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The economic potential for closed cage fish farming and the total economic value of the wild salmon stock

A literature review

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Abstract
The aquaculture industry has been in rapid development in the last decades. Norwegian Atlantic salmon farming has proven to be an efficient and fast growing industry. Being able to develop and utilize open net-pens on the Norwegian coastline has been a key factor for the industry. However, the open net-pen technology are facing problems with external environmental effects. These environmental problems has caused the government to impose strict regulations on the industry, which limits growth. In an attempt to achieve sustainable growth new, green development permits have been introduced. Some of these development permits are intend to give incentives to the development of closed cage production technology.

The analysis will determine how much more closed-cage production can cost in private economic costs to have the same profitability as the open net-pen production, measured in NOK per kg salmon produced per year. In addition, the thesis estimates the total value of the wild salmon stock, which is one of the greatest values current regulation intends to preserve.

Findings suggest that the private economic potential for closed cage salmon farming is 8.33 to 9.11 NOK per produced kilo, caused by a reduced need for sea lice treatments and a potential price premium due to an environmental friendly production. However, the real profitability of closed-cage technology can only be revealed after big scale testing is completed. The total value of the wild salmon stock was estimated to be 2.86 billion. The total value incorporates use-value and non-use value such as the value of recreational fisheries and existence value of the wild salmon. The results implicates that there is a large economic disparity between the wild salmon stock and the value generated by the salmon farming industry.

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1 Introduction

Global fish consumption has increased steadily the last fifty years, from an apparent yearly average consumption per capita of 9.9 kg in 1960 to 19.2 kg in 2012 (FAO, 2014). A significant part of this growth has emerged from aquaculture, which accounted for 42.2 percent of food fish production in 2012. The growth rates of aquacultures has surpassed all other food industries and exceeded a 6 percent annual growth rate in the last decade (FAO, 2014). Wild fisheries are not expected to grow much further, since the majority of wild fisheries already are fully or overly exploited (FAO, 2014). Aquaculture is therefore essential for meeting the growing demand for fish products, a demand caused by population and income growth (International Food Policy Research Institute, 2015). In order to ensure a sufficient supply of fish and aquatic products the growth in aquaculture needs to continue. It is important that the development is sustainable both economically, environmentally and socially (FAO, 2014). Salmonids made up 4.2 percent of the total seafood supply in 2013 and a big share of this supply was farmed salmon. Compared with other farmed species salmon is one of the more industrialized (Marine Harvest, 2015).

Norway produced 1.2 million ton of Atlantic salmon, of the total 2.2 million tons produced globally in 2014 (Marine Harvest, 2015). Salmon farming in Norway is a relatively new and growing industry. There have been increasing export activity from the Norwegian coast in the last decade. In 2014, there was an export with a total worth of 42 billion kroners (NOK), which is about 4.2 percent of the total exports from Norway (Statistics Norway, 2015). Figure 1 illustrates the exported amount of salmon and its value from 1997 to 2014.

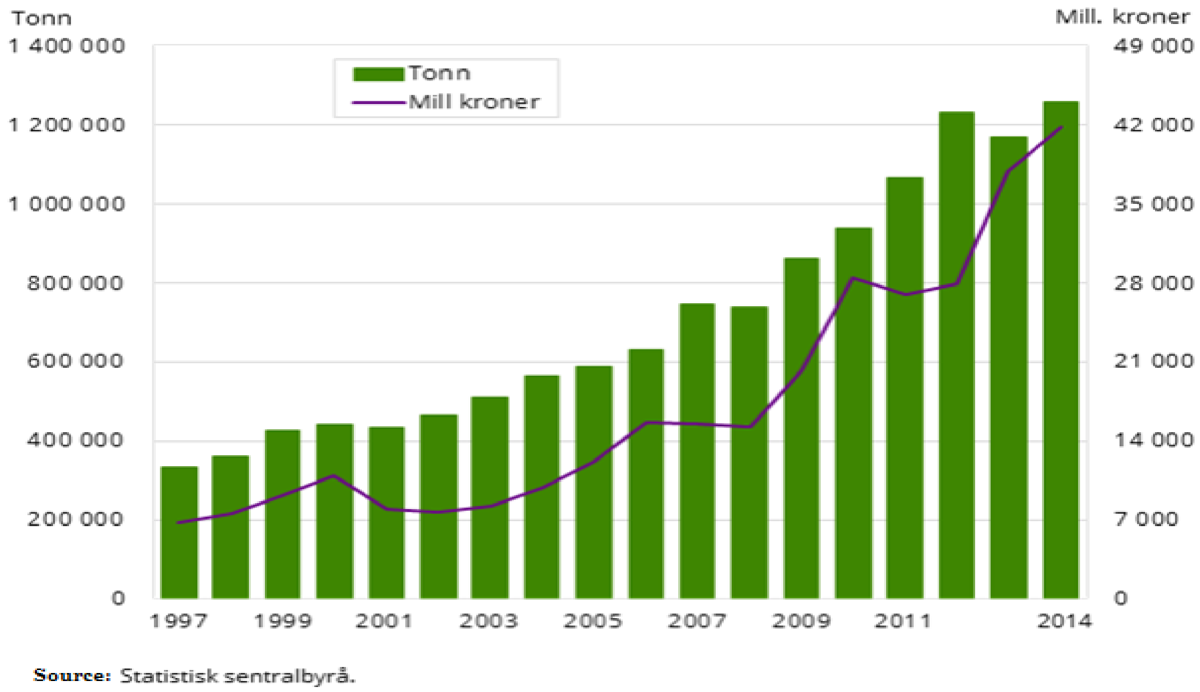

Figure 1. Annual sold quantity and export value of farmed salmon

The salmon farming industry in Norway is in rapid development and high economic growth rates are shown in the period between 1995 and 2012 when there was a remarkable average economic growth of 15.4 percent (Nærings- og Fiskeridepartementet, 2014-2015). Furthermore, future growth is predicted, with figures predicting potential for a fivefold increase in production from the year 2010 to 2050 (Det Kongelige Norske Videnskabers Selskab (DKNVS) and Norges Tekniske Vitenskapsakademi (NTVA), 2012). This is the equivalent of a 4.1 percent yearly growth. The growth target might be possible to reach. This is largely due to the natural comparative advantage given by the protected coastline in Norway, which offers suitable temperatures and streams for fish farming. Other advantages in the Norwegian industry is a cluster effect, where businesses, competence and institutions boost the efficiency of the market structure (Iversen, Andreassen, Hermansen, Larsen, & Terjesen, 2013; Teknologirådet, 2012). Aquaculture is expected to increase in relative importance for Norway, due to the reduction of oil and gas activity.

The salmon farming industry has problems with external environmental effects, for example sea lice and escaped farmed salmon. High sea-lice concentration, caused by salmon farming activity, can lead to higher mortality rates for wild fish stock like wild salmon and brown trout (Nærings- og Fiskeridepartementet, 2014-2015; Olaussen, Liu, & Skonhoft, 2015; Thorstad et al., 2015). Additionally, escaped farmed salmon may disrupt the wild salmon’s genepool by breeding with nearby wild salmon stocks (Liu, Olaussen, & Skonhoft, 2011; Norwegian Scientific Advisory Committee for Atlantic Salmon Management, 2015). This results in a halt of allocations of new permits to the industry, and strict regulation concerning sea-lice levels. (Nærings- og Fiskeridepartementet, 2014-2015). One counter measure to the environmental problems facing the industry is the introduction of new green development permits from the government. These green permits are meant to help develop new technologies that can reduce the negative impacts on the environment. The present thesis presents the economic possibility for one of these emerging technologies; the new closed cage production system. In addition, the thesis estimates the social-economic value of the wild salmon stock, which current regulation intends to preserve.

1.1 The Present Thesis

Given that closed-cage farming is still in its infancy, there are no known estimates of the production costs for this type of technology. While the production costs for closed-cage farming are likely to be higher than for traditional farming, this does not necessarily imply that it is less profitable. Some costs in traditional farming may be avoidable in closed-cage production, and there is a potential for a price premium for closed-cage produced salmon. To assess the potential for closed-cage farming this thesis determines how much more closed-cage production can cost and still be as profitable as the open net-pen production. The aim of this thesis is to systemize and analyze previous findings, with the purpose of revealing possible private economic savings and gains for closed cage production in the future, and to estimate the total economic value of the wild salmon stock in Norway.

