmon is to keep them in the fjords. If you farm them on land, you have to make sure they have enough oxygen, good temperature, which all costs a lot of money.* (Interviewee 5, in-person conversation, March 6, 2020)

Figure 20. Interview statement on land-based RAS systems 3

4.1.5 – Category 4 – Land-based RAS systems seen as a threat to the Norwegian SFI

The theoretical concept of s*trategic sensemaking* originated from the research domain of organizational decision making and refers to the cognitive process by which decision-makers infer strategic sets of policies and plans from environmental information (Dutton & Duncan, 1987; Thomas et al., 1993). According to this concept, organizations can be seen as systems that constantly aim to scan and interpret their environments in order to strategically align with new, unexpected, or even confusing circumstances (Wong & Blandford, 2004). When organizations interpret their environments, the most common labels they can assign to environmental information are “opportunity” and “threat” (Thomas et al., 1993, p. 241).

Concerning the Norwegian SFI, it came to light that interview participants predominantly were aware of the emergence of new farming companies that utilized land-based RAS systems as full grow-out solutions. In particular, the company Atlantic Sapphire was frequently quoted as an example for such occurrences. Founded in 2010 by two Norwegian entrepreneurs, Atlantic Sapphire has identified the US as the world’s largest market for farmed Atlantic salmon (Atlantic Sapphire, 2020a). To achieve their vision of supplying this market, Atlantic Sapphire currently conducts its operations at two locations: a pilot plant in Denmark, as well as a large-scale facility in the US state of Florida (Sapin, 2019d). As previously mentioned, land-based farming using RAS is associated with increased production costs (Bjørndal & Tusvik, 2017). Yet, Atlantic Sapphire has recognized the benefit of substantially reducing their airfreight costs, stemming from their close-to-consumer production (Atlantic Sapphire, 2020a). The airfreight costs from Norway to the US are estimated to be at around NOK 14 per kilogram, constituting a large additional cost to the total production costs of Atlantic salmon (Mowi, 2019; PwC, 2017).

Though the Norwegian SFI’s main export markets are the EU and Asia, decision-makers interviewed from the Norwegian SFI acknowledged the potential disruptiveness of land-based farming technologies and interpreted the use of these technologies as substitutes for open net pen farming as a major threat facing the domestic industry (Eurofish, 2020). In his book *Theory of Economic Development,* Austrian-born economist Schumpeter (1911) addressed the impact of innovations on industries and companies. Schumpeter (1911) reasoned that market dynamics are mainly caused by *creative destruction* resulting from innovations that constantly change economic structures by dismantling old ones and perpetually creating new ones. The notion of creative destruction can be applied to the case of land-based RAS farming systems used as substitutes, since interviewees perceived this alternative approach to farming as having the

> *On land-based RAS systems:*
> *Potential disruptiveness from land-based [RAS farming] makes us put more focus on efficacy of the sea-based production, both when it comes to cost and sustainability.*
> (Interviewee 2, in-person conversation, February 24, 2020)

Figure 21. Interview statement on land-based RAS systems seen as a threat 1

potential to render the Norwegian SFI's competitive advantages obsolete, and thus alter the industry's economic structure.

More recent contributions refer to the phenomenon of technological change that holds the potential to alter an industry's structure as *technological discontinuities* (Eggers & Francis Park, 2018; Park & Magee, 2019; Tushman & Anderson, 1986). Tushman and Anderson (1986) examined several empirical studies dealing with technological change, and established the basic normative conclusion that technologies evolve through cycles of incremental progress which are eventually interrupted by technological breakthroughs, leading to discontinuities on the evolutionary trajectory of technologies (Tushman & Anderson, 1986). Thereby, technological change over time observes the following three phases. First, the occurrence of a *technological breakthrough*, or *discontinuity*, happens erratically and can lead to novel industry-wide expectations about a new technology's future performance, as well as to increased perceived uncertainty about established firms' future competitive positions (Tushman & Anderson, 1986). This occurrence is commonly followed by a so-called *era of ferment*, in which new and old technological regimes compete for dominance (Eggers & Francis Park, 2018). Additionally, competition for dominance might also manifest among different new technological regimes (Eggers & Francis Park, 2018). The era of ferment ends when a dominant design is established, representing a technological de facto standard (Park & Magee, 2019). The emergence of a dominant design reduces the variety of technological regimes and leads to lowered perceived uncertainty within an industry (Tushman & Anderson, 1986). Lastly, the phase of *incremental change* comprises bit-by-bit improvements to an existing dominant technology's performance (Tushman & Anderson, 1986). Figure 22 summarizes these three phases of technological change on the two dimensions of performance and time.

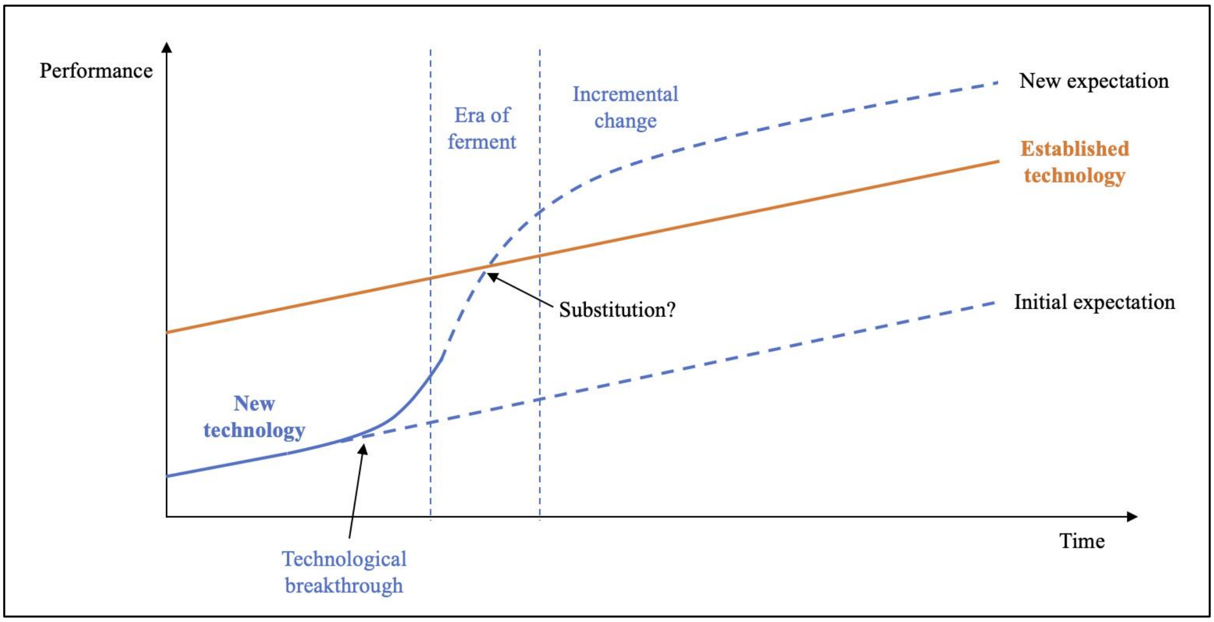

Figure 22. Model about the phases of technological change and the occurrence of a competence-destroying technological breakthrough

Note. The established technology resembles the technological regime of open net pen faming. The linear increase (incremental change) in performance is analogous to the Norwegian SFI's central strategic objective to drive incremental profitability improvements through exploiting currently-held competitive advantages. The new technology in this context refers to the occurrence of land-based RAS systems used as substitutes for open net pen farming. The technological breakthrough could be signaled by the occurrence of new industry entrants (for example, Atlantic Sapphire) that envision to make land-based RAS farming economical through minimizing airfreight costs (by utilizing close-to-consumer production). The dashed lines refer to performance expectations about the new technology before and after the technological breakthrough. Updated expectations caused by the perceived technological breakthrough lead to major uncertainty because it is not possible to predict whether the new technology's performance will surpass the performance of the established technology. Adapted from "Technological Discontinuities on Organizational Environments," by Tushman & Anderson, 1986.

Whether a technological breakthrough leads to higher levels of perceived uncertainty about established firms' future competitive positions is contingent on if the new technological regime is competence-enhancing or competence-destroying for established firms (Tushman & Anderson, 1986). While competence-enhancing breakthroughs commonly originate from incumbents and build on existing competences held by the incumbents, competence-destroying breakthroughs comprise entirely novel technological approaches, mostly coming from young and innovative firms, that have the potential to outperform and, thereby, substitute conventional technological regimes (Tushman & Anderson, 1986). Since land-based RAS systems largely did not build on the two aforementioned main sources of the Norwegian SFI's currently-held competitive advantages, this technological regime could be classified as competence-destroying. In fact, interviewees indicated that the emergence of new industry entrants, employing land-based RAS systems as substitutes, increased their perceived uncertainty about their organizations' future abilities to safeguard or enhance their competitive positions. Consequently, Knight's (1921) notion of true uncertainty is also applicable to the potential disruptiveness of competence-destroying land-based RAS systems which threatened the competitive advantages the Norwegian SFI held. This is because interviewees were bounded in their ability to predict whether the performance of land-based RAS systems used as substitutes would surpass the performance of the open net pen farming technology in the future. Performance in the case of farming technologies could, for example, be depicted by the total costs of production and distribution. Fierce competition could lead to price battles in which companies that exhibit lower costs of production and distribution would suffer under less economic distress. The case of Atlantic Sapphire illustrates the difficulty of predicting the performance of land-based RAS farming used as a substitute. At the time of writing, the company's land-based RAS facility in Florida had not begun selling its harvests to consumers, making it unclear to what extent airfreight costs will be able to compensate for presumably increased production costs, and obfuscating the impacts this would have on the Norwegian SFI's future competitive position in the US consumer market (Atlantic Sapphire, 2020b). Atlantic Sapphire is only one example of the occurrence of new industry entrants that employ potentially disruptive farming technologies. If the overall costs associated with the production and distribution of slaughter size salmon cultivated using land-based RAS systems become economical enough to replace the Norwegian SFI's prevailing method of production in some geographical markets, new entrants could also emerge in other countries that hold a larger share of the Norwegian SFI's export volume.

> *On land-based RAS systems:*
> *The moment when the code is cracked for producing slaughter-size salmon on land – it will be a really tough time for the Norwegian aquaculture industry. If you look five years ahead of us, I think the large land-based RAS facilities producing slaughter-size salmon, in every country you can imagine, may be one of the biggest challenges for the Norwegian aquaculture industry. This is because the Norwegian aquaculture industry is based on open cages on the coasts.*
> (Interviewee 1, in-person conversation, February 17, 2020)

Figure 23. Interview statement on land-based RAS systems seen as a threat 2

Based on this reasoning, interview participants classified the occurrence of land-based RAS systems used as substitutes for open net pens as a threat to the domestic industry's currently-held competitive advantages, which led to an increased uncertainty about the Norwegian SFI's future competitiveness on a global scale. Comparing Tushman's and Anderson's (1986) theory on technological breakthroughs with industry insights from this subchapter, the use of land-based RAS systems as substitutes exhibited the same effects as did competence-destroying technological breakthroughs: that is, changed expectations about the alternative technology's future performance and increased uncertainty about firms' future competitive positions. The fact that the first large-scale land-based salmon farms were under construction during the time of the interviews could have signaled a significant performance increase of land-based RAS systems to the Norwegian SFI, which is also analogous to the concept of technological breakthroughs.

4.1.6 – Category 5 – The Norwegian SFI's approach to alternative production technologies

A reoccurring observation in academic literature has been that when faced with competence-destroying technological discontinuities, many incumbent firms have considerable difficulty recognizing and adequately adapting to changing relative performance levels of alternative technological regimes, often leading to weakened competitive positions or even bankruptcy in severe cases (Rosenbloom & Christensen, 1994; Sull et al., 1997; Tripsas & Gavetti, 2000). Hill and Rothaermel (2003) referred to the explanation for incumbent firms' behavior of neglecting the future potential of alternative technological regimes as the *standard model*. According to the standard model, the reasons for this negligence comprise the incumbent firms' divergent economic incentives, forces of organizational inertia, and strategic orientations (Hill & Rothaermel, 2003). Economic disincentives to assess in a timely manner the potential of alternative technological regimes are associated with firms' narrow financial focus on safeguarding or enlarging existing revenue streams, stemming from currently-held competitive advantages (Hill & Rothaermel, 2003). The reasoning behind forces of organizational inertia is that most incumbent firms' information systems and decision processes are aligned to ensure predictability and reliability which requires bureaucratic organizational structures that, in turn, inhibit these firms to adapt quickly to changing environmental factors (Hill & Rothaermel, 2003). Lastly, incumbent firms' strategic orientations require the establishment of extensive value networks, consisting of various financial and non-financial stakeholders, which may lead to an adverse inflexibility to realign technological capabilities (Hill & Rothaermel, 2003). Yet, the standard model depicts only a part of the reality. Some incumbent firms are able to successfully adapt to the changing relative performance levels of alternative technologies. Rosenbloom (2000), for instance, described how NCR Corporation, an incumbent firm during the time of mechanical cash registers, managed to successfully adapt soon after the emergence of alternative technological regimes in the form of digital cash systems. In this subchapter, we show how the Norwegian SFI considered the performance potential of alternative production technologies.

A consistent finding during the interviews was that all interviewees exhibited a profound knowledge about the technological and economic benefits and downsides of the alternative production technologies of land-based RAS, semi-closed containment, and offshore farming systems. Inconsistent with Hill's and Rothaermel's (2003) standard model, this existing profound knowledge showed that the interviewed decision-makers, in fact, considered and assessed the performance potential of the alternative technological regimes. While all of the interviewees' farming companies specialized in open net pen farming, there was no prevalent consensus on which specific alternative production technology was or could become technologically and economically feasible, hinting at the conclusion that the technological development of these alternative technological regimes was still taking place in the era of ferment (Tushman & Anderson, 1986). Hence, the assessments of the performance potentials of the different alternative production technologies varied among participants. These assessments were based on the R&D commitments each interviewee's company had made in the past. We observed this by mapping the interviewees' statements regarding alternative production technologies against their companies' applications for development licenses, which are published periodically by the Directorate of Fisheries (Directorate of Fisheries, 2020e). That is, interviewees appraised the performance potentials of the alternative production technology that their respective companies had been most optimistically focusing their R&D activities on.

One interviewee stated that their company steered its R&D activities towards the development of semi-closed containment systems. Another interviewee regarded offshore farming as the alternative production technology with the highest performance potential. One interviewee did not consider any of the aforementioned technologies to be potentially technologically or economically feasible, while all other participants stated that their respective companies were either concentrating on further developing existing complementary land-based RAS systems for the production of larger post-smolts, or on developing land-based RAS systems for covering the whole grow-out phase.

Cohen's and Levinthal's (1990) concept of *absorptive capacity* describes a firm's competence in scanning, comprehending, and utilizing information from its external environment, which plays a crucial role in the decision to allocate resources into certain R&D efforts. Further, Cohen and Levinthal (1990, pp. 149-150) suggested that a firm's prior knowledge base constitutes a central antecedent of its absorptive capacity, stating that, "absorptive capacity is more likely to be developed and maintained as a byproduct of routine activity when the knowledge domain that the firm wishes to exploit is closely related to its current knowledge base."

Considering the Norwegian SFI, we were able to identify another antecedent of absorptive capacity represented by the infrastructural resources a firm possessed. More specifically, it was reasoned that the majority of salmon farmers did not promote R&D activities for offshore aquaculture systems because the long distance of such facilities from the shore would not allow their companies to utilize existing infrastructure (such as office buildings, feed warehouses, and laboratories), usually located in close proximity to the shore. We deduce that the industry characteristic of capital intensity associated with heavy industries, such as the Norwegian SFI, which requires heavy production equipment and transportation vessels, may moderate the importance of a firm's existing infrastructural resources as an antecedent for its absorptive capacity. In other words, the more capitally intensive an industry is and the more dependent it is on existing immobile infrastructure, the more likely it is that absorptive capacity is not only a byproduct of a firm's existing knowledge base, but also of its existing infrastructural resources.

> *On existing infrastructure:*
> *You also have to remember that we have quite a large infrastructure on land serving these [open net pens] in the sea. So, by moving the sites, you also have to do something with the infrastructure … And we see that it's a much longer way to develop a good offshore farm system, compared to [semi-closed containment systems].*
> (Interviewee 1, in-person conversation, February 17, 2020)

Figure 24. Interview statement on existing infrastructure

As mentioned, most of the interviewees' companies fostered R&D activities for land-based RAS systems, either as complements to open net pen farming or as substitutes for it. Though interviewees agreed that it was not foreseeable which alternative production technology would eventually become technologically and economically feasible, the least optimistic performance expectations were attributed to offshore farming for the aforementioned reason. Furthermore, interviewees explained that the Norwegian SFI's willingness to experiment with alternative production technologies through the promotion of certain R&D activities was based on the "good profits" (Interviewee 3, in-person conversation, March 5, 2020) the industry had benefited from in recent years. Participants explained that development licenses incentivized their companies to build prototypes of alternative production technologies. This proves the effectiveness of these licenses, meaning that these licenses indeed fulfilled their central objective in incentivizing investments into innovative, environmentally sustainable farming technologies (Mowi, 2019).

> *On development licenses:*
> *The big reason why the big innovations happen in Norway in general is that the authorities, the government, have these instruments – development licenses. That is the main driver.*
> (Interviewee 2, in-person conversation, February 24, 2020)

Figure 25. Interview statement on development licenses

To summarize, we were able to observe that a dominant design among alternative production technologies had not emerged. Interviewees recognized that it was not foreseeable which alternative production technology would eventually become technologically and economically feasible, but the industry predominantly still indicated a clear tendency towards R&D endeavors for land-based RAS systems. While investments into offshore farming were predominantly discarded due to the technology's incompatibility with existing infrastructural resources, the majority of companies favored the experimentation with land-based RAS systems for their compatibility with the companies' existing knowledge bases, which had been built on prior experience with these systems' complementary application aimed at cultivating larger post-smolts. Only one company fostered R&D efforts towards semi-closed containment systems near the shore, which was reasoned to be motivated by the system's compatibility with existing coastal infrastructure. Consequently, we found that each company's decision to focus its experimentation towards a certain alternative production technology was strongly influenced by its absorptive capacity, and that this was further complemented by a firm's possessed infrastructural resources. This leads to the following hierarchy: R&D efforts into land-based RAS systems were largely favored, semi-closed containment systems were advocated by only one interviewee, and offshore farming systems were also supported by only one interviewee, though the skepticism about this technology from other decision-makers was remarkable. Generally, the industry's aspiration of promoting R&D activities was financially incentivized by the government's development licenses, since these licenses are awarded free of charge for 15 years, after which they can be transformed into commercial licenses at a lower-than-market expense.

> On uncertainty:
> *Which [alternative] technology will succeed? That we don't know, so that you have to wait and see.*
> (Interviewee 3, in-person conversation, March 5, 2020)

Figure 26. Interview statement on uncertainty

Ultimately, we conclude that there was not only uncertainty in the Norwegian SFI about the effects of land-based RAS systems used as substitutes, as explicated in the previous subchapter, but also about the performance potentials of semi-closed and offshore farming systems. While the emergence of land-based RAS systems used as substitutes exhibited analogies to the concept of technological discontinuities, also leading to uncertainty about the companies' future competitive positions, other alternative production technologies were not interpreted as threats to the Norwegian SFI. We hypothesize that land-based RAS systems used as substitutes constituted a special case because the emergence of new industry entrants on a global scale might have signaled a technological breakthrough. Yet, to account for the overall uncertainty about the performance potentials of all of these alternative production technologies, the companies represented by the interviewed decision-makers uniformly adhered to two different practices, which we hereafter explain by consulting the two theoretical concepts of *real options* and *coopetition*.