In order to conduct this study, a reviewing of the theory regarding externalities and environmental valuation is required. Data are extracted from existing literature. The analysis will contain a quantification of national yearly private economic potential for closed cage aquaculture. This will be done by investigating the cost associated with sea lice treatments, and the possibility for a price premium achieved from an environmental friendly production. Furthermore, the total value of the wild salmon stock are estimated, by estimating its use-values and non-use values.

The main hypothesis of the study question if the closed cage technology have an economic advantage compared with net-pens technology caused by high sea-lice treatments cost and a potential price premium.

Furthermore, for our second hypothesis, the author asks if the value of the wild salmon stock and the possible welfare loss due to sea lice induced mortality is smaller, compared to the generated value by the salmon farming industry and the sea lice treatment cost.

2 Background

2.1 Production Methods in Norwegian Aquaculture

The most common production technique applied in the salmon farming industry is open net-pens, which typically is located in fjords. Open net-pens were introduced in the seventies and are still the dominant production method today. It has proven to be an easy and efficient way to produce salmon. The construct is a solid plastic or steel ring, with a net beneath it where the fish is contained. Generally, the cages have become bigger and more efficient throughout the years. For instance, the cage is 128 times bigger in modern production compared to the ones used in the 1970s (Teknologirådet, 2012). In addition, surveillance and automatic feeding systems have been introduced in production. The open net-pen technique is well developed and costs associated with it are low, compared to other production techniques. The construct takes advantage of natural occurring streams, securing a good and safe water quality. The physical requirements to install an open net-pen are small and cheap. Especially, plastic installation have a flexible quality that makes it durable to waves and weather restraints (Teknologirådet, 2012). However, this production technique does have problems with sea lice, escapes and sickness (Nærings- og Fiskeridepartementet, 2014-2015). The salmon farming industry is reliant on accessibility of new locations to be able to grow (Iversen et al., 2015). The external effects has resulted in strict regulations and a halt in new licenses allocations from the government (Liu et al., 2011; Nærings- og Fiskeridepartementet, 2014-2015; Teknologirådet, 2012). If a fivefold growth potential may be realized, the industry have to meet the environmental regulations set by the government. Closed cage production systems might contribute in realizing this future growth.

2.2 The Closed-Cage Production Method and Concepts

The closed cage is an alternative method to open net-pens. This construct has a physical barrier between the fish and the surrounding environments. Materials used in this method can be tarpaulin, fiberglass or polyethylene (Lekang, Salas-Bringas, & Bostock, 2016). The installation can be floating on the surface or be attached to the sea floor (Teknologirådet, 2012).There are several advantages of closed cages, for instance water can be pumped in from depths of 20 to 40 meters where parasites and sea-lice larva does not thrive. To avoid spread of pollutants the replaced water may be filtered, which reduces the installation impacts on its surroundings. Additionally, it is possible to collect organic materials from the production, which otherwise would be released into the environment. Closed cages may also have a higher security against escapes due to the physical barrier between the fish and the surroundings. Lower cost may be achieved through better feed-ration and lower dissipate (Teknologirådet, 2012). One possible shortcoming of the closed cage technology may be potential system failures and outage of the pumps system. These problems will be devastating for the fish's health, subsequently making backup systems essential to prevent such events place to prevent such events. In addition, the initial investment cost and the need for electricity or fuel to run the pump system might affect its economic viability (Teknologirådet, 2012).

There are several possible degrees of closure of closed cages. The classifications of these degrees of closure are divided into four levels. Level one consists of a simple barrier between the fish and the environment. Depending on the intensity of the water exchange, it is possible to add oxygen and remove C02, if necessary. The second level has the same qualities as level one, in addition to a doubled escape security, filtration of sea lice larvae and other particles like excess feed and feces. Level three has all the qualities of the second level and besides removal of microorganisms like bacteria and viruses from the inlet. Lastly, level four contain all qualities that the previous levels contain, as well as a biological water treatment that minimize water use and to remove other organic organisms. The technology applied is from Recirculating Aquaculture Systems -technology (RAS). Water usages is the key factor, the less water one uses the more considerations and measures are necessary (Asche, Hansen, Tveteras, & Tveterås, 2009; Teknologirådet, 2012).

There are many different closed cage concepts that are currently in development by different industry actors, which can be defined under the generic term closed sea cage. These actors have invested significant sums of capital to develop closed cages systems. Among others, Marine Harvest have intentions to develop large egg-formed systems. The investment made by Marine Harvest is approximately 600 million NOK and large-scale testing is expected to start in 2018 (Lilleby, 2016). The firm AkvaDesign started to develop a floating closed-cage system in 2011, and they will complete their first big-scale test in 2017. The preliminary testing has shown promising results. Indeed, in a pilot project AkvaDesign produced a total of 200 tons salmon which had high quality, low levels of lice and 99 percent survival rate (Aadland, 2015a). Aqua Farm Equipment has developed a floating closed-cage system with a volume at 21 000 square meters. However, due to sickness in the facility the first test failed, which resulted in slaughter of the salmon. Late in 2015, it was decided by Aqua Farm Equipment to produce mega-smolt, larger and older smolt than regular smolt, in a new and improved cage. Furthermore, Aqua Dome is a floating closed-cage system developed by MSC Aqua AS. Unfortunately, the facility was destroyed during a storm. They decided to rebuild a new Dome, but results from this project are not ready jet (Aadland, 2015b). There are also other projects in progress like Lerøy and Preline Fishfarming Systems closed tubs system, which is intended to simulate a river. FLO Marine has a floating concrete facility which may be powered by wave technology in the future (Aadland, 2015b; Teknologirådet, 2012).

There are special requirements for developing permits. Firstly, the developing permit must contribute in innovation of new technologies that involves significant investment sums. Secondly, it should also differ from former knowledge and experiences that have previously been acquired in the salmon farming industry. Thirdly, the experiences acquired from this work should be shared with the rest of the industry (Ellefsen, 2015).

As of June 6 2016, the Norwegian fishery department is currently processing 25 applications for different development permits and 12 of these permits are for closed-cage production, the applicants for closed cage developing permits are shown in Table 1.

Table 1

Current applications for close-cage development permits

Applicant	Date received	Size applied for	Concept	County
AkvaDesign AS	18.12.2015	10 licenses (7 800 ton)	Closed cage technology	Nordland
Gigante Offshore AS	13.01.2016	8 licenses (6 240 ton)	"Supertank cage" – pipe design moored at anchor	Nordland
Marine Harvest Norway AS	10.02.2016	14 licenses (10 920 ton)	"The egg" - closed cage technology	Hordaland/ Sogn og Fjordane
MNH Produksjon AS	04.03.2016	8 licenses (6 240 ton)	"Aquatraz" - semi-closed cage	Nord-Trøndelag
Kobbevik og Furuholmen Oppdrett AS	04.04.2016	4 licenses (3 120 ton)	"Steelline" – closed cage in acid proof steel	Hordaland
Marine Harvest Norway AS	15.04.2016	8 licenses (6 240 ton)	"Marine Donut" covering the entire surface, closed cage	Nordland
Lerøy Seafood Group AS	18.04.2016	9 licenses (7 020 ton)	"Pipefarm" closed cage length upstream plant	Hordaland/Sør-Trøndel./ Troms
Stadion Laks SUS	26.04.2016	15 licenses (11 700 ton)	"Stadionpool" – closed cage pool	Sogn og Fjordane/ Møre og Romsd.
Steinvik Fiskefarm AS	02.05.2016	8 licenses (6 240 ton)	Floating closed-cage	Sogn og Fjordane
Engesund Fiskeoppdrett AS	06.05.2016	3 licenses (2 340 ton)	Floating closed regeneration plant in concrete	Hordaland
Marine Harvest Norway AS	01.06.2016	6 licenses (4680 ton)	Closed units in bulk carriers	Sogn og Fjordane
Øyfisk AS/Blue Salmon SUS	07.06.2016	4 licenses (3 120 ton)	Steel-construct with closed tanks	Nordland

Figure 2 illustrates the six stages in technology development from basic research to full commercialization. Initially, the cost per unit is high; gradually the cost decreases as the technology matures. Many of the current projects is located in the demonstration project / early commercialization stage (Teknologirådet, 2012). This implies that there is still uncertainty associated with the future of the production technique and its associated costs.

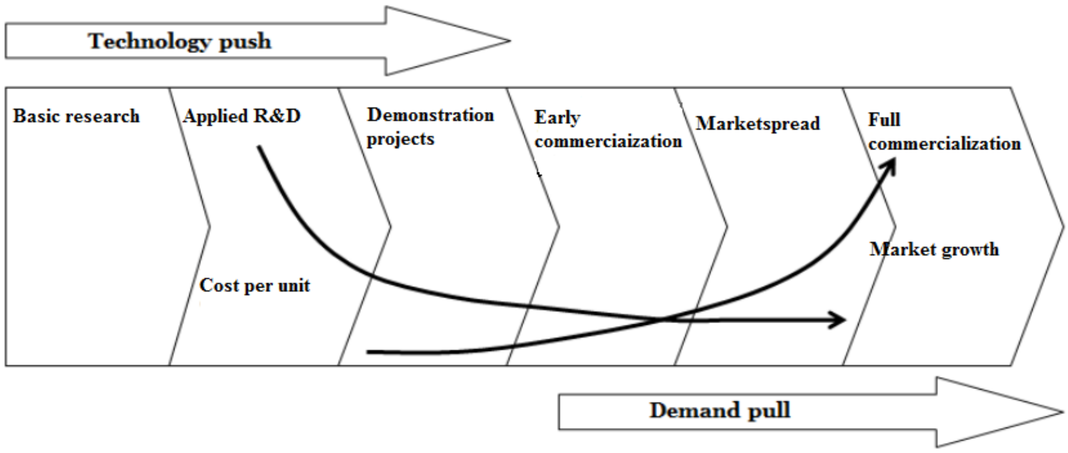

Figure 2. The six stages in technological development

Source: Teknologirådet (2012)

2.3 Environmental Challenges for Open Net-Pens in Aquaculture

Open net-pens are in direct contact with the surroundings, allowing the spread of parasites, organic waste and disease. Organic waste from aquaculture in the form of fish excrements and excess feed can contribute to an accumulation of nutrient salts locally around the installation (Asche & Bjørndal, 2011). If the natural carrying capacity, the nature's natural ability to abate pollution, is lower than the pollution rate this might become a problem. However, only five percent of the nutrient salt emission in Norway originates from aquaculture. Organic waste is not considered a major problem by the government , due to regulations where locations are monitored and fallowed regularly (Nærings- og Fiskeridepartementet, 2014-2015). Nevertheless, if the salmon farming industry continues to expand, then accumulation of organic waste might become a concern in some areas in the future.

Sea lice (Copepoda Caligidae) is one of the most significant challenges the industry is facing today. The parasite has eight different life stages. First it hatches from egg strings carried by adult female lice and then it free-swims until it finds a suitable host (Nikitina, 2015). When the sea lice is attached to the host it feeds on the hosts mucus, muscle and skin (Thorstad et al., 2015). Sea lice exists naturally in the environment, it has been observed in low numbers in periods before fish farming (Thorstad et al., 2015). However, simultaneously as the fish farming industry emerged, the amount of sea lice significantly increased (Nikitina, 2015; Thorstad et al., 2015). Although the sea lice is not considered a fish health problem in the industry, the high densities of fish cause high sea lice levels that in turn may increases the mortality rates of wild salmon and trout stocks (Nærings- og Fiskeridepartementet, 2014-2015; Olaussen et al., 2015). Studies show that the sea lice level is higher in areas with high farming activity than in areas with low activity (Norwegian Scientific Advisory Committee for Atlantic Salmon Management, 2015). Other factors that affect sea lice infestations levels are salt content, water temperatures and natural streams. Sea trout is especially vulnerable to the sea lice as the fish is located at the coast through its entire sea stay, while salmon is mainly exposed to infestation when emigrating from the river into the sea (Norwegian Scientific Advisory Committee for Atlantic Salmon Management, 2015; Nærings- og Fiskeridepartementet, 2014-2015). Norwegian Scientific Advisory Committee for Atlantic Salmon Management (2015) states that sea lice is an unstable stock threat for wild salmon, and argues that the problem is not under control. Figure 3 illustrates the yearly national average of adult female sea-lice infestation per farmed fish (source lusedata.no). Regulation states that there should not be more than 0.5 female adult sea-lice per salmon (Nærings- og Fiskeridepartementet, 2014-2015). It should be noted that there are large periodical and local differences in these numbers, which implies that some farmers may not need any treatments while others may need several.

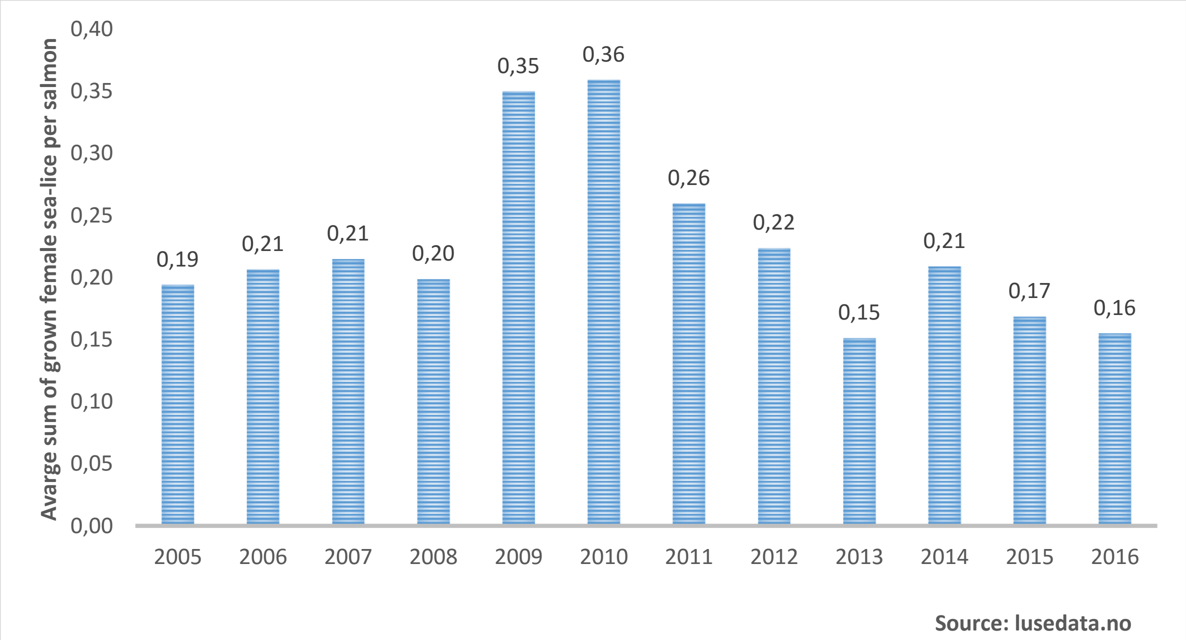

Figure 3. Average annual infestation of adult female sea-lice per salmon

Different diseases have challenged the salmon farming industry. Chilean salmon farming had an incidence in 2007 where there was a severe outbreak of the Infectious Salmon Anemia Virus (ISA-virus) that resulted in a substantial decrease in production (Asche et al., 2009). Luckily, the natural conditions are different in Norway, meaning that the impact of outbreaks in Norway has not been as severe as outbreaks in for instance Chile. Still, the economic loss for a facility that is affected by sickness is significant. Aunsmo, Valle, Sandberg, Midtlyng, and Bruheim (2010) estimated the economic impact of one singular Pancreas Disease (PD) outbreak on one site to be 14.4 million NOK. The cost is associated with direct mortality, growth loss, carcass quality and feed-ration. It is unclear how disease from farmed salmon affects the wild fish stocks.