Investment decisions based solely on the NPV of future cash flows are made under the assumption that if the NPV of an investment opportunity is positive, a firm will generate the projected returns (Cornelius et al., 2005). Consequently, such investment appraisals always lead to “either/or” decisions. Yet, there is a chance that due to unforeseen future developments, investments diminish in value and other investment opportunities that have not been considered become more valuable. Real options provide managers with room for maneuver, and represent the ability, not the duty, to make certain financial commitments in the future in order to exploit future returns when uncertainty about these returns is high (Kogut & Kulatilaka, 2001). In other words, real options comprise current investments that enable managers to exploit potential opportunities in the future without requiring them to fully commit to these possible future opportunities before uncertainty has dissolved (Kogut & Kulatilaka, 2001).

With regard to the Norwegian SFI, the uncertainty about the performance potential of alternative production technologies was observed to be high, and decision-makers noted that it is not predictable which of these production technologies will eventually reach sufficient technological and economic maturity. Unexpected technological developments constituted the uncertain future developments that real options aim to resolve. The Norwegian SFI’s open approach to experimenting with certain alternative production technologies, while not rejecting the performance potentials of other technologies, provided salmon farmers with the flexibility to expand or abandon investments into certain technological regimes. For example, if technological regimes had reached their expected performance levels, the companies could still have been able to further expand their R&D investments. If, on the other hand, technological regimes had turned out to be unprofitable, companies could have divested from certain R&D efforts. In the latter case, investments already carried out would not be entirely sunk, as the R&D-related capabilities generated could be utilized for the creation of other production technologies. The notion that capabilities, created during past R&D activities, have option value was also substantiated by Kogut and Kulatilaka (2001, p. 745), who stated that, “because capabilities

> On investment strategy:
> *We are not into offshore now, but obviously we’ve seen what other companies are doing. So, there we could be second-movers – we follow.*
> (Interviewee 3, in-person conversation, March 5, 2020)

Figure 27. Interview statement on investment strategy

are platforms that create a generic set of resources, they represent investments in future opportunities."

While fundamental implications of coopetition have been addressed mathematically in game theory, the two American professors Brandenburger and Nalebuff (1996) transferred the underlying idea of this concept to practice. According to the authors, coopetition is a portmanteau composed of the two words cooperation and competition, and denotes market phenomena in which the duality between competition and cooperation persists, resulting in the potential of win-win situations for the companies involved. Coopetition can lead to better solutions for all companies involved than would be the case in naïve competition. Most commonly, the cooperation activities in coopetition take place in R&D and production endeavors. Concerning R&D cooperation, competing firms may exhibit congruence of interests, caused by cost reductions, complementarity of resources, and knowledge transfers. Problems may occur in particular from opportunistic behavior and lack of trust. Research participants cited that the Norwegian SFI had a long-lasting culture of cooperation which stemmed from the commonly shared vulnerability to the changing environmental conditions. Since the domestic industry's early days, salmon farmers had been supporting each other in crisis situations, such as during outbreaks of toxic algae. However, competition in the Norwegian SFI also appeared to be sustained beyond crisis situations. Participants explained that development licenses required approved projects to be detailed and made public. Cooperation for alternative production technologies was, thus, positively affected both by the supportive and sharing culture of the industry, and the policy that technical and developmental details of projects approved for development licenses had to be disclosed. Hence, if a technological regime had become technologically and economically feasible, companies that were committed to other technologies would have been able to utilize a verifiably successful R&D project by, for example, adopting parts of it and thereby saving initiation and switching costs. This may be particularly cost-saving for the "research" component of R&D projects, which can be characterized by a comparatively high stochastic

> *On industry cooperation:*
> *There is a tradition within the industry – that we act like a corporate team that works together across companies, sharing knowledge, sharing learnings.*
> (Interviewee 6, in-person conversation, March 10, 2020)

Figure 28. Interview statement on industry cooperation 1

> *On industry cooperation:*
> *With development licenses you are obliged to send reports at certain stages to the Directorate of Fisheries and these will be published. You're also obliged to publish your own status on the project … All the reports about the project, the implementation, the stages, and learnings will be public. And this is for all development licenses. It's sort of institutionalized to share the learning.*
> (Interviewee 6, in-person conversation, March 10, 2020)

Figure 29. Interview statement on industry cooperation 2

nature, as well as by being far from the market. It was not clear whether such forms of cooperation between competitors in the Norwegian SFI led to win-win situations, but we believe that the Norwegian SFI is a unique example of an innovative industry that could contribute to understanding the phenomenon of coopetition, reinforced by cultural and regulatory aspects, and its practical conditions, implications, and outcomes.

4.2 – Analysis – Documentary research

To further uncover the indicators behind the Norwegian SFI's innovation activities into alternative production technologies, recent IntraFish news articles were grouped and analyzed using LDA topic modeling, with the goal of creating a comprehensive picture of the industry's development. During our construction and implementation of the LDA topic modeling method, several tuning parameters were decided upon to optimize the results retrieved from the topic groupings. When initializing an LDA model, the researcher will always be required to specify the number of topics the model should produce, and when coupled with Gibbs sampling, additional parameters must be determined. Our choice of the parameters linked with Gibbs sampling was motivated by the paper "Understanding LDA for Software Engineering" by Binkley et al. (2013), the relevant portions of which are hereby explained and applied in the following text. Gibbs sampling works by randomly sampling observations from LDA's posterior distribution of the probability of a topic existing in a document, represented by θ, as well as from the posterior distribution of the probability of a word existing in a topic, represented by φ. θ and φ are codependent variables, meaning that the value of one relies on the value of the other. When Gibbs sampling has generated a value for φ, it can subsequently update the value for θ based upon this new φ value, and likewise, φ can be updated with respect to the new value for θ. Many iterations should be cycled through to come to the resultant LDA model. The values of θ and φ will gradually come to approximately resemble the desired posterior distribution, but due to the effects of random sampling, early versions of the model may be wildly inaccurate upon initialization.

To mitigate these effects, the researcher can set a *burn-in (b)* period, in which the earliest samples are calculated to build up accurate values of θ and φ, but then discarded beyond this use. Setting a low value for *b* will result in the model being influenced by the faulty initial sample observations, and the only disadvantage to setting a high value for *b* is the expenditure of extra computational effort. For this reason, we chose to use a high value for *b*, resulting in the discard of 500 sampling iterations, in order to optimize the model's results. In addition to a burn-in period, the researcher must decide on the number of useful observations sampled from the posterior, represented as n. This is the number of additional iterations which occur after the burn-in period and which are implemented in the final model. Setting a low value for n will not be sufficient for establishing a representative estimation of the posterior distributions θ and φ. Again, the only cost to the model incurred by setting a high value for n is the computational time and effort that come with many iterations. Therefore, we also chose to set a very high value for n, employing 2,000 iterations which were utilized in the resultant model. In total, 2,500 iterations were run – the first 500 of which were discarded, and the subsequent 2,000 of which were directly responsible for building our model.

The choice of the number of topics in the model, K, is arguably the most important parameter for the researcher to define, and it is not often fruitful to determine this value based purely upon the use of quantitative metrics (Eickhoff & Wieneke, 2018). Calculations such as the log likelihood, which is a measure of how likely the LDA's model parameters are to represent the actual structure within the dataset, can offer some guidance in narrowing down the potentially useful values of K (Blei et al., 2003; Hannigan et al., 2019). The number of topics defined will influence the level of detail the researcher will be able to coerce from the model, however, the choice of "too many" topics can result in topics which are unidentifiable and lack any significant meaning for the researcher (Binkley et al., 2013). Roberts et al. (2014) suggested that the number of topics should be chosen by the researcher based upon his or her goals, as well as the nature of the documents being examined. Additionally, they proposed two criteria which can be of assistance in evaluating the semantic interpretability of the resultant topics: *cohesivity*, in which high-probability words defined within a topic occur frequently across documents assigned to that topic; and *exclusivity*, in which a topic's defining words do not occur frequently within the list of high-probability words of other topics. We considered both of these features in our choice of K. Ultimately, topic interpretation is reliant on the researcher's subjective judgment and this sense of practical understanding is what allows him or her to make meaningful conclusions from the dataset (Baumer et al., 2017). For these reasons, human interpretability was the primary criterion used when evaluating our models for the choice of K which best suited our research purpose and produced distinct, identifiable topics.

After defining our b as 500 and n as 2,000, we chose to test a range of LDA models with K values from 5 to 30, evaluated in increments of 1. This resulted in a total of 26 individual models which were compared and considered based upon the cohesivity and exclusivity of words categorizing the resulting topics. Initial models in the low range of K resulted in topics that seemed to blend potentially important themes into one, or to produce topics which did not clearly indicate a coherent theme. At a *K* starting around 8 and 9, we saw stronger themes emerging, with more exclusive and characteristic words appearing commonly in some topics, while other topics remained too general to derive much value from. This trend continued until around a *K* of 16, after which point we noticed that topics were losing words that would have been very descriptive of their respective themes, indicating a weakening of topic exclusivity. At around a *K* of 22, we began to observe the appearance of more topics which were very hard to identify without directly investigating their associated news articles, hinting at a possible drop in the model's cohesivity. At this point, we also saw splits of topics we considered strong and necessary themes in explaining the developing state of the industry, and this was not desirable in our final model. Due to this phenomenon and the overall trend of weakening topics, we chose not to evaluate the remainder of the models with *K* values of 23 through 30. We produced a plot of the development of the models' log likelihood values as *K* increased, in order to investigate the quantitative evolution of the model, which is presented below in figure 30.

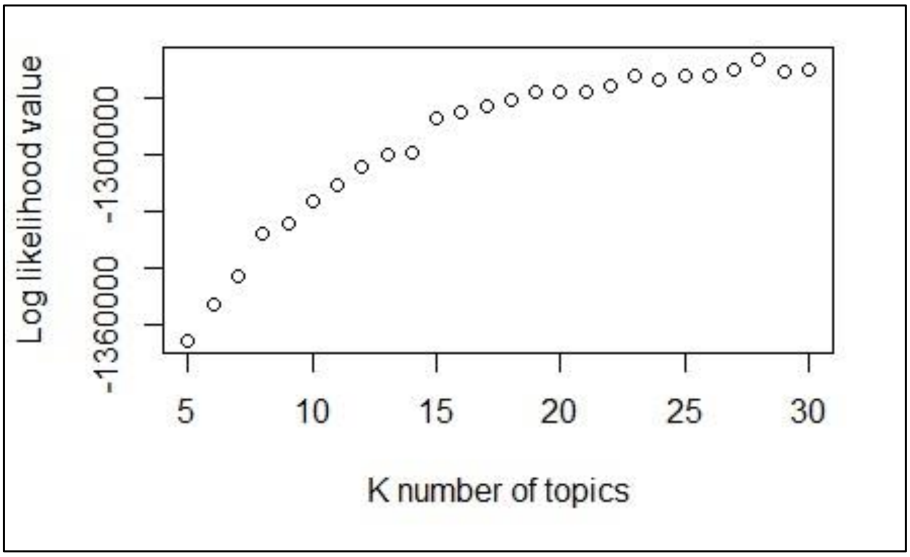

Figure 30. Log likelihood for LDA models with K topics

Note. Higher values of log likelihood indicate a statistically "better" model

Visualizing the progression of the log likelihood over the range of *K* would indicate that, on the whole, the model became more accurate upon augmenting the number of topics. According to the log likelihood metric, the model improved significantly in the jump from seven to eight topics, and from 14 to 15 topics, approximately in line with our subjective judgment. At around a *K* value of 15, the curve leveled off, indicating a stable convergence in the model. This means that, statistically, only slightly greater value is attained by adding an additional topic to the model. Using our subjective interpretation of the topics, as well as the information attained by observing the development of the log likelihood over the range of *K*, we decided that implementing an LDA model with a *K* of 16 produced results which were most sufficient in fulfilling our research goals and defining the overarching categories of the news articles.

4.2.1 – Overview of the results – Topics produced by the LDA model

To accomplish the practical application of LDA topic modeling, as described in subchapter 3.4.2, we produced our model using the *LDA* function provided by R's *topicmodels* package (Grün & Hornik, 2020). The following parameters were used: a *K* value of 16, a *b* value of 500, and an *n* value of 2,000. Sixteen topics were generated, which are summarized in table 7, as presented on the following page.

Table 7. Overview of the 16 resultant topics from LDA analysis on IntraFish articles

Topic	**Label**	**Key terms within top 30 words**
1	Management changes	company, CEO, new, director, role, position
2	Value chain and retail market	products, consumers, sales, retail, brand, marketing
3	Price fixing lawsuit	companies, case, lawsuit, price, fixing, investigation
4	**Canadian salmon farming development**	**Canada, farms, environmental, operations, province, Trudeau**
5	**Salmon feed technology**	**feed, oil, sustainable, technology, Skretting, BioMar**
6	Russia ban on salmon imports from Chile and Norway	Chile, Russia, ban, authority, operations, restrictions
7	Quarterly earnings	million, year, percent, quarter, tons, earnings
8	Salmon spot prices	NOK, prices, per, kilo, week, market
9	**Salmon loss due to algal bloom and escapes**	**algal, bloom, affected, mortalities, escape, directorate**
10	**Treatment for salmon lice and disease**	**lice, research, health, control, treatment, disease**
11	Coronavirus impact	coronavirus, seafood, China, outbreak, employees, impact
12	**Land-based RAS salmon farming**	**land, based, project, RAS, capacity, facility**
13	International seafood demand	market, China, united, states, exports, consumption
14	Stocks and shareholders	million, company, percent, shares, stock, Oslo
15	IntraFish summary articles	seafood, industry, farming, news, world, sector
16	*Lacked topic exclusivity; coherence*	*said, will, told, can, going, need*

Topic labels were chosen based upon the 30 most commonly occurring words in each topic, as well as by reviewing the articles which were classified as being most strongly representative of each topic. Not all topics identified by the model were considered useful in answering our research question, such as the financial, administrative, and legal topics defined as "Quarterly earnings," "Salmon spot prices," "Stocks and shareholders," "Management changes," and "Price fixing lawsuit." Another topic, labeled "IntraFish summary articles," consisted of brief summaries of several topics recently covered by the news site, and was therefore not represented by a single industry theme which would assist us in building a conclusion about the roles that alternative production technologies play in the development of the Norwegian SFI. Topic 16 was characterized by short verbs that lacked the exclusivity necessary to characterize a single, coherent theme. Upon inspection, we found that even for the documents which ranked most highly in this category, this theme comprised a much lower portion of these documents than observed for other, more descriptive themes. To further illustrate the point, we noted that of the content contained within the document most highly represented by Topic 9, 71% was categorized as belonging to this topic, whereas the corresponding metric for Topic 16 was only 40%. We postulated that the articles included in this topic may mainly consist of themes found in the other topics but use more explanatory verbs than the articles which were grouped into their primary topics.

We perceived the remaining topics of consideration, topics 2, 4, 5, 6, 9, 10, 11, 12, and 13, as having substantial implications for either the supply or demand affecting the Norwegian SFI. Of this subgroup of topics pertaining strictly to supply and demand, we considered topics 2 ("Value chain and retail market"), 6 ("Russia ban on salmon imports from Chile and Norway"), and 13 ("International seafood demand") as primarily encompassing the demand side of the Norwegian SFI. Topics which were identified as leaning most heavily towards this demand side were not evaluated in our analysis. This decision was made because we considered the supply aspect of the industry to exclusively be of notable significance in providing some insight into the alternative production technologies that the Norwegian SFI employs and is considering as potential investment opportunities in the pursuit of industry development. Due to biological and regulatory constraints within Norway, domestic salmon farming companies may wish to optimize their production output by utilizing alternative production technologies, thereby maximizing the levels of Atlantic salmon supply that the Norwegian SFI is able to sustain. Therefore, any of our model's topics which are linked to the focused theme of supply may contain information about salmon farmers' responses to today's challenges, and hint at the prospects of technological development and widespread usage of production technologies within the industry. Topic 11 ("Coronavirus impact") could be seen as affecting both supply and demand within the industry, however, we did not foresee the articles contained within this topic as being of use in pinpointing the alternative production technologies that will be utilized within the industry to solve supply constraints over a long period of time.

This process narrowed down our interest to the news articles defined by the following five topics: "Canadian salmon farming development," "Salmon feed technology," "Salmon loss due to algal bloom and escapes," "Treatment for salmon lice and disease," and "Land-based RAS salmon farming." Though we acknowledge that the topic labeled "Canadian salmon farming development" largely concerned operational developments in Canada, many of these sites are owned by Norwegian companies. Additionally, we considered the current circumstances within Canada a special case that could illuminate the effects of technological requirements which may impact Norway's salmon farming operations in the future. Due to the fact that the findings in this group of articles did not directly represent developments of the SFI's Norwegian operations, these results are presented last. The topic distribution of all topics over all of the 1,011 documents in the sample are presented in figure 31 below, with emphasis on our five topics of interest. Additionally, to provide the reader with a deeper understanding of the word compositions within the topics of interest, visual representations of the 100 most frequently-occurring words in these five topics, called *wordclouds*, are included in Appendix P.

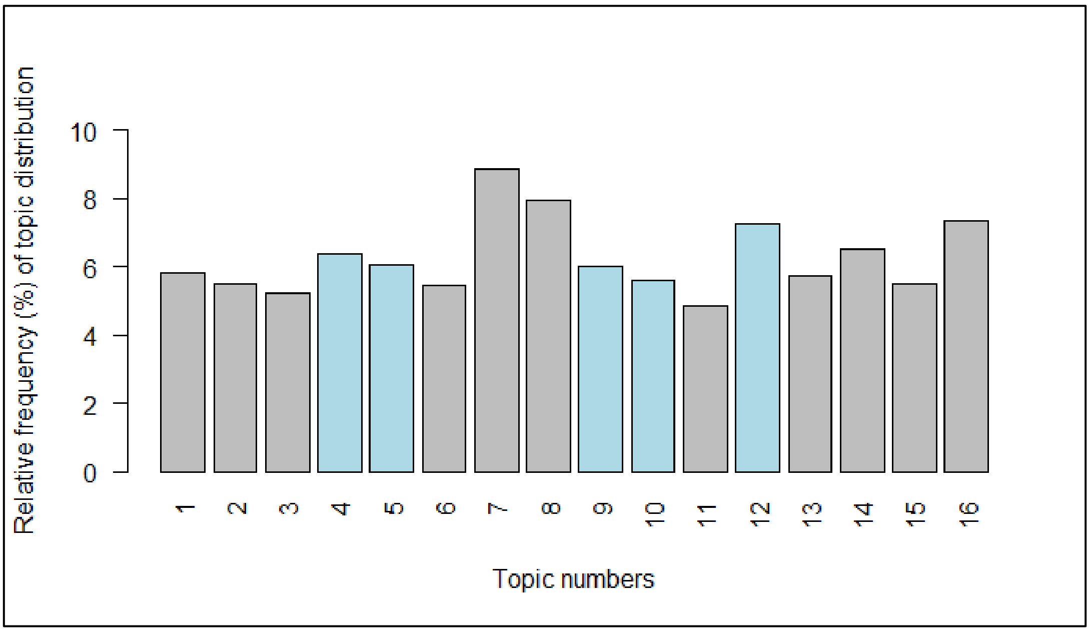

Figure 31. Topic distribution over all documents categorized by LDA model

After narrowing down topics to those which could indicate potential developments in the Norwegian SFI's supply, we then used these focused topic categorizations to refine our sample of articles, with the goal of retaining only those which could give further insight into the specific production technologies employed by the industry. To accomplish this, we identified the articles which were most highly represented by one of the five topics of interest defined previously. This means that every article that was grouped into one of the five topics did not have a higher assignment to another topic than to the topic in which it was placed for analysis. In this manner, we aimed to elicit the articles which were most relevant to our topics of interest and which could therefore provide the most valuable information. This resulted in the following outcome: 81 articles were represented by Topic 4 – Canadian salmon farming development, 51 articles were represented by Topic 5 – Salmon feed technology, 68 articles were represented by Topic 9 – Salmon loss due to algal bloom and escapes, 50 articles were represented by Topic 10 – Treatment for salmon lice and disease, and 103 articles were represented by Topic 12 – Land-based RAS salmon farming. This resulted in a total of 353 articles on which a deeper analysis could be conducted. All articles within each group were read manually by the researchers, further categorized, and used to detect the technological trends which are proposed by the Norwegian SFI as solutions in developing and enhancing the industry.