Escaped farmed salmon is considered a problem for the economic loss it represents, but also because farmed salmon may interrupt the natural genepool by breeding with wild salmon stock. Fiske, Lund, and Hansen (2006) stated that there is a relationship between farming intensity and occurrence of farmed salmon in nearby river. The effect of crossbreeding between wild and farmed salmon are lower spawning production in the river, where the cumulative effect may be devastating (Norwegian Scientific Advisory Committee for Atlantic Salmon Management, 2015). Escaped farmed salmon may also threaten the biodiversity that wild salmon offers, since they are bred to maximize growth and profitability (van der Meeren, 2013). Figure 4 illustrates the amount of escaped individuals in the period from 2001 to 2015. There are concerns that escaped salmon incidences are under reported

(Nærings- og Fiskeridepartementet, 2014-2015). Heuch et al. (2005) suggested that the real number is three times as high as the reported amount in 2001. The main cause for escapes are poor maintenance and montage of structural equipment which counts for nearly 80 percent of the incidents (Nikitina, 2015; Teknologirådet, 2012).

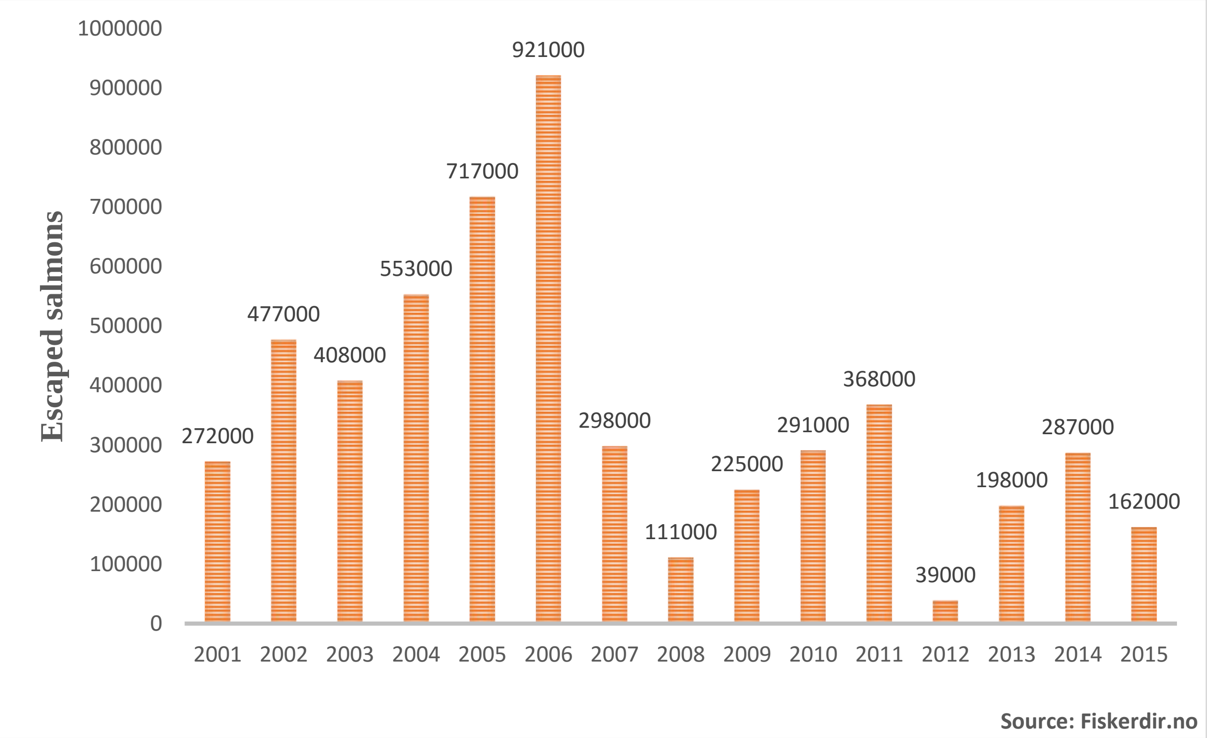

Figure 4. Annual escaped farmed salmon in Norway from 2001 to 2015

2.4 Existing and Emerging Treatment Methods for Sea-Lice

Traditional delousing methods usually involves medical treatment with feed compositions or bath treatments in the net-pens or fish carriers (Iversen et al., 2015). Betamax, Salmosan Alfamax and H_2O_2 are the most commonly and frequently used medicaments and the cost of these treatments has increased in the last years. The high numbers of treatments have caused a resistance problem, consequently making treatments less effective (Iversen et al., 2015; Torrissen et al., 2013). For this reason, H_2O_2 has become more popular in the later years, although it is expensive compared to the other medicaments. In addition development of new treatment methods has begun (Iversen et al., 2015).

The effort to combat sea lice is formidable and there are many approaches and techniques. Lekang et al. (2016) has described several technologies and techniques that are in development. For instance, some actors are applying lumpfish into the containment where it is supposed to eat the sea lice of the salmon. The technique has been attempted more frequently in recent years, and there is an ongoing attempt to farm lumpfish instead of catching it in the wild. Another relatively new approach is lice-skirt, which surrounds the containment from the surface to 10 meters' depth. Since the sea-lice larva are located near the surface of the sea, it effectively blocks the sea-lice larva outside of the containment. However, utilizing lice-skirts cause problems with the oxygen feed into the net-pen, since the masking is extremely fine. Breeding new types of salmon that are more resistance to lice infestation is a viable alternative; this will however take time to develop. Techniques that are more mechanical are also a future alternative, like a high-pressure jet, which wash the fish clean of sea lice. Alternatively, using lasers that detects, shoots and kills the sea lice can be implemented. Thermo-cleaning has also been researched where the infected fish is exposed to a 30-degree bath in a short period of time which kills the sea lice. However, this also affect the salmon. Lastly, there is also future promise in introduction of polyculture into aquaculture, which can reduce the environmental restrain by applying other species that may remove sea lice and disease.

Lekang et al. (2016) investigated which precautions to prevent farmed fish from escaping are used. The authors found that failure to routinely maintain cages and nets was a factor that caused many escapes. Measures to counteract escapes are to use two net-pens or use net materials that are more durable. In addition, surveillance of the weather effect on net-pens can help to reduce escapes rates. A new method that may contribute to reductions of escapes are electrical wiring around the net-pen, which gives a signal when the electrical currents cut off, which allows farmers to repair the damages early on. Additionally, breeding of sterile salmon can be a solution. This effectively shuts down the escaped farmed salmons' ability to reproduce with wild salmon and disrupt the genepool.

2.5 Regulation of Norwegian Fish Farming Industry

Markets are generally good at finding efficient, social-economic equilibrium, as seen in the classical supply and demand cross. However, the market equilibrium is not always optimal; this is known as a market failure. A market failure can occur if the actors in the markets do not take into account external effects. In the salmon farming industry, sea lice and escaped salmon are considered the most significant external effects (Nærings- og Fiskeridepartementet, 2014-2015; Solås et al., 2015). Regulations are justified due to these external effects and because the areas of the Norwegian coast which the aquaculture lays claim on is considered common property (Hersoug, 2015; Nærings- og Fiskeridepartementet, 2014-2015).

Licenses are the main means of regulatory practice; policymakers have controlled the quantity of market participants with licenses since the 1970s. The licenses also contains further restriction on numbers of cages and locations (Hersoug, 2015). Political targets and regulatory practices has changed throughout the years. Local ownership and districts interests was prioritized in the nineties. From the 1970s the regulation restrictions were based on the volume of the production installation, and later feed quotas was implemented as a regulatory requirement (Hersoug, 2015). In 2005, a new regulatory practice was introduced, which was based on maximal allowed biomass (MAB). Since 2009, there have been political agreement that the industry should be environmentally sustainable and regulatory practices should be based on environmental factors (Nærings- og Fiskeridepartementet, 2014-2015).

2.6 Regulation of Future Growth

The government published a White paper in 2015 that established a fiscal rule (Nærings- og Fiskeridepartementet, 2014-2015). New permits should be distributed based on environmental status in the given production area. Indicator variables like lice per salmon determines if the respective production area should be offered a five percent increase, no change or a decrease in maximum allowed biomass (Nærings- og Fiskeridepartementet, 2014-2015). The new allocative system is called a traffic light system due to the following color-coding: green, yellow and red, which represents the former measures respectively. The goal of this policy is to incentivize the industry to operate as environmental friendly as possible. Critiques state that this policy will lead to collective punishment because of production area division, where disreputable farmers can operate with high lice level, which affects other nearby locations. They rather want an allocation process that evaluate individual locations (Nærings- og Fiskeridepartementet, 2014-2015). Some argue that there is too much focus on environmental sustainability in the current policy, while social and economic sustainability are under prioritized (Solås et al., 2015).

The Norwegian Ministry of Trade, Industry and Fisheries proclaimed that they want to stimulate a sustainable growth in the industry. They proclaimed that they wanted to maximize economic growth in the industry and that it should be environmentally sustainable (Nærings- og Fiskeridepartementet, 2014-2015). In order to achieve sustainable growth new dark green development permits was introduced. These permits are meant for actors that develop new technologies, which has a significant lower environmental impact, than current methods. The key requirement to dark green licenses was specifically a maximum 0.25 – 0.1 lice per fish (Hersoug, 2015; Nærings- og Fiskeridepartementet, 2014-2015).

3 Method

3.1 Theory

In order to conduct the analysis of the salmon farming industry there is a need for an economic framework. This chapter will therefore describe the theoretical and methodological background of economic externalities and environmental valuation. In resource economics the purpose of pollution policy are to find the optimal level of pollution and find the most advantageous method to get there (Perman, Ma, Common, Maddison, & McGilray, 2011).

Perman et al. (2011) describes an externality well:

"An externality occurs when the production or consumption decisions of one agent have an impact on the utility or profit of another agent in an unintended way, and when no compensation is made by the generator of the impact to the affected party" (p.121).

Externalities cause market failure, which means that the market equilibrium is not optimal. Goods that has beneficial externalities are usually under-produced, while goods with harmful externalities leads to overproduction (Rosen & Gayer, 2010). An example from aquaculture is the rising levels of sea lice in locations with high farming intensity, which in turn may affects wild fish stocks and other fish farmers. The classification of the sea lice externalities is production-consumption and production–production effect. The classification production-production implies that an agent production activity affects another agent production, in this case salmon farms affecting other nearby salmon farms. While the classification production-consumption means that, an agent production activity affects another agent consumption, in this case that fish farms may affect recreational and commercial fishers.

Figure 5 illustrates how an externality can cause an over production and thereby an ineffective equilibrium. Private agents intentions usually is to maximize profits, which leads to equilibrium were marginal private cost (MPC) equals marginal benefit (MB). This output level is called Q'. However, from society's point of view this equilibrium Q' exceeds the marginal social cost (MSC), since marginal social cost take the marginal damage (MD) into account. The optimal level for society is MSC = MB leading the Q* output level, thus the private equilibrium leads to an ineffective equilibrium.

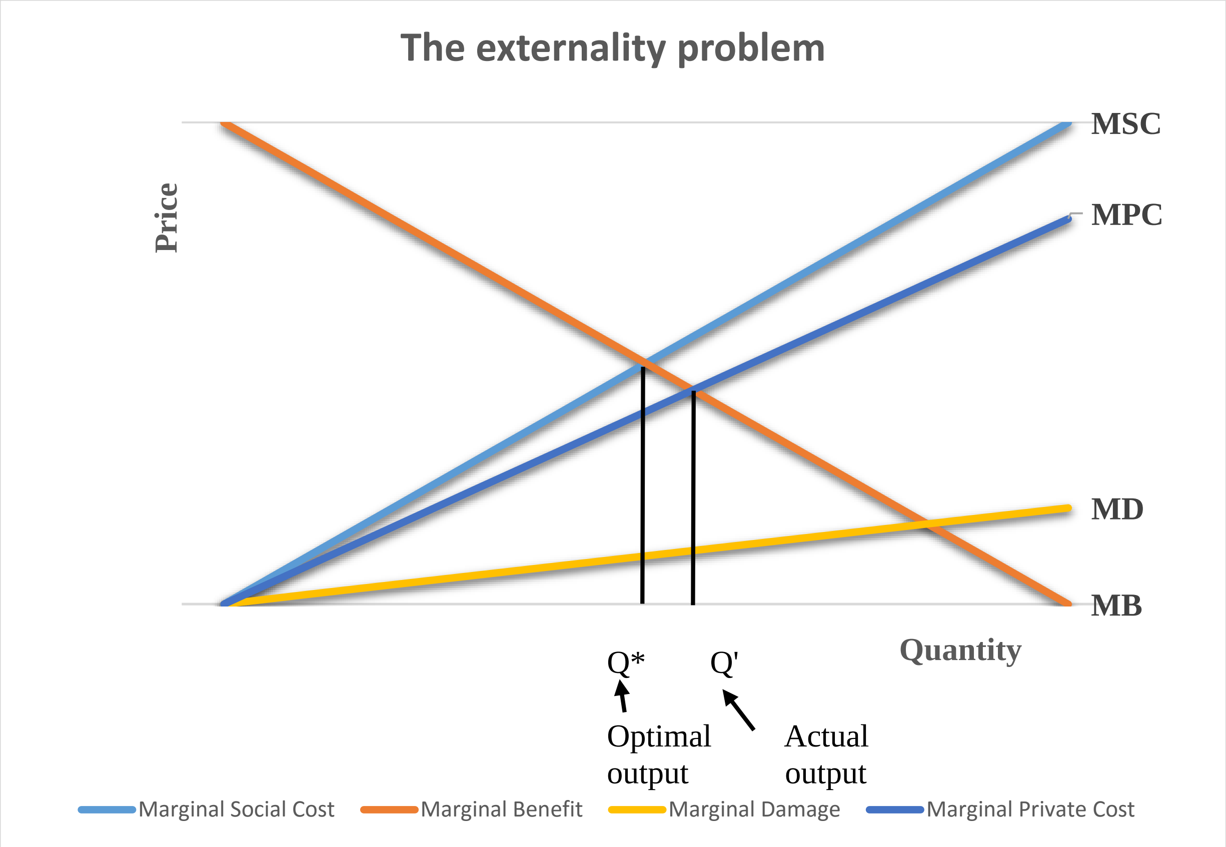

Figure 5. The externality problem

The purpose of pollution control is to adjust a market to a more preferable level. Different instruments can be applied in order to achieve a more preferable market clearance. The challenge is to apply the best-suited instrument for the given case. The choice of instrument should be based on the principles of cost-effectiveness, long run effects, flexibility and dynamic efficiency (Perman et al., 2011). In the case of Norwegian aquaculture, licenses with production caps is the current instrument, while the new regulatory proposal suggest stepwise emission targets, to give the industry incentives for additional cuts in emission.

In Norway, there are approximately 450 salmon rivers (Liu, Diserud, Hindar, & Skonhoft, 2013). In the period from 1983 to 2014 the wild salmon stock has been reduced by 55 percent and the fish farming industry is considered a possible contributor to this reduction (Norwegian Scientific Advisory Committee for Atlantic Salmon Management, 2015). The total value of the wild salmon stock represents socio-economic values that may be harmed by aquaculture. The use value of the wild salmon stock are revealed by investigating the economic activity associated with recreational fisheries. The following valuation and effects are the common argument for conserving the wild salmon stock.

The wild salmon produces ecosystem services such as symbolical values and genetic resource. The symbol value of wild salmon refers to its cultural significance as a motive in paintings, contribution in fairytales, songs, religion, poetry and place names. In addition, it serves as a genetic resource for the fish farming industry and research institutions (van der Meeren, 2013). The wild salmon genes may be important in handling new sicknesses and production problems in the future. The biodiversity offered from the wild salmon is wide, due to its difference in habitat in different rivers (van der Meeren, 2013). This might be considered an option value of the wild salmon stock. The estimation of these values are notoriously difficult, and they are not included in the present analysis.