The results of the analyses are hereby presented in the following subchapters 4.2.2 through 4.2.6. It should be of note to the reader that all specific industry events and conclusions drawn by industry participants are presented in the past tense, whereas the researchers' interpretations of how the emergent themes within the news articles represent contemporary developments within the Norwegian SFI are given using present tense verbiage. Additionally, the reader should be mindful of the fact that, though filtering methods were applied to the sample dataset to elicit only articles which were relevant to the Norwegian SFI, some opinions and events arose in the results which stemmed from or affected other locations. When findings are deduced from these observations that impact the salmon farming industry more generally, we make note of this by referring solely to the "SFI" or the "industry," where applicable.

4.2.2 – Topic 5 – Salmon feed technology

Of the 51 articles which were categorized as being most represented by Topic 5, 31 were found to be directly related to salmon feed technology, five to matters involving industry investments and expansion, two to other production technologies, two to other operational technologies, and 11 covered miscellaneous events which were not of any interest to the topic's theme. These findings are summarized in figure 32, as presented below.

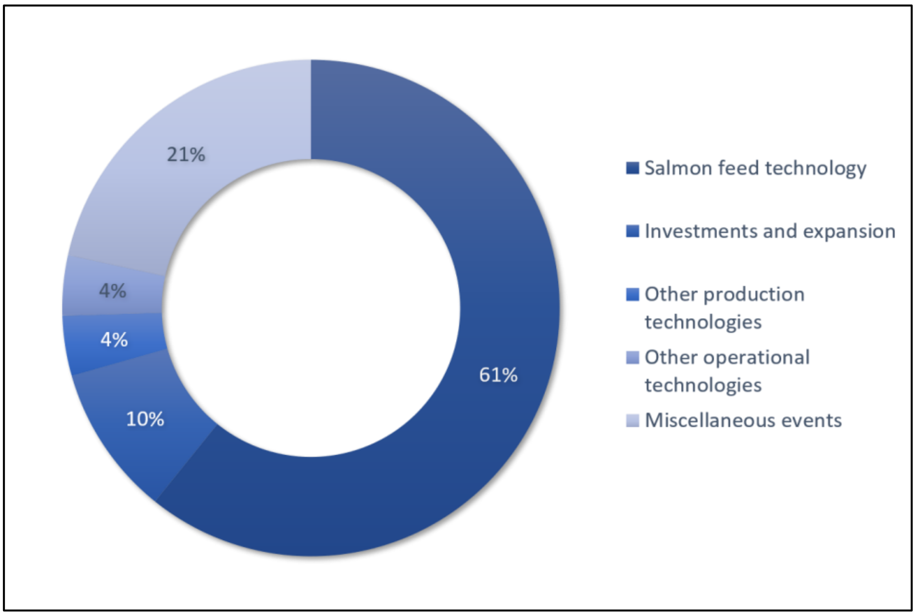

Figure 32. Content of articles in Topic 5 – Salmon feed technology

Articles categorized under this topic largely spoke of an increasing focus within the industry on environmental sustainability and responsible sourcing of feed components. The primary catalyst cited in the development of salmon feed was the need for the SFI to limit its reliance on wild pelagic fish stocks as a source of the nutrients necessary in maintaining high levels of fish welfare and sufficient growth rates among farmed salmon. Alternative and supplemental feed components proposed included algae oil, insect meal, plant-based oils and meals, single-cell proteins generated by methane or ethanol, and seafood trimmings from existing production processes. These technological developments were recognized as a crucial means to securing reliable levels of production volume within the Norwegian SFI, and in ensuring that the industry can play a key role in the expected doubling of global protein demand by the year 2050 (Mutter, 2019b). In response to this challenge, Pilar Cruz, president of Cargill Aqua Nutrition, is quoted as commenting of the industry: "There are social and environmental challenges. Feed has a major influence over that" (Mutter, 2019a, para. 12). In addition to being capable of optimizing growth and harvests in open net pens, new developments in salmon feed were said to also be a critical factor in supporting the use of alternative production technologies such as land-based RAS operations, as specialized feed blends which are compatible with the rearing system must be employed.

The industry was noted to be taking part in a sort of "space race" (Mutter, 2019a, para. 15) to develop viable alternatives to fish meal and fish oil, with the goal of enhancing security in the supply of inputs to farmed salmon production. Of the feed developments discussed within this group of articles, the use of algae oil as a substitute for fish oils obtained from wild pelagic stocks was most frequently mentioned. Algae oil has already been implemented alongside traditional fish oils for a few years, by companies including Lerøy, as a supplement to provide the farmed fish with additional nutrients such as omega-3 fatty acids (Unlay, 2020). In addition to providing the consumer with a product of greater nutritional value, the incorporation of algae oil in salmon feed was also mentioned to have the potential to increase the harvest size of each salmon by nearly half a kilo, thus resulting in higher production volumes, ceteris paribus (Unlay, 2020). A total replacement of fish oils with algae-based alternatives within the industry has been infeasible to this point, due to high costs that are forcing feed producers to maintain a balance between profit margins and their exposure to the volatility of wild pelagic fish stocks. The high costs of alternative inputs are passed on to the salmon farmers and with a complete phase-out of fish oil and fish meal, would result in an end product sold at a price higher than what would currently be acceptable for the consumer market. However, this trend may be changing, as new methods of production for feed alternatives are developed and economies of scale are attained. In July 2019, the Dutch feed producer Veramaris opened a marine algae oil facility which was capable of supplying the SFI with around 15% of its total need for the marine oils used in feed (IntraFish Media, 2019d). Steps in this direction can help the industry to reduce its dependence on uncertain wild fish stock harvests and to ensure stable volumes of farmed Atlantic salmon production in the coming years.

Feeds that were specifically formulated to work well in land-based RAS facilities were also of notable interest in this group of articles. New, specialized feeds were being developed with respect to performance goals that were different from traditional feeds. For example, the articles indicated that effective RAS feeds should contain raw materials that are easily digestible for the fish, minimizing the amount of nutrients present in the water that could eventually lead to pollution at high levels (Furuset, 2020c). The physical form of the feed itself should also be designed in a manner that allows the pellets to sink slowly and that discourages dissolution, further reducing the amount of waste which requires additional effort from the filtration system to remove (Furuset, 2020c). Adoption of these newly developed feeds was considered necessary for salmon farmers utilizing RAS facilities, as a suitable aquatic environment must be maintained in order to optimize production volumes by reducing the number of fish lost to mortalities caused by poor water quality. Synergies between the use of salmon with specialized genes and fish feed optimized for the type of production technology they are reared in were cited to lead to higher density growth and more efficient uptake of nutrients within the fish stock (Navarro, 2019a). Recent industry developments in feed technology indicate that salmon feed is able to play a strong supporting role in the operation of alternative production technologies and can be an important determinant of their success.

The articles categorized as belonging to Topic 5 largely highlighted increasing consumer pressures on the industry to implement more sustainable and environmentally-conscious practices. Both the usages of wild pelagic fish stocks and soybean, which has been used as a plant-based alternative to fish-based feed inputs, had increasingly been recognized by consumers as an undesirable practice carried out within the SFI. Karim Kurmaly, Chief Executive Officer (CEO) of Veramaris, acknowledged the “growing consumer awareness of the pressure on wild-catch fisheries” (Korban, 2019, para. 1), which had become a source of inspiration to make changes within the industry. Nicolas Baroux, head of procurement at French retailer Supermarché Match, stated that, “feeding salmon with natural marine algae oil resonates strongly with increasing consumer demands for nutritious, sustainably farmed seafood” (IntraFish Media, 2019a, para. 5). The incorporation of ingredients such as algae oil can also allow companies within the Norwegian SFI to differentiate their products based upon new third-party certifications, moving some of the industry focus away from increasing production volumes to expanding the value chain.

Though most of the relevant articles focused on the issue of industry sustainability through the lens of consumer perception, there was also a lesser emphasis on the industry’s acknowledgement of the potential bottleneck in future production volumes caused by waning wild capture marine resources. Alternative production technologies among these articles were mentioned in the context of how developments in feed both can allow these production facilities to operate properly, as well as to stimulate growth and optimize harvest volumes of Atlantic salmon. In this group of articles, alternative production technologies were not singled out often, but rather, farmed salmon production methods of all types were recognized as necessitating an overhaul to their foremost variable input – feed. With this challenge in mind, the articles underlined a central theme, that whether the catalyst is consumer demand, or production security, an industry transformation towards employing alternative feed sources is critical in safeguarding future success for the Norwegian SFI.

4.2.3 – Topic 9 – Salmon loss due to algal bloom and escapes

Of the 68 articles which were categorized as being most represented by Topic 9, 32 were found to be related to the impacts of algal blooms, 24 to matters involving salmon escapes, three to other production technologies, and nine covered miscellaneous events which were not of any interest to the topic's theme. These findings are summarized in figure 33, as presented below.

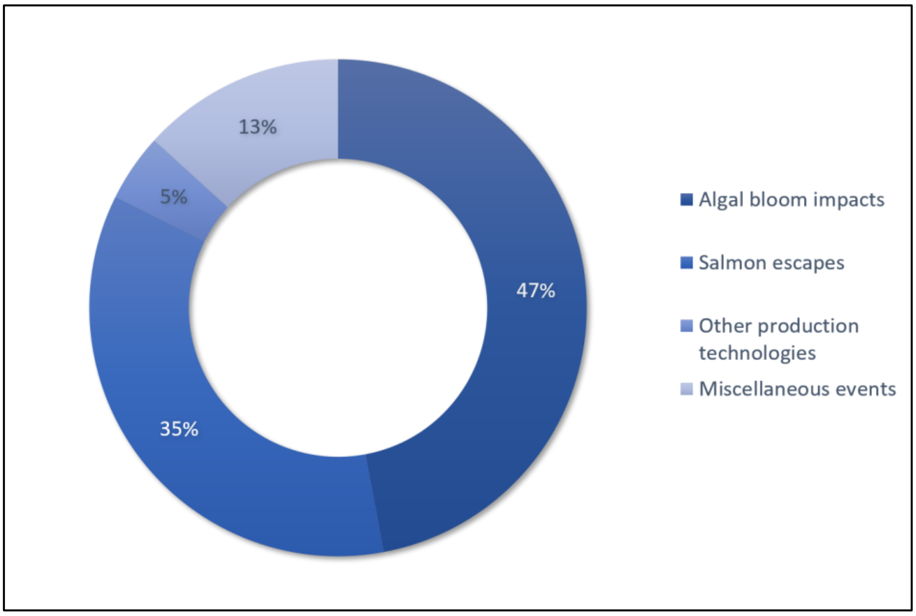

Figure 33. Content of articles in Topic 9 – Salmon loss due to algal bloom and escapes

The articles within this topic largely brought attention to two industry challenges which had notable consequences for production volumes attained by the Norwegian SFI in 2019, namely, that the industry experienced its highest annual number of salmon escapes in Norway in nearly a decade, as well as the highest annual number of salmon mortalities caused by an algal bloom in Norway in three decades (Furuset, 2019a; Grindheim, 2019c). Most of the articles which were given the label "salmon escapes" mentioned a single, distinct event in which salmon escaped from the open net pens at one location. Conversely, the majority of articles which were given the label "algal bloom impacts" gave continuous updates on the weeks-long development of algae spread throughout areas of Northern Norway, and to a lesser extent, on similar events occurring in Chilean and Canadian salmon farming sites.

Within the period between mid-May and early June 2019, a large bloom of the algae strain *Chrysochromulina* swept the waters of Northern Norway, causing substantial mortalities of farmed salmon which were being reared in the area's open net pens (IntraFish Media, 2019b). The most recent article published by IntraFish within the sample period tallied the losses at 3.7 million fish in Nordland county, corresponding to 6,400 tonnes, and at 4.0 million fish in Troms county, corresponding to 6,800 tonnes (Riise, 2019a). In addition to the direct losses in production volumes sustained due to salmon mortalities, Norwegian salmon farmers were also forced to harvest some of their stock earlier than anticipated, thus prohibiting the fish from reaching their complete grow-out size, in order to avoid further mortalities that would result in larger numbers of non-harvestable fish. Though a report by the Norwegian Directorate of Fisheries concluded that some companies would try to compensate for the loss in harvest volumes by restocking the affected net pens or by employing the freed-up production capacity in other locations, the event was likely to have caused a net negative effect on the 2019 production volumes achieved by the Norwegian SFI (IntraFish Media, 2019a).

Algal blooms were mentioned to be caused by a combination of certain environmental conditions, including heavy rainfall, warm temperatures, and direct sunlight. High concentrations of algae lead to decreases in the levels of dissolved oxygen in the water, and can result in salmon mortalities (IntraFish Media, 2019f). The biological nature of these algal blooms makes it an especially difficult problem to tackle for salmon farmers conducting operations in open net pens, which are influenced by the quality of the surrounding waters. The articles within this category indicated that there were not many measures being taken by the Norwegian SFI to prevent the onset of algal blooms within the net pens, but rather, that reactive tactics had to be employed in an attempt to maintain a sufficient water quality within the enclosures. Several techniques were used to accomplish this goal. A physical barrier which limits the amount of algae that is able to reach the fish stock could be installed around the net pen, such as an algae skirt or bubble curtain (Mutter, 2019e). Additionally, algae requires sunlight to thrive, meaning that deeper waters which do not receive high exposure to sunlight will contain lower concentrations of algae (Riise, 2019a). The water from deeper in the sea could be pumped into the net pen to dilute the algae, or the salmon could be fed at lower depths to limit their exposure to the harmful organism (IntraFish Media, 2019f). Even though the impacts of passing algae blooms can still be devastating to individual salmon farms, the industry has been evolving over time and is becoming better suited to deal with the issue. Regarding the SFI's ongoing battle against algal blooms, managing director Rocky Boschman of Grieg Seafood's British Columbia operations said, "ten years ago, I'm certain we would have lost 100 percent of the fish. Sometimes Mother Nature kicks you so hard you don't have an answer for it. But you can measure improvements over the years" (Sapin, 2019a, para. 3).

A high number of salmon escapes was also a source of production volume losses for the Norwegian SFI in 2019. In total, the Norwegian Directorate of Fisheries was notified of 45 incidents resulting in the escape of 287,000 salmon in the country during the course of the year, equating to a nearly 50% increase from the prior year (Korban, 2020). The actual number of escaped fish may have been even higher than reported figures, as many of the articles detailing the escapes indicated that the exact number of escaped fish was unknown, and in some instances was also not approximated. From the information provided in the sample, the Norwegian SFI did not seem to have a dependable method of accounting for lost fish, and instead relied on local fishermen to catch the escapees in order for the salmon farming company to make an estimate. One general manager of a company operating in Hardangerfjord commented on the scale of escaped fish sustained in one particular incident, saying that, “it may have been 20, or it may have been 1,000, but based on the number of fish caught, it’s not a significant escape” (Sandvik, 2019, para. 4). A perceived lack of responsibility within the Norwegian SFI to track its fish stocks led to calls for stricter regulation to compel companies to better manage and relay their environmental risks. Proposed measures included requiring salmon farmers to take greater efforts to retrieve escaped fish and to establish a contingency plan to address any resulting negative production externalities (Riise, 2019b). Furthermore, salmon farming companies could also be subject to production limitations if they had a history of escape incidents due to human error, or if they failed to report these incidents to the appropriate authorities (Riise, 2019b). In the worst case, open net pen salmon farming could eventually be banned altogether if escapes caused the risk posed to wild fish stocks to become too great, as had been decided upon in Washington state and would be decided on within Western Canada (Cherry et al., 2019; Mutter, 2020b).

Salmon escape incidents mentioned within the sample articles almost uniformly were caused by tears in the netting material containing the fish. No suggestions of material modifications or additions to the netting or cage structure were given as methods of alleviating the issue, though better worker training was cited as being an area of industry improvement which could lead to fewer incidents of escape (Riise, 2019b). Unavoidable weather events will always pose some risk of causing damage to the open net pens, however, three out of every four escape incidents were identified as occurring outside of work hours, indicating that measures could be taken to better secure the premises when they are unmanned (Riise, 2019b). In accordance with current and proposed Norwegian legislation, sufficient internal controls to regularly secure the sites and inspect for areas of weakness may be the best solution in the prevention of salmon escapes (Njåstad, 2020).

No references to alternative production technologies were made within the articles categorized in Topic 9. To reiterate, solutions for the issue of algal blooms consisted of additional systems retrofitted onto open net pens to either modify their aquatic conditions or create a permeable barrier on the perimeter of the structure, as well as adjustments made to the feeding process in order to restrict the amount of algae the fish were exposed to. Additionally, calls were made by industry representatives for the advancement of algae detection technology to allow salmon farmers to take timely action to protect their fish stocks before the situation became dire (Furuset, 2019b). The only measures suggested to lessen the number and severity of salmon escapes were of systematic nature, including improving the industry's competence on handling and preventing incidents, enhancing the employment of risk-based audits, and using production-limiting regulation to force salmon farming companies to analyze and minimize their risk of experiencing escapes. We hypothesize that alternative production technologies may not have been a proposed solution within this topic due to the relatively low number of farmed salmon that these two issues affect, in comparison with other industry challenges such as salmon lice. Though alternative production technologies are capable of providing a barrier to both protect fish stocks from undesirable conditions found within the natural environment, as well as to protect the surrounding ecosystem from lice spread or genetic pollution caused by farmed fish, these technologies may have been considered too costly to mitigate the problems of algal blooms and salmon escapes, when considered exclusively. Regardless of the enclosures the industry utilizes, the Norwegian SFI still must take proper action both to protect its own fish stocks as well as to preserve the health of the surrounding ecosystem, in order to avoid provoking threats of increasingly stringent regulation.

4.2.4 – Topic 10 – Treatment for salmon lice and disease

Of the 50 articles which were categorized as being most represented by Topic 10, 33 were found to be directly related to salmon lice issues, 10 to other salmon health and welfare issues, three to other operational technologies, and four covered miscellaneous events which were not of any interest to the topic's theme. These findings are summarized in figure 34, as presented below.