In addition to the direct utility derived from the wild salmon it has non-consumptive uses. Existence value is a nonmarket or non-use valuation of an environmental good. A nonmarket value is the value of a commodity not traded in a market. It may refer to an activity like recreational use of an environmental good for example; the value an individual derives from hiking in a forest. The goal of existence valuation is to reveal an environmental commodity's total economic value, which implies incorporating all, use values and non-use values. The existence value is simply the derived utility from knowing that wild salmon species exists in Norwegian rivers. Altruistic and bequest values referrers to utility from knowledge that others and future generations respectively, may derive utility from the existence of a species (Perman et al., 2011).

In order to reveal the existence value of environmental goods, several valuation techniques can be used. Contingent valuation is one of them, based on survey data collected from a representative sample of the population. The purpose is to reveal individual willingness to pay (WTP) or willingness to accept (WTA) for an environmental good. Willingness to accept is an individual minimal amount of a monetary compensation the individual are willing to accept for a reduction in an environmental good. While willingness to pay is maximal amount of money an induvial is willing to pay to conserve an environmental good (Perman et al., 2011). By investigating the publics' willingness to pay for the existence of the wild salmon stock, it is possible to estimate its existence value. The advantage of applying a contingent valuation is its ability to incorporate non-use values as well as direct use values, in order to reveal to total value of an environmental good (van der Meeren, 2013). Critiques of the method has pointed out that it may contain biases and may have a significant WTP/WTA disparity (Perman et al., 2011).

Environmental impacts caused by salmon farming may harm the Norwegian farmed salmons' reputation. The public may react if the wild salmon stock was further negatively affected or became extinct. In turn, it would affect the consumers' valuation or purchase frequency of the farmed salmon, which would result in a price decrease. Figure 6 illustrates the effect a negative reputation can cause in a scenario where the wild salmon become extinct. MD represents the marginal damage to the environment, here the negative impact on the wild salmon stock. The optimal market equilibrium is located at MSC = MB. These terms stand for marginal social cost and marginal benefit respectively. If the wild salmon stock go extinct it would no longer be necessary to integrate the MD since it ceased to exist. The new optimal equilibrium is MPC (marginal private cost) equal MB. However, the negative reputation shifts the MB to MB*, which results in a trade-off between reduced treatments cost and consumer fleeing. Since the reputation effect is greatest in example, we observe an economic welfare loss, even after the wild salmon stock has gone extinct

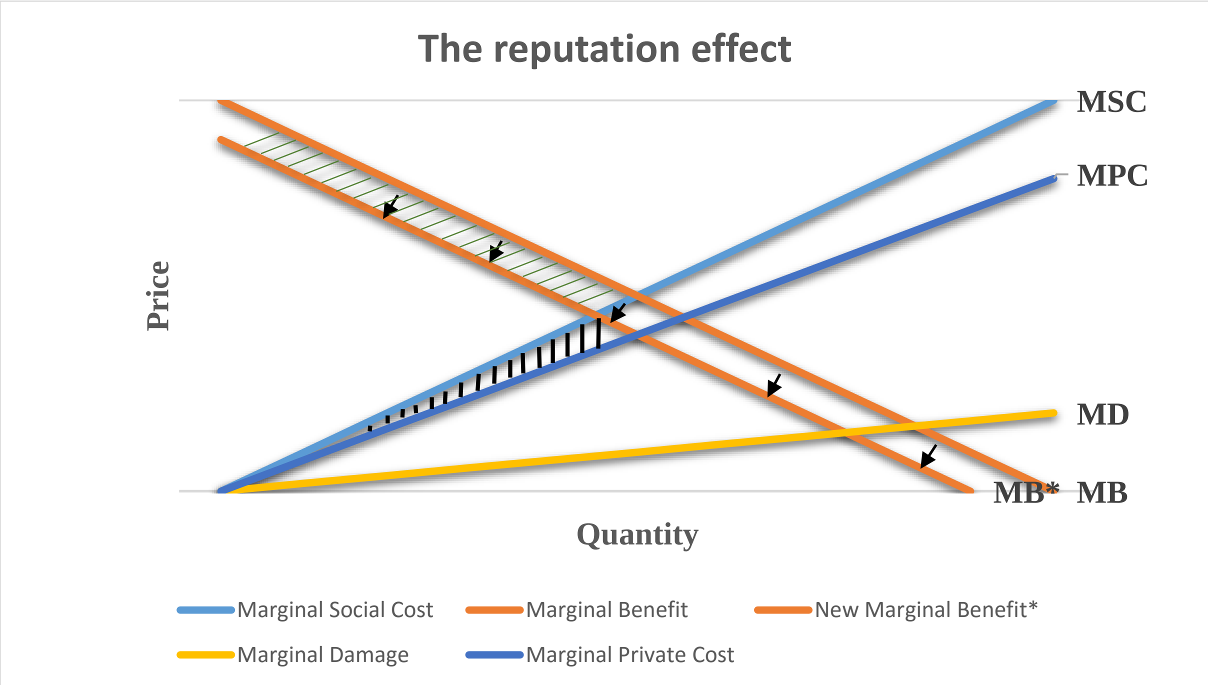

Figure 6. The reputation effect

3.2 Analysis

To reveal the private economic potential of closed-cage fish farming we assume that the technology will succeed to maintain low sea-lice levels (<0.1 per fish). Such low sea lice levels lead to a minimal need for delousing, and thereby the treatment cost significantly less compared to open net-pens. Additionally, it may be possible to achieve a price premium for salmon produced in closed cages, because it is an environmental-friendly production method. It is also possible to reduce some local external effects, avoiding negative effects on wild fish stocks. These factors contribute in reducing private and social-economic costs for closed cage aquaculture. When the closed cage technology is fully developed there is expected a differences in investment cost and operation cost, where the closed-cage has a higher cost. The analysis will, determine how much more closed-cage production can cost in private economic costs to have the same profitability as the open net-pen production, measured in NOK per kg salmon produced per year. In addition, the analysis will reveal the total social-value of the wild salmon stock.

This analysis will estimate three aspects of the valuation of wild salmon. First, the wild salmon's direct economic value are estimated, given by the recreational value the stock has will be evaluated. The commercial fisheries is of little economic significance compared to recreational fisheries and will not be included. Secondly, the existence value of wild salmon is estimated. Lastly, we will examine the potential of the reputation effect, which might affect the fish farming industry: a threat of extinction due to the fish farming will lead to public outcry and can reduce demand.

4 Data

Data is obtained from government reports, research articles and news articles. To be able to compare findings they are in collected in the form of annual national average. The data is inflation adjusted to match 2014 NOK.

4.1 Key Numbers for the Industry: Price, Cost and Margins

In order to conduct the analysis, the author have gathered annual time series data. These key numbers consist of yearly national average cost, price and margins from the salmon farming industry. The effects presented in the analyses are expected to have an impact on national average productions cost or price per kilo salmon, illustrated in Table 2.

Table 2

Norwegian aquacultures key annual national average economic numbers from 2008 – 2014

Year	2008	2009	2010	2011	2012	2013	2014
Average net profit margin	10.2 %	20.9 %	32.9 %	16.4 %	6.5 %	26.4 %	25.4 %
Average production cost per kilo salmon in NOK	20. 98	20.11	22.87	22.18	21.98	25.33	25.83
Average selling price in NOK	26.35	30.87	37.26	31.99	26.58	39.59	40.30

Source:{HYPERLINK: "http://fishpool.eu/price-information/spot-prices/history/"} and fiskeridir.no

4.2 Treatment Cost

Sea-lice treatment represents a significant cost for the industry. Nofima analyzed the rising average national production cost of salmon farming in recent years. They found a significant cost increase associated with sea lice problems and sea lice treatment (Iversen et al., 2015). Findings suggest that the practice of counting sea-lice has emerged after it became a regulatory requirement in 2012, this cost is represented in Table 3 as control costs. The utilization of cleaning fish has recently become more common, and are categorized as the cleaning fish post in Table 3. An increase in net cleaning cost are imposed when utilizing cleaning fish, due to extra fouling, which is represented as net cleaning in Table 3. The treatment cost associated with classical medical delousing has increased significantly in the last years. Bath treatment is commonly used, where well boats are used across several days, which are costly. In recent years, traditional chemicals have proven less effective due to resistance, therefore has the more expensive and laborious H_2O_2 have been applied more frequently. This has resulted in the rate of treatments going up and each treatment costing more. Lice-feed is used to treat sea-lice infestations, where the lice-feed has a higher price than traditional feed. The increased cost, due to utilization of lice-feed and treatments is included in the treatment post in Table 3. Furthermore, the loss post represents an increase in mortality due to treatments. Sickness contribute to increase this mortality rate, since sick and weak fish do not withstand the stress associated with treatments. Before a treatment period, the fish are starved and thereby they lose growth potential, which affect the feed conversion. The feed conversion ration is a measure of efficiency of converting feed input into mass output (Iversen et al., 2015). The loss associated with a higher feed conversion is represents as feed conversion post in Table 3.