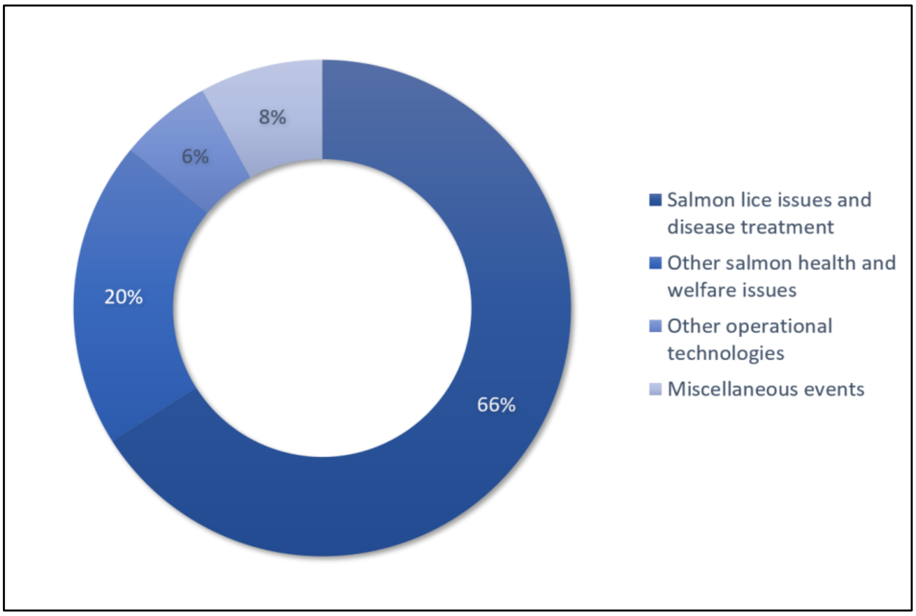

Figure 34. Content of articles in Topic 10 – Treatment for salmon lice and disease

Many articles identified sea lice as the foremost issue present within the industry, one of which going as far as to state that in 2019, "the biggest bane of the sector continued to cause losses, so much so that the year could be dubbed 'the year of the sea lice'" (Riise, 2020, para. 5). Undoing the damage caused by salmon lice treatments constituted the year's most significant fish health challenge for farmers. Not only was there a decline in fish welfare caused by the parasite and the harmful effects associated with delousing treatments, but frequent treatments which required periods of starvation resulted in a loss in production volumes due to the reduction in the number of feeding days. Additionally, during the sample period, Norwegian research institutions identified a correlation between the frequency of salmon lice treatments and the incidence of salmon mortalities, further underscoring the negative impact that lice have had on the Norwegian SFI's harvestable volumes of Atlantic salmon (Riise, 2019f). Even Mowi, Norway's largest salmon farming company, cited biological challenges as a primary reason that it had not been able to sustain production volume increases within recent years (Navarro, 2019b). For these reasons, the benefits that the Norwegian SFI would experience in implementing a practical, effective, and reliable lice treatment are tremendous, and would allow the industry to overcome much of the production stagnation it has incurred over the last eight years.

Several candidates for game-changing solutions to the problem of salmon lice were proposed in this topic's articles, and could be grouped within distinct categories, including: genetic technology, immunization through vaccines, new feed compositions, alternative feeding methods, alternative production technologies, individualized or localized treatments, and treatments involving fresh water, heated water, or pressurized water. Some of the most promising, novel lice treatments are summarized hereafter.

Researchers from Norwegian breeding company AquaGen discovered that salmon with certain genetic markers could naturally be more resilient against salmon lice infestations (Riise, 2019e). Though the Atlantic salmon's genetic make-up is complex and its resistance to the parasite could potentially be reliant on 1,000 or more individual genes, the company had observed 50% fewer salmon lice present among experimental salmon populations after just two generations of genetic selection (Riise, 2019e). New vaccine technologies were also researched that could render salmon populations immune to salmon lice. Agricultural company Felleskjøpet Fôrutvikling tested an immunization method in which substances produced by salmon lice are injected into egg-laying hens, which then produce antibodies that become present within their eggs' yolk (Riise, 2019d). These antibodies could then be passed on to salmon populations either by direct vaccination or through the salmon's feed (Riise, 2019d). The company announced positive results in their experimental salmon stock, when compared against a control group (Riise, 2019d).

New types of salmon feed were also discovered to deter salmon lice from settling within farmed salmon populations. Researchers from the University of Tromsø found that the inclusion of certain types of algae-based ingredients in salmon feed resulted in the salmon expelling a fatty acid to which lice are averse, ultimately resulting in a lower prevalence of salmon lice among the fish (Riise, 2019c). Not only were the compositions of feed adjusted in an effort to combat salmon lice, but their methods of distribution were modified as well. As salmon lice are predominantly active only within the shallowest 10 meters of water, the salmon's exposure to lice could be reduced by encouraging the salmon further down into the water (Cherry & Unlay, 2019). This could be done by feeding the salmon at lower depths, as Arctic Offshore Farming's underwater feeding system was planned to demonstrate, or by using cylindrical tubes contained within the net pen to funnel the fish into deeper waters, as Akva Group accomplished with its tubenet systems (Cherry & Unlay, 2019; IntraFish Media, 2019).

Individualized or localized treatments stand to become increasingly important within the industry. Cermaq's iFarm project was awarded four development licenses to employ its novel farming technology which includes image recognition of individual fish (Mutter, 2019f). Sensors are installed which can identify, for example, when a fish is affected by salmon lice, and iFarm's integrated systems can separate these fish requiring treatment from the general population within the pen (Mutter, 2019f). A digital database can then establish health records for each fish on site and monitor them for changes which would require further medical attention (Mutter, 2019f). The company hoped to install the technology in existing open net pens (Mutter, 2019f). Researchers from the University of Tromsø also emphasized the importance of putting an end to generalized lice treatments for salmon, and rather urged farmers to address the issue on a pen-by-pen basis (Kvile, 2019). Findings made by the University showed that the genetic strains of salmon lice vary widely depending upon their location and will respond to treatment differently based on this factor (Kvile, 2019). Using revolutionary genetic technology called metabarcoding, water samples may be retrieved from net pens and analyzed to determine which species have been present in the area (Kvile, 2019). This can allow salmon farmers to pinpoint the specific type of lice present among their stock and apply treatments accordingly.

Within this sample of articles, there were few mentions related to the explicit goal of lice prevention by using alternative production technologies such as semi-closed containment systems or land-based RAS facilities. Only two references to alternative production technologies were made in this sample: one concerning Mowi's Egg salmon farm concept, which is a semi-closed containment system; and the other concerning Mowi's Aquastorm system, which is a subsea farming method incorporating autonomous operations and remote management (Grindheim, 2019a, 2019b). Both were cited as being capable of minimizing the exposure of the farmed salmon to surrounding populations of lice. Conversely, there were many mentions of R&D taking place within genetic advancements, feed improvements, and monitoring technologies to lessen the impact of lice. The general sentiment in this group of articles conveyed an interest in developing improvements to existing operations within Norwegian Atlantic salmon production, rather than implementing entirely new methods of farming to obtain higher production volumes by mitigating the threat of salmon lice. Therefore, we postulate that there may be greater interest within the Norwegian SFI in generating incremental improvements on existing operational and structural elements of the well-established open net pens, by means of retrofitting and the use of better production inputs, than in completely replacing the means of production by using alternative production technologies.

4.2.5 – Topic 12 – Land-based salmon farming

Of the 103 articles which were categorized as being most represented by Topic 12, 58 were found to discuss land-based RAS salmon farming facilities in the context of raising salmon to harvest size (grow-out), 15 discussed land-based RAS salmon farming facilities in the context of raising salmon to their post-smolt stage, 14 involved other production technologies, six involved other operational technologies, three consisted of matters involving industry investments and expansion, and seven covered miscellaneous events which were not of any interest to the topic's theme. These findings are summarized in figure 35, as presented below.

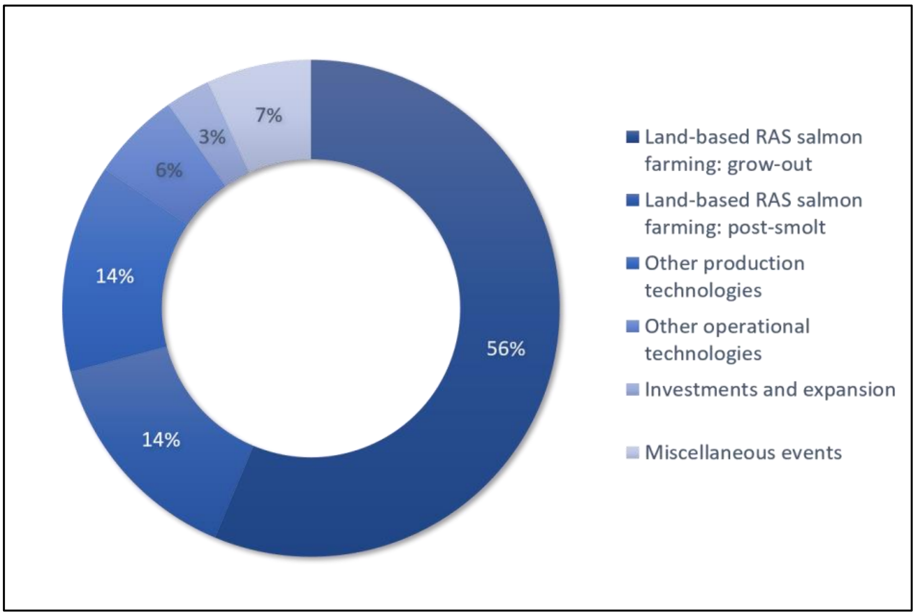

Figure 35. Content of articles in Topic 12 – Land-based salmon farming

Relevant articles present within this topic spoke of an industry-wide trend in which salmon farmers globally were increasingly employing more land-based RAS technology in the rearing of salmon to their post-smolt stage, as well as expanding upon these existing land-based RAS farming competencies to begin producing harvest-ready salmon without ever needing to utilize an open net pen. RAS usage within *hybrid systems*, in which post-smolts raised on land are later moved to the sea to reach their full grow-out size, was perceived by the industry as having reached commercial feasibility and was embraced as a method of reducing the environmental risks posed to the fish during their final stages of growth in open net pens (Sapin, 2020a). In contrast, the utilization of land-based RAS facilities for the production of fully-grown salmon was viewed with some apprehension by investors, technology suppliers, local stakeholders, and current industry participants, resulting in challenges for prospective RAS salmon farmers to implement this method of production in their operations. In spite of this skepticism, land-based RAS technology was seen as having the potential to be a significant disruptor once the industry had navigated past early hindrances. As the technology and industry confidence progresses, the Norwegian SFI may be forced to adapt its strategic approach in the global market, due to the opportunity that RAS facilities offer for new competitors to establish production operations outside of existing salmon farming countries.

The topic of discussion which was most consistently mentioned throughout these articles concerned recent developments made by a company which was relatively new to the industry – Atlantic Sapphire. The company was poised to create an enormous impact on the future of global Atlantic salmon harvest volumes, as by the year 2031, its Miami Bluehouse and Danish pilot facility were anticipated to jointly produce a total of 220,000 tonnes of salmon annually (Evans, 2020). If these expectations were to hold, Atlantic Sapphire would have only been surpassed by Mowi in the rankings of the world's largest producers of Atlantic salmon, by volume (Evans, 2020). By raising and harvesting its salmon within the US, Atlantic Sapphire aimed to place itself closer to North America's large consumer market (Fiorillo, 2020). This would allow the producer to recapture some of its initial capital expenditures in the long term by circumventing the high costs of airfreight that are largely necessary to deliver fresh salmon to North American consumers (Fiorillo, 2020; Mutter, 2019a). In this manner, Atlantic Sapphire could remain cost competitive with salmon farmers producing in open net pens outside of the continent. Andreas Kvame, CEO of Grieg Seafood, also recognized the opportunity that exists in establishing production closer to the American consumer, noting that, "the US market is the world's largest and fastest growing market for Atlantic salmon, but only a third of US demand is currently met by North American production" (Mutter, 2020a, para. 8). The US consumer demand for salmon is primarily served by Chile and Canada, with Norway supplying a limited portion of the nation's market (Evans, 2019). Though this may imply that a competing market entrant may not directly have a great effect on the state of the Norwegian SFI, the establishment of a major land-based RAS facility which is capable of producing large amounts of harvest-ready salmon signals to potential investors that this technology can be successfully utilized in areas independent of any natural environmental conditions traditionally required to raise salmon in sea-based enclosures.

New land-based RAS facilities were in the planning stages for many areas that previously have not been capable of raising Atlantic salmon, including Saudi Arabia, Sweden, Spain, China, Japan, Vietnam, Poland, and Russia. Several US states in addition to Florida began to follow Atlantic Sapphire's suit in establishing grow-out RAS salmon production facilities, such as Maine, Nevada, Maryland, and California. One central commonality uniting the motivation behind these new constructions was to provide local consumers with a source of healthy protein that traditionally had necessitated a reliance on foreign imports. In the wake of effects caused by the 2019 novel coronavirus, participants within the salmon farming industry began to place increased emphasis on the importance of food security generated within a nation's own borders.

The CEO of Norwegian-owned company Vikings Label, which was in the process of establishing land-based RAS salmon farming within Saudi Arabia during the sample period, remarked that, “countries should not depend on imports as much as they do right now” (Riise, 2020b, para. 11). In this light, land-based RAS salmon farming may become more attractive in the coming years, as countries realize the importance and potential opportunity of producing their own, local harvest volumes of protein-rich foods. This phenomenon is capable of introducing a very real threat to the prominence the Norwegian SFI retains in being the global leader in salmon aquaculture.

Several difficulties stood in the way of bringing the establishment of new land-based RAS salmon farming facilities to fruition, not least of which was the sheer amount of time it could take from ideation of the project to the completion of its first production cycle. For Whole Oceans’ new RAS farm to be established in Bucksport, Maine, the entire permitting process was said to be completed relatively quickly, taking two years from the company’s initial announcement of its plans (IntraFish Media, 2019g). The project was expected to finish construction three years from obtainment of the final permits, after which point Whole Oceans could begin operations to produce its salmon (IntraFish Media, 2019g). Once production had commenced, the first harvests of fully grown salmon would be ready for purchase by consumers in two years’ time (IntraFish Media, 2019g). In this case, it was anticipated to take seven years to finally bring the product to market, demonstrating that there could be a significant lag between the moment that a salmon farming company recognizes the potential for land-based RAS technology to fill an industry need, and the moment that that company can begin to realize a positive return on its investment. Delays of the same scale were also experienced in Norway, with Norwegian agriculturalist Knut Langeteig reported to still have been waiting for final permits to be issued, two years subsequent to his application, for what would be Norway’s first commercial, land-based RAS salmon farm capable of raising harvest-ready salmon, planned for establishment in Finnmark county (Furuset, 2019d). The extensive time necessary to plan and construct a land-based RAS salmon farming facility may both deter potential investors, as well as delay the economic effects observed in the market subsequent to the introduction of this technology, which has the potential to disrupt the industry.

Another strain on the turnaround time to bring land-based salmon to consumers was that the technology utilized for RAS facilities is highly specialized, meaning that very few companies have the capability to design systems and provide materials for the construction of these salmon farms. Akva Group, a Norwegian company which supplies equipment to the SFI, reported that of the 69 different land-based projects that had been presented to them, it was possible that only five would eventually be carried out to completion (Furuset, 2019c). Similarly, sales director Marius Haegh of Billund Aquaculture, which also equips the industry with land-based farming infrastructure, remarked that the demand for RAS salmon farms far outweighed the available capacity to supply them (Furuset, 2019c). Haegh stated that, "there are a number of large projects that require thousands of engineering hours. Today, there are probably only five suppliers globally that can deliver a land-based RAS system for salmon of 10,000 metric tons" (Furuset, 2019c, para. 9). This dilemma forced the suppliers to be extremely selective of the projects they chose to work on, requiring of their clients' financial security as well as a reassurance that their team had the competence necessary to successfully conduct the eventual operation of the plant. Many planned projects may fall short of such requirements in times of high demand for land-based RAS construction, meaning that the global SFI's production capacity will be limited by the ability of technology suppliers to support producers in creating new facilities.

Despite facing a challenging modern era in which technological advances will allow new countries to compete in the global production of Atlantic salmon, the Norwegian SFI still retains many characteristics that give the country an edge on upcoming industry entrants. A noteworthy sentiment which arose within this topic's articles is that even though land-based RAS technology significantly expanded the range of where salmon production was possible, most areas did not have the same extensive access to an experienced workforce with the competence necessary to carry out these initial projects with a high degree of success. The Norwegian SFI is an industry that has built up its knowledge base over decades of trial and error, and the wisdom gained in this time has resulted in a pool of local talent which may possess some non-transferrable skills that only are attained from many years of firsthand experience in salmon rearing. Erik Heim, CEO of the Norwegian land-based salmon farming company Nordic Aquafarms, expressed that countries such as the US had not had an established local industry within finfish farming, resulting in difficulties for companies to recruit qualified candidates (Heim, 2019). He asserted that this was in contrast with Nordic countries, which were in turn perceived by investors in the global SFI as lower-risk contenders in the operation of newly-established RAS facilities (Heim, 2019). As a result of these perceptions, the competitive advantage for the Norwegian SFI, when observed on a global scale, may be more strongly emphasized by the country's experience and competency in the industry, which can be used to advise countries which are newer to Atlantic salmon production.

The future of the Norwegian SFI appears to be heavily influenced by the prospect of land-based RAS facilities becoming more commonplace within the global development of Atlantic salmon farming. We conjecture that the role that this alternative production technology has to play is very different for the Norwegian SFI than it is for the countries which do not currently produce their own volumes of salmon. This is due to the fact that Norway already has a well-established infrastructure of sea-based farms, utilizing open net pens, that take advantage of the country's natural waterways to produce salmon in a manner that is relatively cost-efficient. Companies which have risen to prominence within the industry have already experienced high levels of success using open net pens and have further increased profitability and harvest volumes through incremental improvement to their existing structures. Therefore, the Norwegian SFI may have little incentive to start anew using a more costly alternative to production, unless such actions were made necessary by government mandates (Furuset, 2019c; Sapin, 2019b). However, land-based RAS systems for the production of post-smolts stand to be a good complement to existing processes used within the Norwegian SFI by reducing the time the salmon spend in the sea, thus limiting their exposure to environmental risks such as salmon lice and suboptimal water conditions. In this way, the utilization of post-smolt RAS systems can play a supportive role to current production operations, allowing for better industry-wide MAB utilization and eventual production volume output. When the role of this alternative production technology is viewed on a global scale, it appears that countries which are not currently producing salmon may be able to fulfill some of their consumers' own demand for salmon with local production volumes. This poses a risk to the Norwegian SFI, as it may ultimately result in reductions in the volumes of Norwegian salmon that are desired as imports from other countries, when a homegrown substitute exists. There also exists the threat of greater competition and greater global supply leading to a deflation in the salmon price, suppressing the future profitability of the Norwegian SFI.