Table 3

The annual national cost of sea lice treatments in cost per kilo produced and in total

Origin of expense		2012	2013	2014	2014 in total
Control		0.14	0.15	0.13	175 million
Cleaning fish		0.25	0.30	0.35	450 million
Net cleaning		0.20	0.25	0.35	450 million
Treatment		0.5	0.6	1.1	1350 million
Loss		0.1	0.13	0.22	280 million
Feed conversion		0.1	0.12	0.18	230 million
Total cost per farmed kilo		1.29	1.55	2.33	3 billion

Source: (Iversen et al., 2015)

The estimates from Nofima is considered to be conservative. The reports states that they expect sea-lice cost to be three to four billion NOK in 2014. Rødseth (2016) argues that the sea-lice treatment is affecting the growth more than the estimate from Nofima illustrates, due to increase in feed conversion, loss in growth and biomass. The author concludes that the final cost is in the highest quantile of the cost range, which he suggests is seven to eight billion NOK. However, these numbers are only crude estimate, since an exact estimation do not exist. Therefore, we assume that the sea-lice could cost the industry three to four billion in 2014. It is important to note that the treatment cost has reached this level due to the current regulations, based on the precautionary principle, concerning the wild salmon stock. The salmon farming industry would have chosen a lower treatment level if the decision was up to the industry (Iversen et al., 2015).

4.3 Direct Costs of Escape Incidence

Escaped fish is considered to represent a relative small economic loss for the industry in general (Jensen, Dempster, Thorstad, Uglem, & Fredheim, 2010). Nevertheless, the cost of an escape incidence is significant for each farmer affected by it, depending on how many fish escaping from the facility. The direct cost of one incidence ranges from 0.14 to 15.5 million, where the amount of escaped individual fish is 1000 to 100 000, respectively (Aarhus, 2011). Since the direct cost of escapes is negligible for the industry as a whole, it will not be included in the analysis. The socio-economic risk of farmed salmon escapes is considered in the valuation of wild salmon stock.

4.4 Potential for Price Premium for Environmental Friendly Salmon

There is a possibility that the producer can reach a higher price for salmon produced in closed-cages. Consumers that are engaged in protection of the wild fish stocks might have a higher willingness to pay for a product produced with a minimal environmental impact. The Chairman in Marine Harvest mooted the idea for a differentiation of their environmental-friendly product when they are market ready (Nodland, 2016). Olesen, Alfnes, Røra, and Kolstad (2010) found that the willingness to pay for organic and animal welfare-labelled salmon achieved a premium on 15 percent compared to a conventional product. The study indicates that consumers are willing to pay for salmon produced with less environmental restraints and with improved fish health. Given that, the quality of the products is equal. If we transfer this finding to closed-cage farmed salmon, we find the following result. Considering the average salmon price in 2014, and add 15 percent to the price, we get 46 NOK per kilo. Thus, it has an additional price potential of six NOK per kilo on average.

4.5 The Use-Value of Wild Salmon Stock

Norwegian Forest Owners Association (2009) conducted a value estimation of hunting and fishing activity. They found that the annual value generated by salmon recreational fisheries was 1131 million NOK in 2009. Compared to a similar estimation done in 2004, which was 1345 million, the generated values have been shrinking. Norwegian Forest Owners Association (2009) claimed the reason for the value decrease was population decline in the wild salmon stock, however, they stated that there was a potential for growth. With better management, the value generated could reach 2095 million NOK within the year 2020. Whelan (2006) conducted an estimation of socio-economic value of aquaculture and sport angling of wilds salmonids in northwestern Europe. They estimated the generated annual value from Norwegian recreational salmon angling to be 160 thousand euro (€), which is approximately 1280 million NOK. Both estimation were based on yearly numbers of anglers and their average spending in the fishing season.

Table 4 presents an overview of the estimations of the value of wild salmon angling. The results have also been inflation adjusted to 2014 NOK, which ranges at 1.23 to1.57 billion NOK (Liu et al., 2011; Norwegian Forest Owners Association, 2009; Whelan, 2006).

Table 4

The direct use value of the Norwegian wild salmon stock

Origin	Norwegian Forest Owners Association (2009)	Norwegian Forest Owners Association (2009)	Whelan (2006)
Annual valuation in NOK (year published)	1.13 billion (2009)	1.3 billion (2004)	1.28 billion (2006)
Inflation adjusted to 2014	1.23 billion	1.57 billion	1.49 billion
Equally weighted average in 2014 NOK	1.43 billion		

4.6 Non-Use Value of the Wild Salmon Stock

Olaussen and Liu (2011) conducted a contingent valuation survey of a random sample of anglers from the Norwegian population. The survey was conducted to reveal the difference in WTP for fishing permits where the stock was only wild salmon, hybrid (half of each) or only escaped farmed salmon. The results show a decrease in WTP of 85 percent when the stock consisted of only escaped farmed salmon, and 60 percent decrease with a hybrid stock, when compared to the WTP for a pure wild stock. This study shows that escaped farmed salmon reduce anglers' utility. Håkansson (2009) conducted a cost-benefit analysis in northern Sweden, which explored the trade-off between salmon and hydropower production. The non-use values contributed with an amount of 96 to 517 million Swedish kroners (SEK) for increasing the salmon population. These studies show that the existence value of wild salmon are significant, but the values are not included in the final analysis, since the analysis dose not stem from Norway.

Toivonen et al. (2004) explored the value of inland wild fisheries for all the Nordic countries. The investigation consisted of survey questioning fishers and non-fishers about their willingness to pay for preserving the fisheries in its current state. Their findings suggest that the Norwegian non-use value was between 87 to 193 million dollars, which is approximately 746 to 1655 million in 2014 NOK. The study asks for WTP for the current fish stock, and investigates general recreational fisheries instead of salmon fisheries. Due to this, it cannot be included in the final analysis. However, the study by Toivonen et al. (2004) can act as a rough estimate of the wild salmons' existence value.

Mørkved and Krokan (2000) did a net present value (NVP) analysis on the total value of the wild salmon resource. They suggested that the existence value of the wild salmon ranged from one to two times the use-value of the wild salmon. They applied a discount of seven percent and calculated for infinite periods. They conclude that the net present value was between 3.5 to 7.3 billion NOK in the year 2000, where the existence value was 1.5 to 3.6 billion, respectively. Since this present analysis operate with annual numbers, and not discounted NPV, it is not relevant. Yet, their technique to estimate the existence value is. To keep the estimate conservative, we assume that the existence value is the same use-value, which is approximately 1.43 billion. Note that there are considerable uncertainties associated with this estimate. Nonetheless, it is included for illustrating the potential for non-use values.

4.7 The Reputational Effect of Externalities

The phenomenon reputation effect was observed in Chile when they experienced an outbreak of the ISA viruses. In addition to the direct economic loss, the reputation of Chilean salmon was harmed. Hansen and Onozaka (2011) found that the purchase intentions and perceived quality of the fish decreased when consumers was informed about disease problems in the industry. Furthermore, they documented spillover effects, which signify that unrelated areas and species may be affected by the knowledge of disease outbreak. In another incidence from Chile, the use of antibiotics became known to the public, which resulted in concerned retailers. The U.S retailer Costco changed their preferences away from Chilean farmed salmon after the revelation of antibiotics use in Chile. Following this, the market shares in the retail enterprise went from 90 % Chilean salmon, to 60 % Norwegian salmon. Since the Norwegian salmon farming industry do not use significant amounts of antibiotic in their farming process (Brandsler, 2016; Seaman, 2015). Brandsler (2016) argues that a severe negative reputation effect will occur if the Norwegian wild salmon stock are further harmed or go extinct. Whitmarsh and Palmieri (2011) found that the environmental concerns of the salmon farming industry led to a lower tendency to buy salmon. Jensen et al. (2010) emphasize that the economic impact from escaped farmed salmon is greater when considering the reputational effect in contrast to the direct economic loss. The negative reputation the industry might get from increased sea lice induced mortality, which may result in a lower selling price, might make a high treatment level profitable, since it counteracts this price decrease. To quantify this impact is however a formidable job and might require hedonic modeling, which is outside of the scope of this thesis.