Finally, we conclude the subchapter by noting that land-based RAS salmon farming seems to be the alternative production technology that stands to make the biggest impact on the Norwegian SFI, when assessing the current capabilities of the various technologies. Subsequent to the announcement of Justin Trudeau's goal of moving all of British Columbia's salmon farming operations to closed containment systems, the Canadian Department of Fisheries and Oceans compiled a report detailing the prospects of success for four distinct methods of alternative production: land-based RAS systems, hybrid systems, floating closed-containment systems, and offshore systems. The report concludes that, "land-based RAS and hybrid systems are the two technologies ready for commercial development … while floating, closed-containment requires 2 – 5 years of further review, and offshore technologies may require 5 to 10 years of review" (Sapin, 2020, para. 3). This information, combined with our own, independent research, leads us to believe that land-based RAS facilities are in a position to play a more immediate and significant role in the development of the Norwegian SFI than the other alternative production technologies described in subchapter 2.6. In line with this proposed phase out of open net pen salmon farming in Canada, we further elucidate in the following subchapter 4.2.6 the motive behind this political action, the responses and opinions of industry actors, and the expected future impacts of a mandated transition to alternative means of salmon aquaculture production.

4.2.6 – Topic 4 – Canadian salmon farming development

Of the 81 articles which were categorized as being most represented by Topic 4, 20 were found to be related to Canada's proposed net pen ban within salmon farming, 13 to issues regarding salmon mortalities and disease, 13 to matters involving industry investments and expansion, seven to stakeholder concerns, and three to salmon lice treatments. 12 articles covered miscellaneous events within Canada which were not of any interest to the topic's theme, and 13 articles were not related to events happening within Canada. These findings are summarized in figure 36, as presented below.

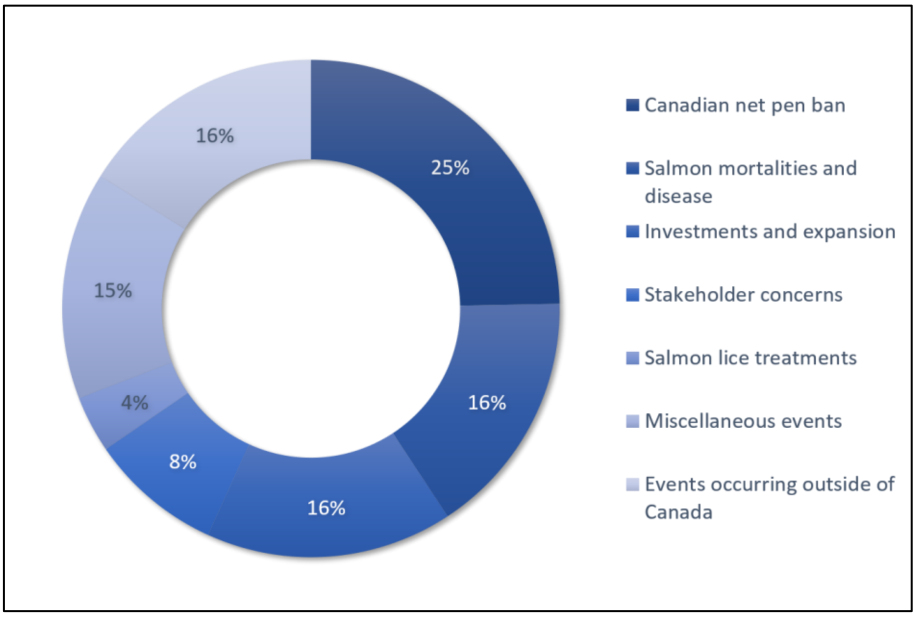

Figure 36. Content of articles in Topic 4 – Canadian salmon farming development

Though it may be clear to the reader that the majority of articles classified under this topic do not directly represent Norwegian salmon farming developments, the reasons that recent events in the Canadian aquaculture industry have strong implications for the Norwegian SFI are twofold. First, many of Norway's major players in the salmon farming industry also manage sites in Canada and are therefore affected by the proposition of new Canadian regulation that would restrict aquaculture operations. Canada's new "Aquaculture Act" (Sapin, 2019e, para. 5) could compel these companies to reallocate their resources to countries with governments more supportive of the industry, such as Norway. Second, these political occurrences in Canada have exposed the large degree to which companies in the salmon farming industry are vulnerable to production limitations or bans instituted by a reigning governmental power. This has already been observed in Norway with the country's TLS restrictions, but Canada demonstrates the potential for the introduction of legislation which is even more difficult for salmon farming companies to contend with.

Prior to his reelection as Canadian Prime Minister, Justin Trudeau announced in September 2019 that he was in support of instituting regulation which would completely ban all open net pen salmon farming in British Columbia by the year 2025, in an effort to protect the country's wild fish stocks (Sapin, 2019c). Some doubt as to the viability of his claims arose within the industry, with both Alf Helge Aarskog, former CEO of Mowi, and Andreas Kvame, current CEO of Grieg Seafood, having expressed their skepticism towards the likelihood of an eventual enactment of the ban (Mutter, 2019d, 2019c). However, such a strong measure promised against Canada's salmon farming industry has introduced significant levels of uncertainty to companies operating within the industry, in addition to legitimizing the claims of the country's aquaculture oppositionists, setting a precedent for future legal complaints against local salmon farmers. The future of tightened regulation on salmon farming may not be exclusive only to Canada. Geir Molvik, CEO of Cermaq, expressed his concern to the Norwegian government, stating that, "we are… uncertain about the consequences this could have for the development of the industry in Norway and not least how aquaculture should be a driving force for achieving the goals of sustainable development" (Furuset, 2020a, para. 8). Salmon producers within the jurisdiction of such legislation will be forced to either adapt their operations to remain in compliance with the forthcoming restrictions, shut down production or transport it to another location, or take on the risk of conducting business as usual with the hope that the restrictions are denounced or delayed before they are set to take effect.

The Canadian government presented the nation's salmon farmers with the possibility to continue producing within the area, under the stipulation that they would need to utilize alternative production technologies including closed containment systems on land or in water, and offshore facilities (Sapin, 2019e). This suggestion elicited a contentious response from local industry members, with John Paul Fraser, Executive Director of the British Columbia Salmon Farmers Association, having called the plan "unachievable" and saying that it "would lead to stagnation and significant unemployment in the British Columbia salmon farming industry" (Cherry et al., 2019, para. 4). Mowi, which operated 37 individual open net pen sites in British Columbia during the sample period, had already experienced that its Canadian productions earned the company the lowest earnings before interest and taxes (EBIT) per kilogram margins of all its global farming regions, attaining only half of its Norwegian EBIT per kilogram, largely as a result of increased environmental challenges (Cherry, 2019). Further strains on Mowi's production costs in Canada may force the company out of areas in which they cannot maintain a positive return on investment. During the sample period, most salmon produced in British Columbia served the US market, which was primarily supplied by Chilean producers (Evans, 2019). Therefore, the need to remain cost-competitive with other salmon producing countries could become a very real threat for the success of the Canadian SFI. Garry Ullstrom, CEO of Canadian land-based salmon producer Kuterra, remarked that the sale of salmon farmed in land-based RAS facilities required "a [price] premium to make it worthwhile" (Evans, 2019, para. 11), compared with traditional open net pen farming. He explained that Canadian land-based salmon producers may not be those who gain the greatest advantage from the forthcoming legislation, and rather that it may be Chilean farmers which can produce at lower costs that would incur the most benefit (Evans, 2019). Though Canadian farmers have held a cost advantage over Chile in transportation to the US market, high initial capital costs associated with building closed containment systems in Canada may deter existing companies from making the transition to land-based RAS facilities, as opposed to shutting down their existing sea-based operations or moving them elsewhere.

The case of Justin Trudeau's recently proposed legislation in Canada exemplifies just how reliant a country's salmon farming industry is on the support of its current local governmental bodies. We do acknowledge, however, that the regulatory environments within Canada and Norway are quite different with respect to the legislative approach taken to safeguard wild fish stocks. The environmental sentiment in Canada may be different due to the country's relatively larger wild salmon fisheries industry (FAO, 2020b). In contrast with the near non-existence of this industry within Norway, Canada has a many-decades long history of capture salmon production in the country, though these catch volumes have been dwindling since the introduction of salmon aquaculture in Canada in the late 1980's (FAO, 2020b). Nevertheless, the case of recent developments in Canada's SFI shows that salmon farming companies may consider alternative production technologies an undesirable investment when faced with a near-future phase out of open net pen salmon farming. More preferable options considered by companies in this instance may be to move production activity or shut down local operations. In the context of the Norwegian SFI, the regulatory approach to alternative production technologies is different, but it may not be assured over a period of many years. In Norway, government incentives are offered in the form of development licenses to encourage the utilization of alternative production technologies to secure both environmental sustainability goals as well as future production volumes. In Canada, government disincentives are proposed to be enacted in an effort to force the industry's transition to alternative production technologies by forbidding open net pen salmon farming as an option. Thus, there is some reason to believe that the Norwegian SFI responds positively to governmental policy designed to advance the development of the industry through the implementation of alternative production technologies, but it may respond in a neutral or negative manner to the transition if financial incentives are removed, or if the switch is mandated due to a moratorium on open net pen production.

5 – Discussion

To start the discussion with a methodological judgment, the consideration of two unique types of data, namely, interviews with decision-makers and industry-specific news articles from IntraFish, evidently enriched our analysis and its resulting conclusions by adding both thematic breadth and depth. The interviews offered great breadth for answering the stated research question by facilitating an understanding of the Norwegian SFI from a strategic perspective, largely encompassing unpublished and confidential information. Consequently, these interviews with decision-makers allowed us to uncover the industry's broad strategic orientation which can, in this work's context, be seen as an analogy for the industry's development. Further, the application of GT was useful for associating findings with extant theories, which allowed us to elaborate upon identified categories and generate theoretically grounded conclusions about the Norwegian SFI. The news articles, on the other hand, turned out to be a valuable source which complemented our findings from the GT analysis and provided deeper and more detailed information and clues about the roles of alternative production technologies in the development of the Norwegian SFI. We deem that such detailed information could not be generated from interviews alone due to the natural human inability to express all knowledge in a short amount of time – especially when this knowledge is, in part, implicit. We find that industry insights generated from both data sources are predominantly congruent, to some extent complementary, and to a relatively small extent conflicting. The challenge that comes with discussing findings generated from two distinctively unique data sources is to concisely distinguish between congruent, complementary, and conflicting results. To overcome this challenge, we discuss our findings in a way that establishes an integrated theoretical framework about the roles of alternative production technologies in the development of the Norwegian SFI. This framework aims to acknowledge concepts with respect to their complex interrelationships across the data. Accordingly, results are presented holistically and mostly encompass congruent information from both data sources examined. Complementary findings are explicitly highlighted in the following paragraphs, while the few conflicting findings are omitted in order to avoid ambiguity of the inferred conclusions.

As briefly noted, the GT analysis transpired to be particularly useful for investigating the development of the Norwegian SFI. The first identified category delineated the reasons that limited production volume growth, uncertain future profitability, and perceived lack of ethical responsibility constitute the Norwegian SFI's central challenges. Interviews clearly underlined that the output-restricting effects of the TLS especially led to the challenge of the industry's limited production volume growth. Increased levels of salmon lice, on the other hand, were only cited by some interviewees. IntraFish articles augmented our findings in this regard by introducing the effects of algal bloom outbreaks and salmon escapements as two additional causes for the challenge of limited production volume growth. The second identified challenge, the Norwegian SFI's uncertain future profitability, is a unique finding from the interviews and highlights the embeddedness of Knight's (1921) definition of true uncertainty in the industry's development. Interviewees reasoned that this uncertainty was caused by the scenario in which the occurrence of an increasing number of foreign entrants to supply-side of the global SFI, employing alternative production technologies, leads to a deflated market price of Atlantic salmon. We infer that although the Norwegian SFI has, according to interviewees, experienced a track record of high profitability in recent years, true uncertainty about its future profitability shapes the industry's development and illustrates the industry's mindfulness about and sensitivity to changing environmental factors. Society's perception of the lack of ethical responsibility fulfilled by the Norwegian SFI, which was, according to decision-makers from the industry, mainly driven by high salmon mortality rates, was also mentioned as a challenge in the articles. Yet, the most highly-mentioned consumer concern in the articles was not represented by the mortality rates, but by the environmentally unsustainable use of salmon feed components including wild pelagic fish and soybean products. We conclude that all three stated challenges significantly affect the development of the Norwegian SFI, and the reasons for these challenges are largely represented by regulatory and biological limitations on the industry's production growth, uncertainty, and consumer pressures.

Exploring the Norwegian SFI's central challenges provided us with a solid foundation for further investigating the industry's development on the grounds of its strategic orientation. We discovered that the challenges of limited production volume growth and uncertain future profitability remarkably affect the Norwegian SFI's focalized strategic objective, which is to generate profitability improvements through exploiting currently-held competitive advantages. While the uncertain future profitability strengthens the industry's strategic orientation towards profitability improvements, the challenge of limited production volume growth prevents most Norwegian salmon farming companies from setting their main strategic objective as increasing their production volumes.

Since decision-makers interpreted the limited production volume growth to be mainly caused by the TLS regulation, we emphasize that regulations may have a strong and long-lasting effect on the industry's development. This leads to the key insight that there seems to be a noteworthy contradiction between the ambitious governmental goal of annually supplying the global market with five million tonnes of Norwegian-raised salmon and trout, and the effects of governmental regulations on the industry's development (Olafsen et al., 2012). In other words, while the government aims to foster production volume growth, it is primarily the TLS that prevents the industry from strategically adhering to this goal. We call for further elaborations in future academic works on this potentially latent conflict between stated governmental goals and instituted legislations, and especially on the question concerning whether the domestic governmental goal is compatible with the current regulatory landscape. We suggest that policymakers and politicians should consider the causal relationship between legislations and the strategic orientation of the industry, and assess measures that can both curb the industry's negative effects on the environment and incentivize production volume growth. Though development licenses provide an alternative avenue for generating growth in production volumes through the implementation of innovative and environmentally sustainable fish farming solutions, we found that these licenses were commonly seen as an economic vehicle for experimenting with such solutions rather than as an incentive to increase production volumes (Directorate of Fisheries, 2020e; Mowi, 2019).

Consulting Barney's (1991) resource-based view, we elaborated on how the industry pursues its focalized strategic objective of generating profitability improvements through exploiting currently-held competitive advantages. While interviewees listed cultivation of larger smolts, genetic alterations to broodstocks, and the more focused use of surveillance technologies as ways to optimize the profitability of open net pens, news articles confirmed this finding but offered more technical insights into how the industry seeks to pursue incremental process innovations to open net pen technology, for example, by retrofitting additional systems onto open net pens in order to avert detrimental effects of algal blooms to farmed salmon stocks (Ireland et al., 2003). Only two news articles mentioned alternative production technologies in the context of improving profitability metrics through the mitigation of salmon lice – Mowi's Egg farm concept, as well as the company's Aquastorm system – which stresses the rather insignificant role that alternative production technologies play in reaching the industry's primary focalized objective.

To summarize, the Norwegian SFI's development is clearly characterized by its central challenges and its strategic orientation. Alternative production technologies play an influential role for the industry's strategic orientation by causing the central challenge of the industry's uncertain future profitability, leading to the focalized objective of generating profitability improvements. However, at the same time, alternative production technologies play a rather insignificant role in dealing with this challenge, as the Norwegian SFI primarily engages in incremental process innovations to facilitate profitability improvements within the prevailing production technology of open net pen farming. Land-based RAS systems used as complements to open net pen farming are utilized to pursue the secondary strategic objective of production volume growth, which is detailed in the following paragraph.

Both interviews and news articles corroborated that land-based RAS systems used as complements to production in open net pens are mainly employed within the Norwegian SFI to overcome production bottlenecks (Wallace, 2020). Additionally, news articles provided deeper clues about the industry by pointing out that the complementary use of land-based RAS systems is also employed to increase production output, not only by overcoming the production bottleneck caused by the TLS, but also by improving the company tier-related MAB utilization through the reduction of farmed salmon mortalities. Ultimately, we conclude that land-based RAS systems used as complements play a rather isolated role in the industry's development, as they are merely employed to achieve the secondary strategic objective of production volume growth. Interestingly, we discovered that the Norwegian SFI's main motivation behind this form of technological diversification does not coincide with the general assumption which holds that diversification efforts are intended to pursue profitability improvements (Cantwell et al., 2004; Silverman, 2002). Quite the contrary, the common industry practice of technological diversification through the utilization of capital-intensive land-based RAS systems used as an intermediate step to open net pen farming is likely to lead to decreased profit margins per kilogram of farmed salmon.

Posing a limitation to our analysis, it remained open to which extent and why the industry is inclined to trade some of its profitability for production volume. Though we hypothesize that the application of land-based RAS systems used as complements offers option value, we wonder if there are other motivations behind this consistent practice of technological diversification in the Norwegian SFI, and suggest further studies in this specific regard. Such studies could expand upon the extent to which this practice is employed and illuminate the reasons for why this practice is pursued by companies in the industry. However, we also want to stress that, as of the time of writing, Bjørndal and Tusvik's (2017) economic analysis of land-based RAS systems dates three years back and that major performance improvements to these systems could have been achieved since the period that data for the authors' analysis was collected. The pace of performance improvements to alternative production technologies might be erratic and difficult to estimate. Additionally, salmon farming companies and their suppliers might have competitive reasons to conceal cost-related data. Therefore, future studies on the extent of and reasons for technological diversification in the Norwegian SFI may either be dependent on the salmon farmers' and their suppliers' willingness to share cost-related data and generate economic analyses that may quickly become outdated, or they may illuminate such reasons from a more strategic point of view, which may ultimately provide valuable and novel insights to the research domain of corporate diversification.

Interviews and news articles uniformly clarified that Norwegian salmon farmers distinguish between land-based RAS systems used as complements and substitutes. While our findings show that there is little skepticism about overcoming production bottlenecks and enhancing company tier-related MAB utilization by means of the complementary use of these systems, they also unveil the uncertainty created by new industry entrants that employ these systems as full grow-out solutions. We used Schumpeter's (1911) notion of creative destruction to emphasize the detrimental consequences that major technological innovations can have on an industry. Furthermore, the theory of technological discontinuities facilitated our understanding of why land-based RAS systems used as substitutes might have been interpreted as a threat by the Norwegian SFI (Tushman & Anderson, 1986). We recognized that while the industry is heavily inclined to foster incremental change in order to make open net pen systems more cost-efficient, the emergence of new industry entrants, utilizing land-based RAS systems as full grow-out solutions, affects the industry's perception in the same way that technological discontinuities do. That is, the competence-destroying and potentially disruptive nature of land-based RAS systems used as substitutes causes an increased perceived uncertainty about the Norwegian SFI's future competitiveness on a global scale. The competence-destroying nature of land-based RAS systems for the production of fully-grown salmon was further detailed in the articles, which illustrated that such systems may not only necessitate novel technological competencies for this alternative production technology, but also new developments in input factors such as salmon feed. Furthermore, the articles vividly highlighted the dominant global trend that an increasing number of countries seek to establish food security by producing their own salmon domestically. Consequently, land-based RAS systems used as substitutes do not only constitute a technological challenge, but their use by new industry entrants from other countries, which can very plausibly become cost competitive over time, may have led to the general perception that these systems pose a threat to the Norwegian SFI's future competitiveness on a global scale.

However, we also found that the industry does not simply ignore the potential disruptiveness of land-based RAS systems used as substitutes, but rather acknowledges their future performance potentials and takes measures to remain competitive. As mentioned, the primary measure taken by the Norwegian SFI is to create cost improvements to existing operations. In addition, real options and the industry's culturally embedded willingness to cooperate provide Norwegian salmon farmers with great flexibility to adapt to changing relative performance levels of alternative production technologies. We deem that the implementation of complementary land-based RAS systems for the cultivation of larger post-smolts constitutes a first step in building necessary technological competencies which provide option value in the case that an alternative production technology eventually reaches technological and economic maturity. Though these alternative production technologies still seem to be going through the era of technological ferment, making difficult the prediction of which alternative production technology may become the industry's dominant design, the potential disruptiveness and the occurrence of new industry participants encourage the Norwegian SFI to favor R&D efforts into land-based RAS systems. Furthermore, the existing knowledge created through the use of land-based RAS systems as complements affects the absorptive capacity of Norwegian salmon farming companies, steering the industry's R&D efforts towards land-based RAS systems.

We have reason to believe that semi-closed containment systems play a less significant role in the development of the Norwegian SFI, as only one interviewee stated that their company aims to experiment with these systems due to their compatibility with existing infrastructural resources. The lowest performance expectations were attributed to offshore farming due to the fact that, generally, the industry has not built up the necessary technological competencies for this technology's implementation, nor does the technology build on existing infrastructural resources within the industry. Articles corroborated this finding, as land-based RAS salmon farming was identified as a substantial and independent topic, whereas semi-closed containment systems and offshore salmon farming remained largely unaddressed in practice, throughout the five topics which were most relevant in depicting the role of alternative production technologies in the Norwegian SFI's development.

To conclude, alternative production technologies significantly shape the Norwegian SFI's central challenge of its uncertain future profitability. Yet, the industry's overarching answer to this challenge is to pursue profitability improvements by aiming for cost reductions to the prevailing salmon farming technology of open net pens. The use of land-based RAS systems as complements is mainly utilized for the achievement of the secondary strategic objective of production volume growth, indicating the rather isolated role of the application of these systems within the domestic industry. Generally, experimentation with land-based RAS systems used as substitutes, semi-closed containment systems, and offshore farming infrastructures represents a secondary method for dealing with the challenge of the Norwegian SFI's uncertain future profitability. Though a dominant design for these technologies has not emerged within the domestic industry, Norwegian salmon farmers seek to experiment with these technologies on the grounds of two reasons. First, these technologies could become technologically and economically feasible in the future and offer new avenues for cost-competitive production. Second, articles indicated that building technological know-how early on strengthens the Norwegian SFI's technological competitiveness on a global scale, potentially providing the opportunity for the industry to incur future economic benefits by advising countries which are newer to salmon farming.

Though this was not explicitly mentioned in interviews or news articles, we hypothesize that, in a globalized world, newly created competencies for alternative production technologies could also allow Norwegian salmon farmers to expand their operations to other countries that do not have a natural landscape conducive to salmon farming, and thereby preempt the emergence of new industry entrants in these countries. The case of the development of Canada's SFI, which manifested itself as an independent topic in our documentary research, shows that some companies operating within the Norwegian SFI already engage in salmon farming activities in other countries, further underscoring the global opportunities that might arise from a strong knowledge base in alternative production technologies. But again, experimentation constitutes a rather peripheral phenomenon in the Norwegian SFI, and a dominant design has not emerged, which is also substantiated by the case of the development within Canada's SFI. Though Canada's and Norway's regulatory strategies differ, articles dealing with the Canadian SFI revealed that salmon farmers may choose to shut down or move local operations when faced with a near-future phase out of open net pen farming, rather than to invest into the construction of alternative methods of salmon production.

We recommend the Norwegian SFI to closely track global governmental developments aimed to both minimize the reliance of foreign countries on food imports, as well as foster these countries' own, local harvest volumes of salmon. We deem that, especially in light of current protectionist movements in politics across the world, such governmental strategies could negatively affect the Norwegian SFI's ability to leverage its technological competencies by constructing Atlantic salmon farms based on alternative production technologies, such as land-based RAS facilities, in foreign countries.

6 – Conclusion

This work's first research objective, as stated in the introduction, aimed to establish a comprehensive understanding of the current state of the Norwegian SFI, which was accomplished in chapter 2. To fulfill this research objective, we outlined the complexity of cultivating Atlantic salmon, thereby highlighting the main environmental challenges facing the Norwegian SFI. More specifically, we found that the negative production externalities of salmon escapements and anthropogenically increased levels of salmon lice caused by salmon farming operations represent the industry's most central environmental challenges, which domestic regulations seek to minimize. Though various global megatrends predict a strong increase in the global demand for Atlantic salmon, the Norwegian SFI clearly struggles to increase its production volume for two primary reasons. First, domestic regulations attempt to mitigate the environmental impact of industry operations, and second, biological challenges constrain salmon farmers' abilities to fully optimize the company tier-related MAB they already hold licenses for. We identified two options for Norwegian salmon farmers to overcome the restrictions on future production volume growth: to either improve upon current production practices within the highly-used open net pen farms, or to look to non-conventional methods of salmon production using alternative production technologies, which offer a viable opportunity to minimize the industry's negative effects on the environment.

While the methods to improve upon current production practices turned out to be a well-researched topic, we found that the second option constitutes a research gap within the literature on aquaculture, especially when considering the roles of alternative production technologies in practice. To our knowledge, there is no current literature which assesses, from the industry's own perspective, the Norwegian SFI's incorporation of alternative production technologies into existing operations. Hence, our second research objective was explicitly intended to answer the stated research question by analyzing proxy indicators for the Norwegian SFI, in the form of interviews with industry representatives and recent industry news articles, to determine the roles of alternative production technologies in the industry's development. We commenced our empirical analysis by elucidating the Norwegian SFI's development and confirmed that the industry faces the challenge of limited production volume growth. Furthermore, we identified two other central challenges in the industry, namely, the Norwegian SFI's uncertain future profitability and the perceived lack of the industry's ethical responsibility in society.

The Norwegian SFI's uncertain future profitability brought to light the first role that alternative production technologies play in the development of the Norwegian SFI. That is, potential new industry entrants from other countries, utilizing alternative production technologies and thereby increasing the global supply of Atlantic salmon, induced decision-makers from the SFI to question the stability of the advantageous current market price for salmon in the long run. The focalized industry-wide answer to this challenge was to facilitate cost reductions within open net pen farming operations. Consequently, the use of alternative production technologies by new industry entrants from other countries steered the Norwegian SFI's development towards the generation of profitability improvements to existing open net pen farming operations.

Concerning the implementation of alternative production technologies in the Norwegian SFI, we uncovered two different applications of land-based RAS systems. First, Norwegian salmon farmers employ land-based RAS systems as complements to the traditional production process, thereby raising larger post-smolts to overcome production bottlenecks induced by the TLS regulation and to optimize the farmers' existing licensed MAB utilizations. Second, RAS systems used as substitutes for open net pen farming are considered a threat to the Norwegian SFI, as countries without waters historically used for salmon farming may start producing their own salmon and be able to avoid the airfreight costs that constitute a substantial cost component in the traditional distribution of Atlantic salmon. Despite the potential disruptiveness caused by the threat of the Norwegian SFI's shrinking export markets, the industry commits to profound R&D activities in order to experiment using alternative production technologies. Though, as of the time of writing, alternative production technologies have not reached technological and economic maturity, the Norwegian SFI is well aware of the fact that these technologies could one day provide a fruitful avenue for curbing its negative production externalities, thereby allowing for growth in production outputs. The Norwegian SFI predominantly attributes the most promising performance expectations to the alternative production technology of land-based RAS systems used as substitutes for open net pen farming. Semi-closed containment systems and offshore salmon farming infrastructure play a relatively insignificant role due to the technologies' incompatibility with the Norwegian SFI's commonly shared knowledge base and existing infrastructural resources.

Ultimately, we conclude that the Norwegian SFI is an industry that is faced by substantial technological upheaval. It is not possible to precisely predict which alternative production technologies will reach technological and economic maturity in the future. Despite the fact that the Norwegian SFI is largely concerned with optimizing its traditional production method, the industry-wide practice to experiment with alternative production technologies, as well as a willingness to participate in coopetition, give it a decisive competitive edge on a global scale. In case that an alternative technological regime becomes technologically and economically feasible, the technological competencies built during the experimentation with these regimes, as well as the industry's innate openness to share knowledge, which is reinforced by the development licenses' requirement that details about approved projects be made public, facilitate a quick adaptation to new circumstances.

It is of note that the chosen time horizon of this work and its external validity constitute the two major limitations of our study. In regards to the time horizon, major technological breakthroughs in the future might alter the Norwegian SFI's attitude towards alternative production technologies and, thus, change both the roles of these technologies as well as the industry's strategic orientation. This work presents a snapshot in time of the Norwegian SFI, which will hopefully continue to experience a fruitful development in future years. We suggest further, longitudinal studies about technological developments in the Norwegian SFI. Thus, this may contribute to the research field of technological change and may give a clearer account for how technological change, through the three phases of technological discontinuity, era of ferment, and incremental change, takes place in practice. Concerning this study's external validity, we note that the examined phenomena are specifically applicable to the case of the Norwegian SFI. Consequently, practical findings cannot simply be transferred to other industries, settings, or periods of time. However, by consulting some fundamental managerial and economic theories, insights generated in this work might be of high value for some of these research domains. For example, we complemented the theory of absorptive capacity by showing that absorptive capacity may not only be influenced by a firm's existing knowledge base, but also by the infrastructural resources it possesses. Furthermore, coopetition in the Norwegian SFI is incentivized by development licenses, indicating that regulatory frameworks can effectively encourage cooperation for R&D activities in an industry. We believe that the Norwegian SFI poses a uniquely interesting case for future studies, dealing with the benefits and downsides of coopetition, as it remained open whether the cooperation in the industry induced by regulations leads to win-win scenarios for all parties involved. Finally, development licenses incentivize experimentation with alternative production technologies in the Norwegian SFI. Future works could contribute to the understanding of how governments can foster innovation in an industry and elaborate whether development licenses in the case of the Norwegian SFI lead to advantageous competitive outcomes.

Ultimately, we hope to encounter more empirical and applied studies in the future on the complex, yet fascinating topic of technological development in the Norwegian SFI. To compare the Norwegian SFI's recently-stagnant production volume growth with a metaphor from the finance world, we understand that trees do not grow to the sky, but we nevertheless remain curious about whether the seedlings of alternative production technologies will be able to contribute to another era of steep growth in the industry's production output.

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Appendices

Appendix A

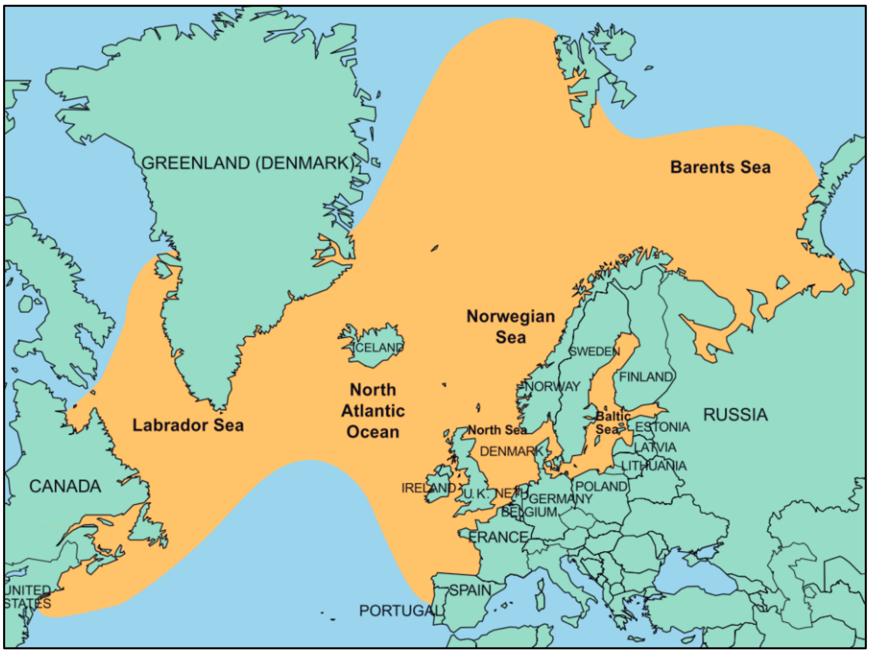


Figure A1. Geographical aquatic distribution of the Atlantic salmon

Note. Adopted from *Atlantic Salmon Ecology*, by Aas et al., 2010.

Appendix B

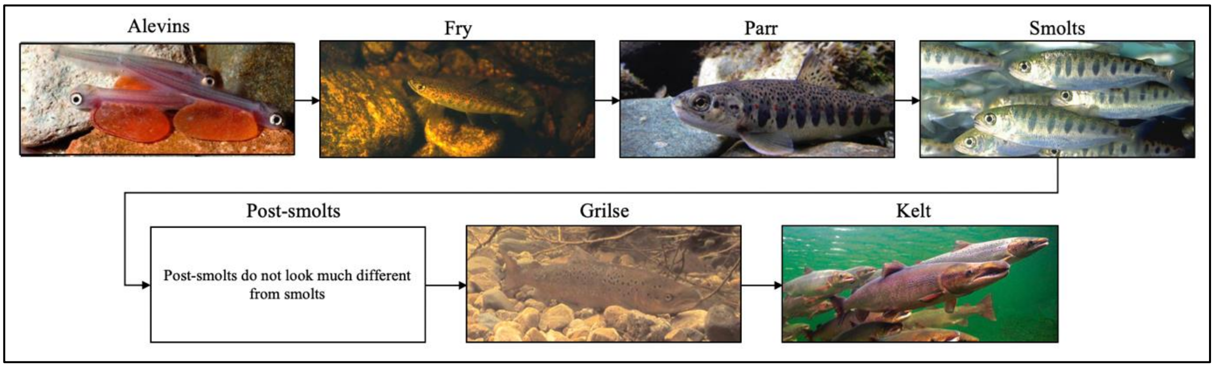


Figure B1. Photographs of Atlantic salmon in their different stages of life
Note. Adapted from "Ecology of Atlantic salmon," by Hendry and Cragg-Hine, 2003.

Appendix C

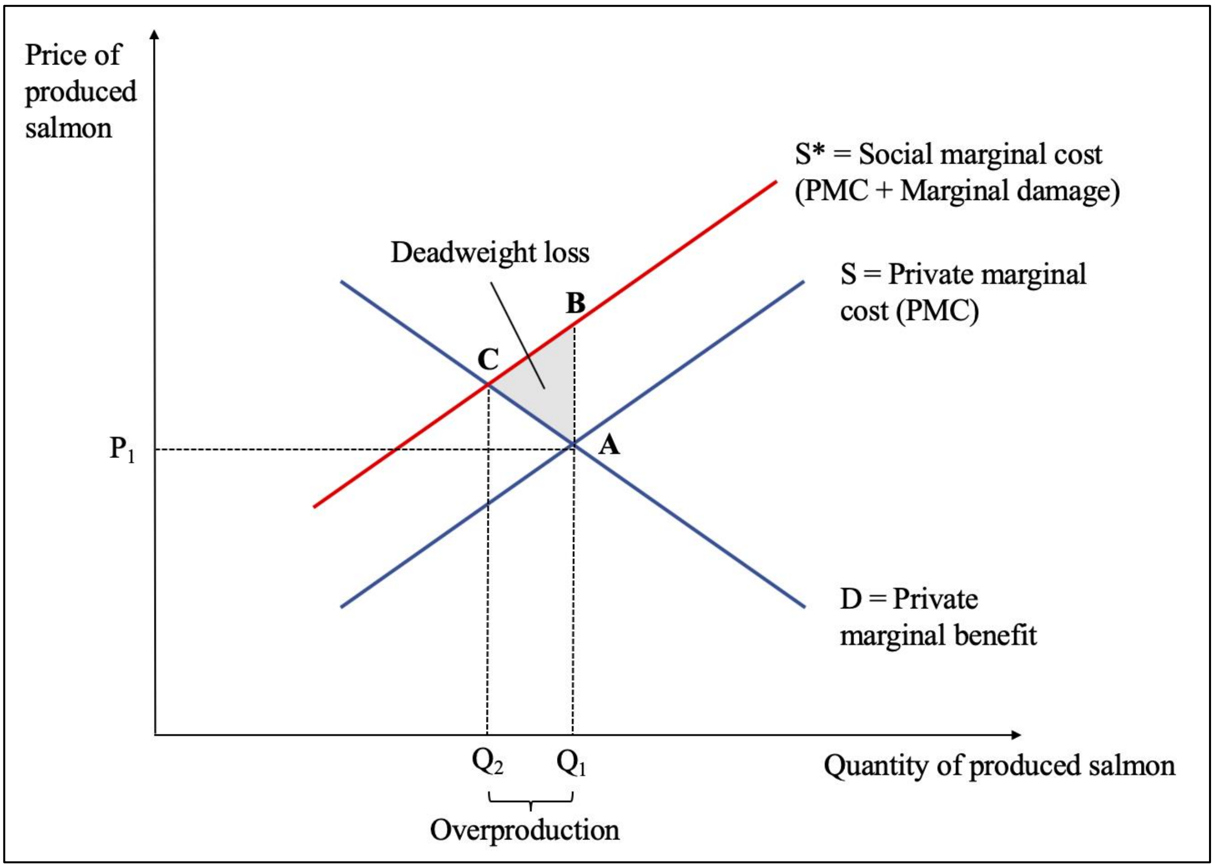


Figure C1. Overproduction caused by the disregard for marginal environmental damage

Note. Social marginal cost represents PMC and external cost of pollution caused by negative production externalities. Adapted from *Externalities: Problems and Solutions*, by Saez, 2020.

Appendix D

Year:	1981	1991	1996	2001 and onwards
Event:	First permanent aquaculture laws	Market crisis: the turning point of the industry	Slowdown of the market liberalization	The era of re-institutionalization
Objectives:	In the late 1960s, the SFI was just in its piloting stage. In 1973, the first *Aquaculture Act* introduced a permission system. Most applicants were granted licenses. In 1981, the second *Aquaculture Act* was more limiting: • Maintaining a small-scale, owner-operated industry structure • Generating employment in rural districts • Controlling influence on the local environment • Ensuring profitability	Due to major financial distress, caused by magnified disease problems and falling prices and profit margins, many farming companies faced bankruptcy. The government replied to the financial crisis by major liberalization of the regulation regime: • Abolishing ownership regulations • Allowing firms to merge and combine licenses • Favoring ownership concentration instead of a relatively even distribution of aquaculture farms	As the Norwegian SFI's main market, the EU, accused the industry of price dumping, a feed quota was implemented: • Limiting production and restricting the industry growth • Prohibiting subsidies in the Norwegian SFI	In 2001, the industry started moving towards a new regulatory regime. The aim was to depoliticize the industrial regulation: • Concentrating on innovative potential in the license allocation process • Dividing the coast up into seven regions and focusing on negative environmental externalities • Implementing a new control system, called *Traffic Light System*

Figure D1. Overview of the historical development of the regulatory regime of the Norwegian aquaculture industry

Note. Adapted from "Land based farming of salmon: economic analysis," by Bjørndal & Tusvik, 2017, and "Political regulation and radical institutional change: The case of aquaculture in Norway," by Aarset and Jakobsen, 2009.

Appendix E

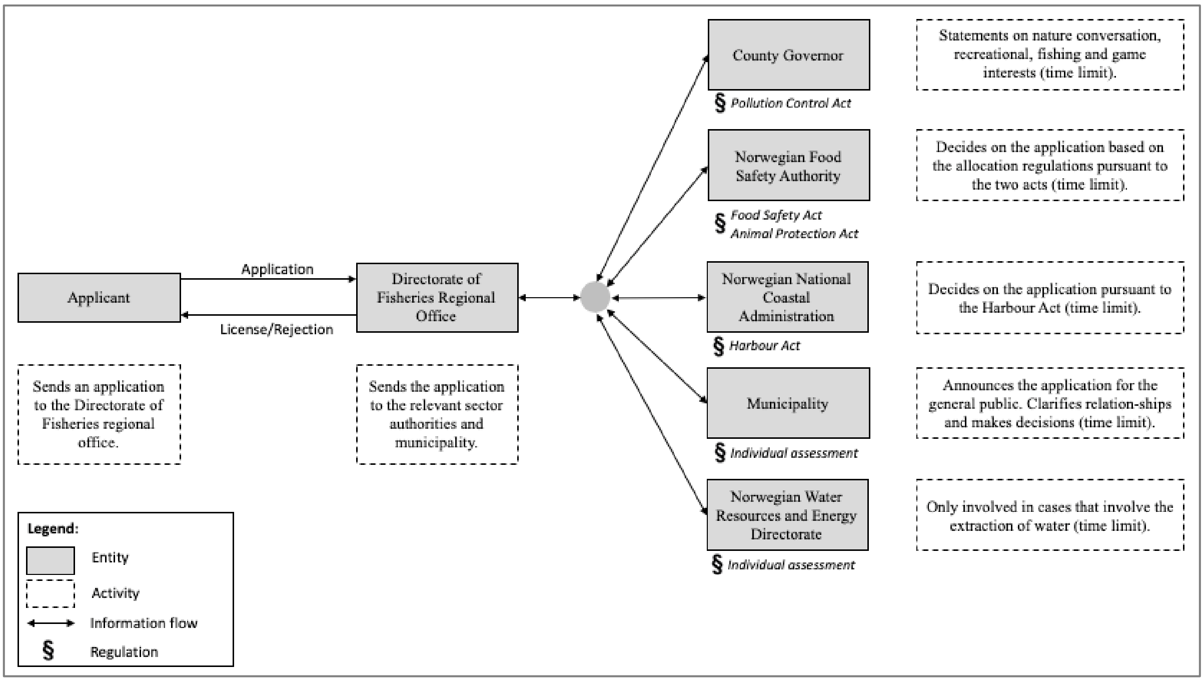
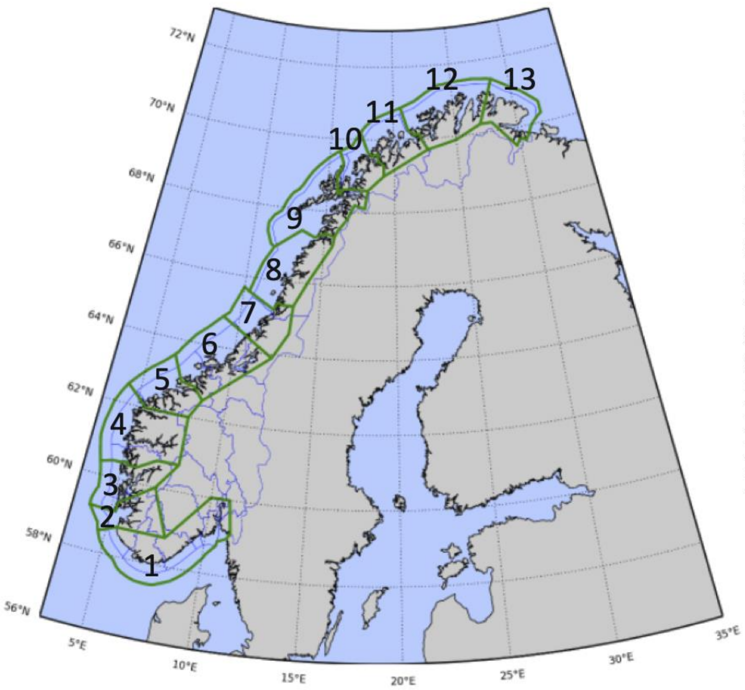


Figure E1. Process flow for aquaculture license applications

Note. Adapted from *The Aquaculture Act*, by the Norwegian Ministry of Fisheries and Coastal Affairs, 2005.

Appendix F



List of the production zones:

1. The Swedish border to Jæren
2. Ryfylke
3. Karmøy to Sotra
4. Nordhordaland to Stadt
5. Stadt to Hustadvika
6. Nordmøre to South-Trøndelag
7. North-Trøndelag to Bindal
8. Helgeland to Bodø
9. Vestfjord to Vesterålen
10. Andøya to Senja
11. Kvaløya to Loppa
12. West-Finmark
13. East-Finmark

Figure F1. The 13 production zones and their names according to the TLS

Note. Adapted from *Forskrift om produksjonsområder for akvakultur av matfisk i sjø av laks, ørret og regnbueørret,* by Lovdata, 2017.

Appendix G

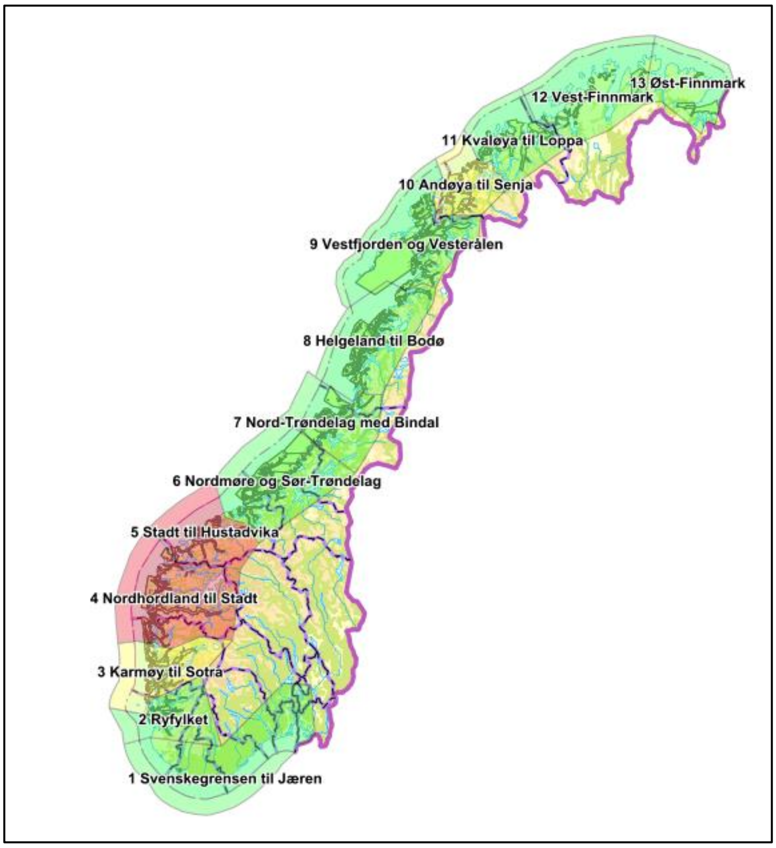


Figure G1. Production zones' environmental status according to the TLS per March 2020

Note. Adapted from *Marine protected areas*, by Directorate of Fisheries, 2020a.

Appendix H

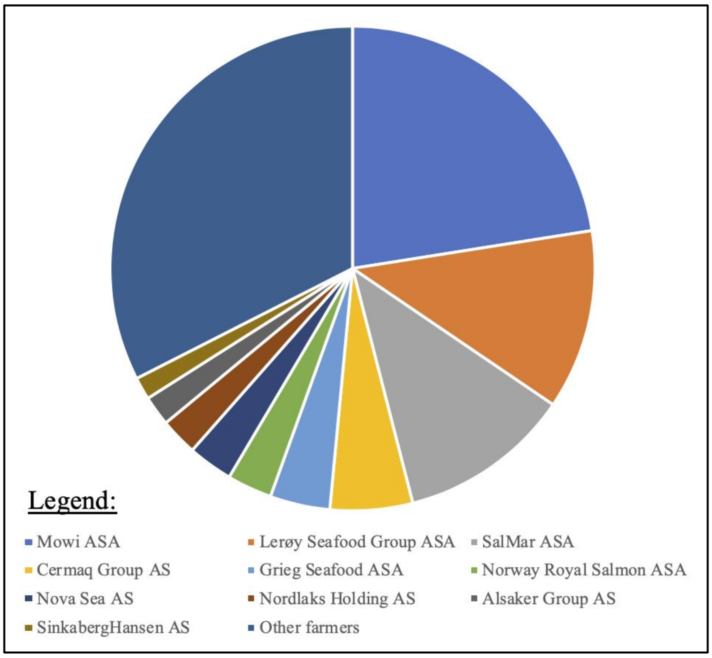


Figure H1. Distribution of Norwegian SFI's total production capacity in 2017

Note. Adapted from *Havbruk til havs - Ny teknologi - Nye områder, by* Ministry of Trade, Industry and Fisheries, 2018.

Table H1. Historical development of the 10 largest salmon farming companies' relative share of the industry's overall sales volume

Year	Relative share in percent
1996	18.9
1997	21.0
1998	24.1
1999	21.6
2000	32.8
2001	32.6
2002	33.4
2003	41.3
2004	41.2
2005	47.6
2006	48.4
2007	58.4
2008	63.9
2009	65.7
2010	64.5
2011	65.8
2012	69.1
2013	68.0
2014	69.9
2015	68.9
2016	67.9
2017	67.1
2018	67.3

Note. Adapted from *The percentage of sale for the 10 largest 1996-2018,* by Directorate of Fisheries, 2020d.

Appendix I

NHH

Norwegian School of Economics
Bergen, Spring 2020

Internal Interview Guideline - Internal

Interview Setting:

Date: February 17, 2020	**Time:** 09:30 – 11:00 a.m.
Interviewer: Vedad Taranin & Shelby Dennis (NHH)	**Interviewee:** Company Representative 1
Other attendants: None	**Interview number:** 1
Interview type: Company	**Communication channel:** Phone call

Introduction

- *We are master's students at NHH and are currently writing our thesis on the technological development of the Norwegian salmon farming industry*
- *We interview decision makers from Norwegian salmon farming companies in order to better understand what the current state of the industry is and what prompts companies to invest into certain alternative production technologies now and in the future*
- *The interview will last for approximately one hour*
- *The interviewee may refuse to answer any question and can end the interview at any time*
- *Results and personal data will be completely anonymized*
- *All personal data will be deleted upon completion of the thesis*
- *Any questions before we begin?*

Initial open-ended, warm-up questions:

1. Can you please tell us about your role at [company name]?
    a. Follow-up: Can you tell us more about your career path at [company name]? (if not already explained)
2. Can you describe what [company name] does?
    a. Follow-up: What makes [company name] distinct from other salmon farming companies?
3. Can you, from your perspective, describe the current state of the Norwegian salmon farming industry?
    a. Follow-up: How would you assess the current business climate? (if not already explained)
    b. Follow-up: Do you see any challenges? If yes, what would those challenges be? (if not already explained)

Intermediate questions:

4. How would you assess the business climate in the industry within the next five years?
5. What is [company name] strategy for the future?
    a. Follow-up: Does [company name] pursue a growth strategy? (if not already answered?)

1

Figure I1a. Internal interview guideline 1

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Bergen, Spring 2020

6. Given your prediction of the future environment, how do you think [company name] strategy will be achievable?
    a. Follow-up: Do you see any challenges? If yes, what would those challenges be? (if not already explained)
7. Can you tell us something about [company name] innovation activities regarding alternative farming technologies?
8. What was the initiator for [company name] to invest into alternative production technologies?
    a. Follow-up: If at all, how are [company name] R&D activities linked to its strategy for the future?
9. Based on which criteria did [company name] decide to invest into those technologies?
    a. Follow-up: Does [company name] use any public data sources to make its decision? Market data, industry predictions, etc.
    b. Follow-up: Why did [company name] not decide for offshore aquaculture as a practicable solution?
10. Can you think of future events that would change [company name] R&D activities?
    a. Follow-up: Which events would have to occur to expand investments into the current alternative production technologies?
    b. Follow-up: Which events would have to occur to decrease investments into the current alternative production technologies?
    c. Follow-up: Which events would have to occur to invest into other technologies?

Ending questions:

11. Is there anyone you can suggest who may be able to give us some insight into this subject? (from other companies)
12. Is there anything else you feel we haven't covered that may be important to know?

2

Figure I1b. Internal interview guideline 1

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Bergen, Spring 2020

Internal Interview Guideline - Internal

Interview Setting:	
Date: March 5, 2020	**Time:** 03:00 – 04:00 p.m.
Interviewer: Vedad Taranin &	
Shelby Dennis (NHH)	**Interviewee:** Company Representative 3
Other attendants: None	**Interview number:** 3
Interview type: Company	**Communication channel:** Personal meeting

Introduction

- *We are master's students at NHH and are currently writing our thesis on the technological development of the Norwegian salmon farming industry*
- *We interview decision makers from Norwegian salmon farming companies in order to better understand what the current state of the industry is and what prompts companies to invest into certain alternative production technologies now and in the future*
- *The interview will last for approximately one hour*
- *The interviewee may refuse to answer any question and can end the interview at any time*
- *Results and personal data will be completely anonymized*
- *All personal data will be deleted upon completion of the thesis*
- *Any questions before we begin?*

Initial open-ended, warm-up questions:

1. Can you please tell us about your role at [company name]?
   a. Follow-up: Can you tell us more about your career path at [company name]? (if not already explained)
2. Can you describe what [company name] does?
   a. Follow-up: What makes [company name] distinct from other salmon farming companies?

Intermediate questions:

3. Can you, from your perspective, describe the current state of the Norwegian salmon farming industry?
   a. Follow-up: How would you assess the current business climate? (if not already explained)
4. What is [company name] strategy for the future?
   a. Follow-up: Does [company name] pursue a growth strategy? (if not already answered?)
5. Given your prediction of the future environment, how do you think [company name] strategy will be achievable?
   a. Follow-up: Do you see any challenges? If yes, what would those challenges be? (if not already explained)

1

Figure I2a. Internal interview guideline 2

6. Can you tell us something about [company name] innovation activities regarding alternative farming technologies?
7. What was the purpose of investing into the alternative farming technologies?
8. How important is the current profitability of those technologies to [company name]?
9. Do you think that alternative farming technologies can improve [company name] competitiveness? If yes, how do you think does this happen?
    a. Follow-up: Does industry collaboration play a role in inventing and implementing alternative farming technologies?
10. What was the initiator for [company name] to invest into alternative production technologies?
    a. Follow-up: To what extent do you think those technologies can cope with the challenges you have described before? (if challenges were described)
11. Can you tell, based on which criteria [company name] decided to invest into those technologies?
    a. Follow-up: Does [company name] use any public data sources to make its decision? Market data, industry predictions, etc.
12. Can you think of future events that would change [company name] R&D activities?
    a. Follow-up: Which events would lead to financial expansion in the current alternative production technology?
    b. Follow-up: Which events would lead to financial retreat from the current alternative production technology?
    c. Follow-up: Which events would have to occur to invest into other technologies?

Ending questions:

13. Is there someone else you can think of who may be able to give us additional insight into this subject? (from other companies)
14. Is there anything else you think we have not covered that may be important to know?

Figure I2b. Internal interview guideline 2

NHH

Norwegian School of Economics
Bergen, Spring 2020

Internal Interview Guideline - Internal

Interview Setting:

Date: March 10, 2020	**Time:** 09:30 – 10:30 a.m.
Interviewer: Vedad Taranin & Shelby Dennis (NHH)	**Interviewee:** Company Representative 6
Other attendants: None	**Interview number:** 6
Interview type: Company	**Communication channel:** Phone call

Introduction

- *We are master's students at NHH and are currently writing our thesis on the technological development of the Norwegian salmon farming industry*
- *We interview decision makers from Norwegian salmon farming companies in order to better understand what the current state of the industry is and what prompts companies to invest into certain alternative production technologies now and in the future*
- *The interview will last for approximately one hour*
- *The interviewee may refuse to answer any question and can end the interview at any time*
- *Results and personal data will be completely anonymized*
- *All personal data will be deleted upon completion of the thesis*
- *Any questions before we begin?*

Initial open-ended, warm-up questions:

1. Can you please tell us about your role at [company name]?
    a. Follow-up: Can you tell us more about your career path at [company name]? (if not already explained)
2. Can you briefly describe what [company name] does?
    a. Follow-up: What makes [company name] distinct from other salmon farming companies?

Intermediate questions:

3. Can you, from your perspective, describe the current state of the salmon farming industry in Norway?
    a. Follow-up: How would you assess the current business climate? (if not already explained)
4. What is [company name] business strategy for the future?
    a. Follow-up: Does [company name] pursue a growth strategy? (if not already answered?)
5. Given your own assessment of the salmon farming industry's future, to what extent, do you think, can [company name] strategy be achievable?
    a. Follow-up: Do you see any challenges? If yes, what would those challenges be? (if not already explained)

1

Figure I3a. Internal interview guideline 3

Norwegian School of Economics
Bergen, Spring 2020

6. How does [company name] deal with those challenges in order to achieve the aforementioned strategy?
7. Can you tell us something about [company name] innovation activities regarding alternative farming technologies?
8. What do you think was the initiator for [company name] to invest into alternative production technologies?
    a. Follow-up: To what extent do you think those innovations can cope with the future challenges you have described before? (if challenges were described)
9. Can you tell, based on which criteria [company name] decided to invest into different alternative farming technologies?
    a. Follow-up: Does [company name] use any public data sources to make its decision? Market data, industry predictions, etc.
10. Why has [company name] decided to be a first or second mover with regards to alternative farming technologies?
11. How were these technologies accepted in your company?
    a. Follow-up: Were the involved decision makers open to adopting existing concepts for alternative production technologies?
12. What role does salmon farming related media (industry media) play in your company?
    a. Follow-up: What is your opinion about Intrafish?

Ending questions:

13. Is there someone else you can think of who may be able to give us additional insight into this subject? (from other companies)
14. Is there anything else you think we have not covered that may be important to know?

2

Figure I3b. Internal interview guideline 3

Appendix J

Norwegian School of Economics
Bergen, Spring 2020

Interview Guideline - External

Interview Setting:

Date: March 5, 2020	**Time:** 03:00 – 04:00 p.m.
Interviewers: Vedad Taranin & Shelby Dennis (NHH)	**Interviewee:** Company Representative 3
Other attendants: None	**Interview number:** 3
Interview type: Company	**Communication channel:** Personal meeting

1. Can you, from your perspective, describe the current state of the Norwegian salmon farming industry?
2. What is [company name] strategy for the future?
3. Given your prediction of the future environment, how do you think [company name] strategy will be achievable? Do you see challenges?
4. Can you tell us something about [company name] innovation activities regarding alternative farming technologies? Can those activities to some extent solve the aforementioned challenges?
5. What was the purpose of investing into the alternative farming technologies?
6. How important is the current profitability of those technologies?
7. What was the initiator for [company name] to invest into alternative production technologies?
8. Can you tell, based on which criteria [company name] decided to invest into those technologies?
9. Is there someone else you can think of who may be able to give us additional insight into this subject?
10. Is there anything else you think we have not covered that may be important to know?

1

Figure J1. External interview guideline

Appendix K

NHH

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Bergen, Spring 2020

Memo – February 24, 2020

Second interview with [company name]

We applied our learnings and conclusions from our last interview. More precisely, we managed to ask our questions in a more open manner which led to a freer and more natural conversation. The interview felt more like a casual conversation due to the openness of our questions. We believe that, by this approach, we succeeded to build more trust and rapport with the interviewee. Having in mind that we want to create a clearer picture about the interviewee's social world and not unconsciously generate answers that fit our own preconceptions, we adapted our interviewing style in a way that would let the interviewee speak and tried to avoid interruptions, where possible.

What was salient is that the interviewee divided the history of the salmon aquaculture industry in Norway into two parts. The first part, the past of the industry, was characterized by growth and a thriving business environment, while the other part, the current state of the SFI, was described as stagnating in terms of production output and as exhibiting impactful regulatory restrictions. The interviewee clearly saw a need for action through innovations and repeatedly voiced his/her positive attitude towards change. This pattern of seeing the growth restriction as major challenge for the industry and stating that increasing innovation activities has the potential to cope with this challenge was repeatedly mentioned and new to us since the first interviewee voiced different concerns and methods to deal with them.

Possible theoretical categories (in **bold**) for the future theory development:

Attitudes towards innovation:

1) The interviewee described innovations not only as a potential solution to the aforementioned challenge of growth restrictions in the SFI, but also as a threat. This goes in line with the theory of **innovative disruption.** This attitude towards innovation could also hint to different approaches for dealing with innovation: **Adoption vs. combat (open vs. closed mindset)**.

Innovations as real options:

2) As for the future, the interviewee mentioned that solving the sea lice problem and improving **operational excellence** should be a major concern of his/her company. This leads to the question whether innovations are just some sort of **plan B** or actually a major strategy in coping with the production constrains affecting the industry. In addition to that, the interviewee explicitly described how his/her company tries to optimize the existing/traditional open net pens technology and make it more efficient and competitive in the future.
    a. **Real options** are choices a company's management makes to expand, change, or curtail projects based on changing economic, technological, or market conditions. By that definition, farming innovations were repeatedly framed as **real options.**

1

Figure K1a. Example of a memo

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b. It seemed that financial growth (higher EBITDA margins by means of operational excellence) is of central importance (**Strategic goals**) whereas market growth was not described as being a central objective for the interviewee's company: **Financial growth vs. market growth.**
    i. This is an interesting observation. If it holds true in other interviews, in our theoretical model we could be able to show that financial growth/stability is more central compared to market growth. It was reasoned that there are still many possibilities to improve the existing/traditional technology of open net pens. This is highly contradictory to the government strategy for 2050. **Company vs. government strategy**.

Initiator for innovations:

3) Regulations (development licenses) were seen as the (external) **initiator** for investing into novel farming technologies. Further, development licenses are seen as the initiator of collaborating with start-up companies (**external scanning**).
    a. **Government-induced innovation / Incentive Policy**

Decision criteria:

4) Start-ups are acquired if:
    a. The team is convincing (**soft factors**)
    b. Strategic fit with the acquiring company
    c. Personal believe / experience / **intuition (intuition-based decision-making)**

Industry collaboration and knowledge transfer:

5) Innovations are adopted and internalized from start-ups and other collaboration approaches (networks e.g. with NCE and other national centers of expertise).
    a. **Open Innovation vs. not-invented-here syndrome** and **industry collaboration/knowledge transfer.**

First mover advantage / trial-and-error principle.

6) **First-mover vs. second-mover (Innovator vs. early adopter).** The interviewee mentioned that his or her company pursues to lead with regard to innovation. They do not take other salmon farming companies as sources of inspiration (**closed innovation**). First movers often are the ones that make use of the trial-and-error principle (**market pull vs. market push**).

2

Figure K1b. Example of a memo

Appendix L

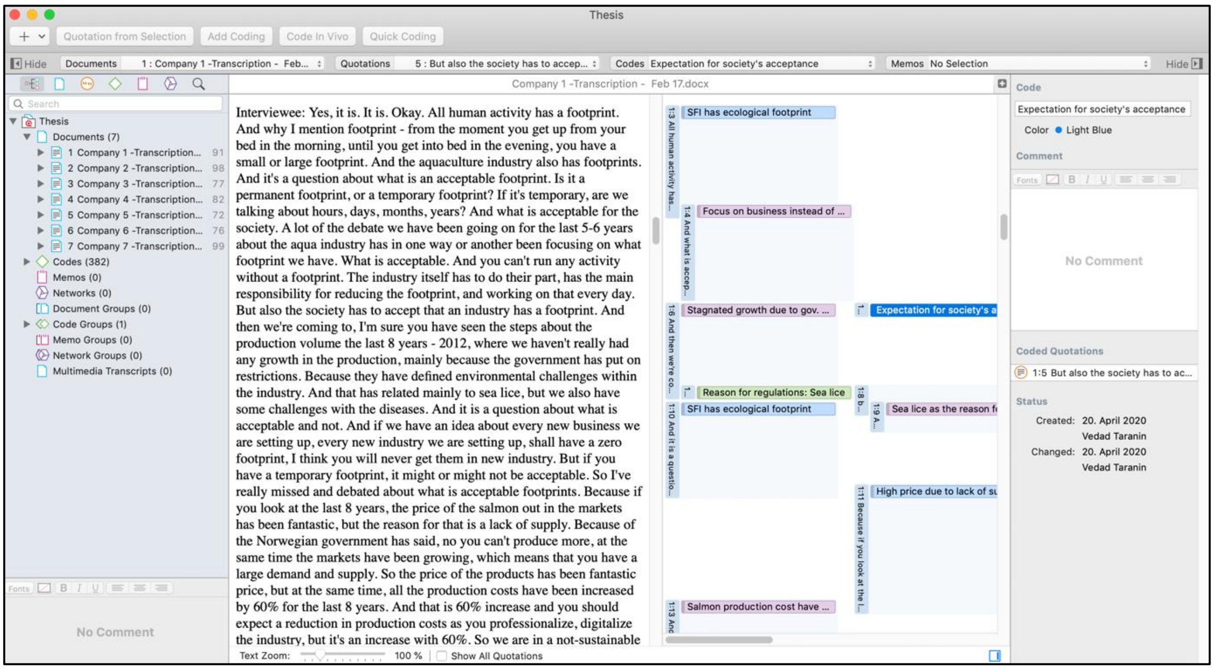

Figure L1. Representative screenshot of our use of Atlas.ti

Appendix M

Table M1. Implemented measures for ensuring reliability

Quality criterion	**Reliability** (also called *dependability* in qualitative research)
Definition	“Reliability refers to the replication and consistency. If a researcher is able to replicate an earlier research design and achieve the same findings, then that research would be seen as being reliable.” (Saunders et al., 2008, p. 202)
Implemented measures	To ensure the potential replication of this study, we put strong emphasis on the rigorous and transparent depiction of the two chosen research strategies and their practical application (GT and documentary research). This may aid the conduct of similar studies in the future. Additionally, there are four common threats to reliability in interview-based studies which we addressed throughout application of GT (Saunders et al., 2008). 1. Participant error (circumstances that can curb the participant’s performance): - Interviews were not conducted right before or after lunch breaks. - Interview participants were informed that they could cancel/postpone the interview at any time, for example in case they did not feel fit or ready for it. 2. Participant bias (circumstances that evoke incorrect answers): - Interviews were not conducted at places where no third parties could listen to the conversations inducing upright answers. - We repeatedly mentioned that the interviews will be anonymized and that it will not be possible for readers of our thesis to trace information back to the interviewee or his/her company. - We noted that there are no right or wrong answers since we sought to understand the industry from the participants’ perspectives/realities. 3. Researcher error (circumstances that can curb the researchers’ performance): - We only conducted an interview when we felt fit and rested enough for it. - The interview guidelines helped us to stay focused and remain a thematic linkage to our research objectives throughout the interviews. - Interviews were conducted in tandem, ensuring that both interviewers could assist each other (for example, by asking a follow-up question that the other interviewer had not thought of) 4. Researcher bias (circumstances provoking biases in the researchers’ recordings): - Instead of solely relying on written notes, which can tend to be highly inaccurate, we used a recording device that would ensure that all responses were recorded accurately. - GT prescribed to develop concepts just throughout the data collection and analysis process, which ensured that we did not begin interviews with already established concepts that we sought to validate/falsify. Instead, our approach to interviewing was open-minded and of naïve nature. - Interviews were conducted in tandem and, after each interview, we discussed our interpretations and created memos together. Fruitful discussions helped us to challenge our understandings and lead to more balanced and objective interpretations.

Table M2. Implemented measures for ensuring internal and external validity

Quality criterion	**Internal validity** (also called *credibility* in qualitative research)
Definition	"Emphasis is placed on ensuring that the representations of the research participants' socially constructed realities actually match what the participants intended." (Saunders et al., 2008, p. 206) This definition is applicable to interview-based research.
Implemented measures	- We consciously built trust by explicitly mentioning that all personal and company-related data would be anonymized in the thesis. This was intended to evoke trustworthy results that would credibly represent the interviewees' thoughts processes. - To entice interviewees to lead the conversations, rapport was established through active listening, note taking, and acknowledging statements by nodding and positive vocal feedback. - Follow-up and clarifying questions helped to ensure that our understanding of the interviewees' statements was accurate. - We applied a method called participant validation. Thereby, we sent all interview transcripts back to the respective interviewees and asked them to clarify, change, or delete statements that were not accurate from their point of view. This retrospective adjustment helped us to attain even more accurate representations of the interviewees' constructed realities (two interviewees had minor comments on the interview transcripts). - The use of Atlas.ti allowed us to remotely create and discuss codes together, despite of the current "Corona situation". The joint coding process and the discussions on codes and concepts helped us to reveal and eliminate preconceived assumptions and ensured that these assumptions were not privileged over the interviewees' constructed realities.
Quality criterion	**External validity** (also called *transferability* in qualitative research)
Definition	"By providing a full description of the research questions, design, context, findings and interpretations, the researcher provides the reader with the opportunity to judge the transferability of the study to another setting" (Saunders et al., 2008, p. 206)
Implemented measures	Arguably, with a sample size of seven for the conducted interviews, the transferability to other settings (for example industries, organizations, times, and situations) is limited. However, it should be noted that qualitative research is often not aimed at being transferred to other settings (Saunders et al., 2008). Instead and in line with our exploratory research purpose, we intend to derive first insights about the Norwegian SFI related to alternative farming technologies. These insights may be used for the generation of novel hypotheses or reveal potential room for improvement for salmon farmers and policymakers. To ensure that our thesis depicts the Norwegian SFI more accurately, we included another research strategy (documentary research), dealing with another source of data, which we believe leads to more representative results on an aggregate industry level.

Appendix N

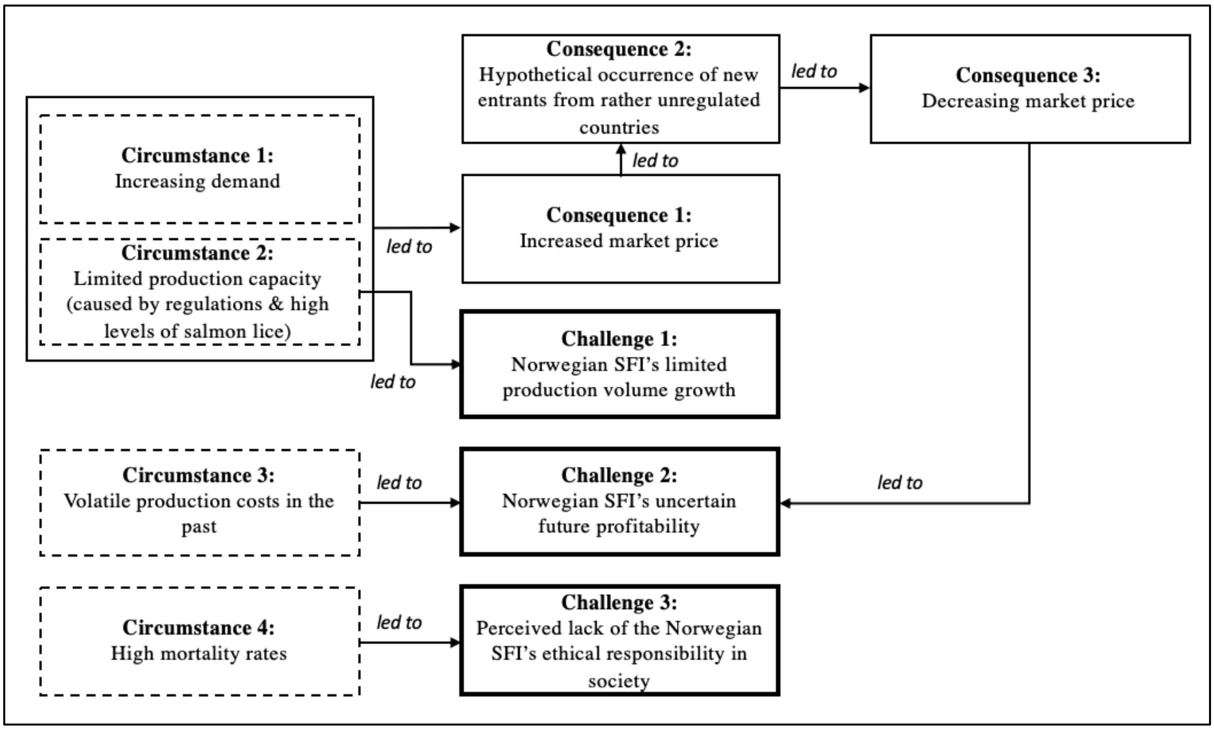

Figure N1. Categorical model 1 – The industry's central challenges

Appendix O

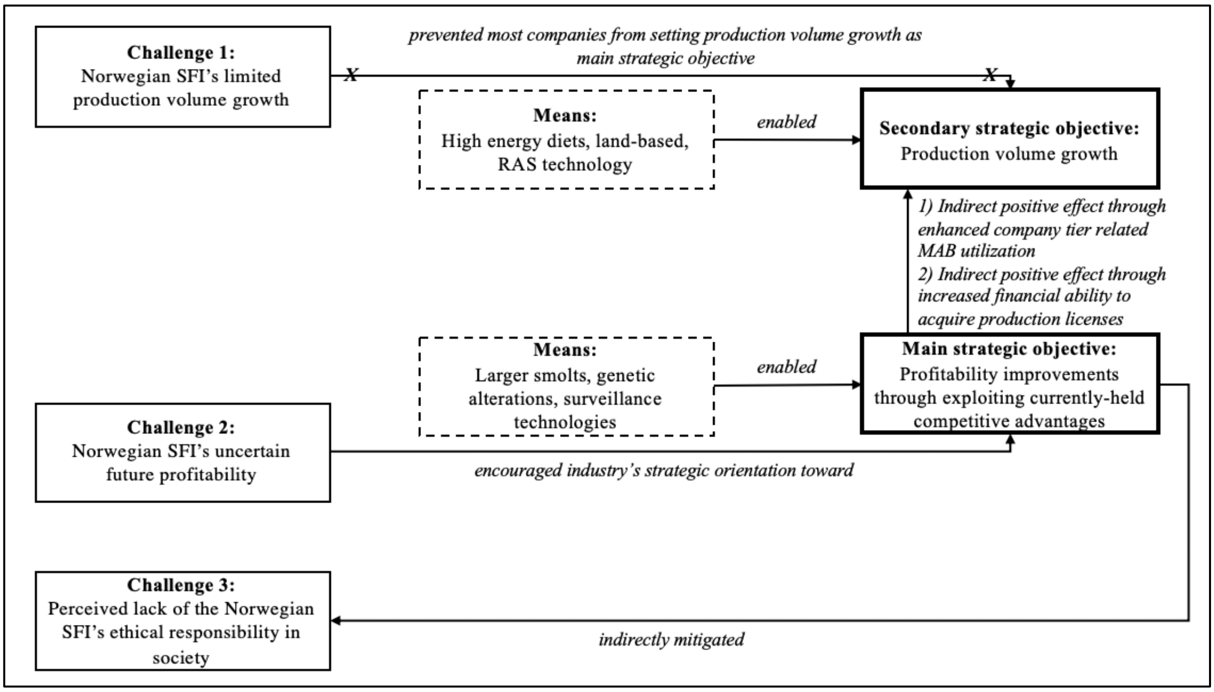

Figure O1. Categorical model 2 – The industry's strategic orientation

Appendix P

Figure P1. Wordcloud Topic 4

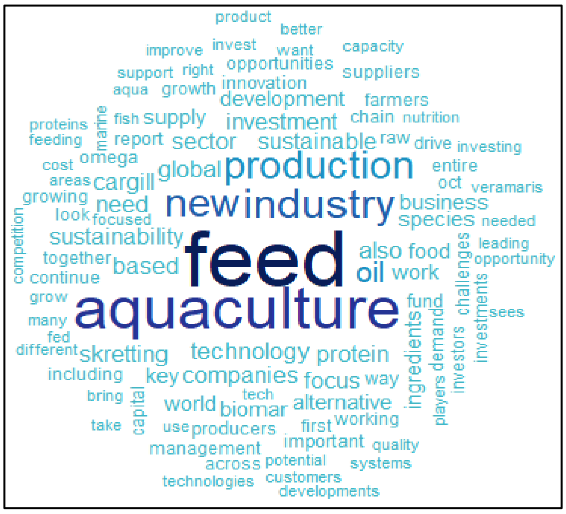

Figure P2. Wordcloud Topic 5

Figure P3. Wordcloud Topic 9

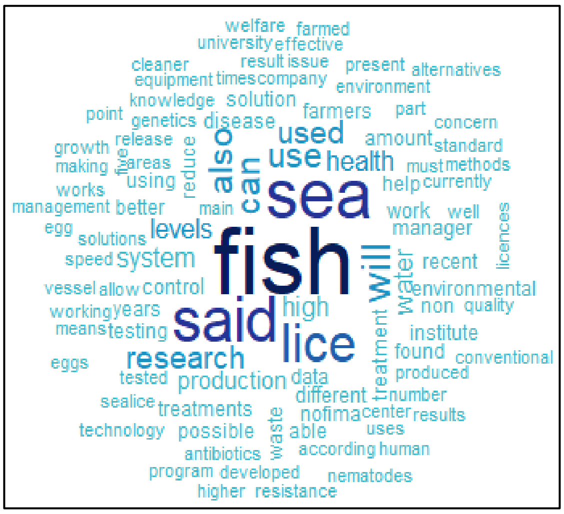

Figure P4. Wordcloud Topic 10

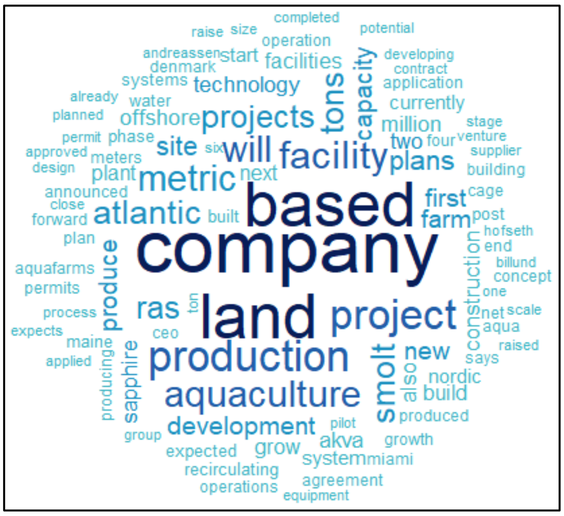

Figure P5. Wordcloud Topic 12