4.8 The Possible Welfare Loss Caused By Sea Lice

Olaussen et al. (2015) applied a bio-economic model to explore how harvest patterns and sea-lice induced mortality affects a wild salmon stock. Their findings suggest that a typical Norwegian salmon river endured a 64 – 74 percent stock decrease and a 15 – 25 percent economic welfare loss mainly due to sea lice induced mortality. The distinction between stock and welfare loss may be due to the fact that even a small stock provide the possibility for recreational fishing. Local variation may affect this finding substantially.

5 Results

This chapter summaries our findings. The private economic potential for closed-cage production can be summed up by adding the price premium and the treatment cost. The socio-economic value of wild salmon can be summed up by use-value and the existence value of wild salmon. We have used values in 2014 NOK to get comparable results. Table 5 summarizes all the factors and effects taken into account in this analysis

Table 5

Summary of private annual economic potential for closed-cage fish farming and the social – economic value of the wild salmon stock in 2014

Private potential	Origin	Total annual value in billion NOK	Cost/price per kilo farmed salmon produced
	Price premium due to environmental friendly production	Depends on production levels	6 NOK
	Treatment cost	3 – 4 billion NOK	2.33 – 3.1 NOK
	Sum	3 – 4 billion NOK	8.33 – 9.1 NOK
Social-economic value of the wild salmon stock	Annual use-value of wild salmon fishing	1.43 billion NOK	1. 11 NOK
	Annual existence value (non –use value of recreational fisheries)	1.43 billion NOK	1.11 NOK
	Total annual value of wild salmon stock:	2.86 billion NOK	2.22 NOK

The private potential is the possible advantages closed-cage production will have on open net-pens, which is a cost reduction in treatment cost and a price premium on the product. The social-economic value of the wild salmon is the value current regulations intend to preserve.

If we combined the total welfare loss found by Olaussen et al. (2015) with the total value of the wild salmon it is possible to get a crude estimate of the actual damage inflicted by the salmon farming industry. The total yearly economic welfare loss may be as high as 572 million NOK.

6 Discussion

The present thesis have investigated the possible economic advantage closed cage technology may have compared to the open net-pens technology. In addition, estimations of the total value of the wild salmon stock have been conducted. The main and the second hypothesis was confirmed by the findings.

6.1 Uncertainties in the Analysis

In the following section, we will discuss different sources of uncertainty in the conducted analysis. The present study is based on former research; all collected sources contain some uncertainty. This implies that the quality of this study heavily depends on the quality of the former research. However, by collecting data from different sources the estimations become more reliable. Unfortunately, some of the estimation are based only on one study since additionally studies were not found.

Missing data is a great source of uncertainties, for example, estimates of what negative reputation can inflict are not included. In addition, culture value and option value of wild salmon is not included. These values are expected to increase the socio-economic value of the wild salmon stock (van der Meeren, 2013). Nor the value of the sea trout is included, which also might be affected by the salmon farming industry.

Furthermore, the estimate of the extent of the treatment cost is solid and up to date; however, it is based on conservative assessments, which implies that the treatment cost might be higher. Moreover, it is not certain that the closed-cage production does not need any treatment for the fish. This depends on the robustness on the technology and which kind of filtration level is utilized. Regardless, it is unlikely that closed-cage production will have the same lice problem as the open net-pens have today.

In addition, the estimate of the potential price premium is based on results from one study. To achieve the price premium the actors is dependent on successful labeling and marketing of their products. The price premium potential is also dependent on the absence of new innovation that solves the environmental problems associated with open net-pens. What’s more, consumer’s preferences may also change in time. Additionally, the size of this niche market is unknown, if production of closed cage farming becomes relatively large the price premium might disappear.

The estimate of the use-value of the wild salmon stock is based on fishing activity and several unrelated studies found similar result. The results are based on older findings and the salmon stock is always changing. Therefore, it is possible that the dynamic nature of the stock makes the estimations less certain. However, the economic activity associated with recreational fisheries has been relatively stable from the period the studies were conducted to

2014 , nonetheless some stock changes has occurred (Norwegian Scientific Advisory Committee for Atlantic Salmon Management, 2015).

Non-use valuation is a controversial topic. Unfortunately, there does not exist much literature covering the existence value of wild salmon. The estimates are based on former studies difference between direct use-value and existence value. To enhance the estimates there is a need for additional data.

The estimated welfare loss is based on only one study, the actual welfare associated with salmon farming is heavily disputed and therefore are there a lot of uncertainty associated with this crude estimate.

6.2 Private economic potential

The avoidable treatment cost may significantly affect the profitability of closed-cage production, a cost that ranges from 2.33 - 3.1 NOK per kilo farmed salmon. The treatment cost has reached a high level due to regulation aiming to preserve the wild fish stock. Thus, the private potential from treatment savings depends on current regulation. Treatment cost may increase in the years to come, due to the new regulatory system that act as an incentive to utilize more sea lice treatments. In addition, it is important to note that the estimate of the treatment cost is a conservative value, which implies that it might has a considerable higher value than stated in the results.

The result illustrates that the largest potential for closed cage production may come from the price premium due to the environmental friendly production, a premium estimated to be approximately 6 NOK per kilo. There is however, more uncertainty associated with this result. If the two values are added together we reveal the economic potential advantage closed cage production have compared to the open net production, which ranges from 8.33 to 9.1 NOK per kilo. Even with this advantage it is unlikely that closed cage production will get similar profitability as open net-pens (Teknologirådet, 2012). This is because the closed cage technology operationalize the water exchange, which is expensive, in contrast to the open net-pen technology, where the process occurs naturally due to natural steams. The closed cage technology faces further challenges, amongst others are maintaining healthy fish and production reliability (Teknologirådet, 2012).

Development permits for new projects may be attractive for private actors since they can be transformed into regular permits, if the target criteria set for that project have been met (Nærings- og Fiskeridepartementet, 2015). The permit transformation will have a fixed price at 10 million NOK. In a closed auction in 2013 permits were sold for 55 - 66 million (Iversen et al., 2015), consequently we assume that these sums represents the market price. In addition, since 2013 the salmon price has increased significantly, which implies that the value of permits presumably also has increased. The price for converting a development permit is significantly lower than a permits market price. The averages numbers of licenses currently applied for is eight licenses, which means that the actors may profit significantly on the permits if they reach their project goals.

The possibility of converting the development permits into regular permits indicate that closed cage production does not necessarily need to be as cost effective as the open net-pens to be profitable for the developers. Indeed, as the market and demand pushes the prices up the possibility for commercialization of the closed cage technology increases. Currently the price are at historically high levels. Nevertheless, this might change due to the volatility in the salmon prices.

There are many different concepts that currently are under development. Nonetheless, it is not certain that all of these concepts will reach commercial operations or that they reach their project target, mainly because technology development are risky. Actors might be affected by the pro innovation bias, which is the tendency to overestimate an innovation usefulness and underestimate its cost. (Son & Rojas, 2011; Tichy, 2004). This bias may also cause policymakers to have an exaggerated faith in the technology.

The lack of empirical data, make it hard to conclude how the closed cage will do economically and environmentally in the long run. This is mainly due the fact that concepts are still in development and there is little knowledge about the concepts reliability and robustness.

6.3 Comparing Treatment Cost and the Value of Wild Salmon

The total value of wild salmon represents the socio-economic cost the industry theoretically can impose on the society. However, the scenario where the extinction of the wild salmon stock occurs is highly unlikely, due to the current measures and regulation that already are in place. However, with the current regulations there are still some economic losses associated sea lice induced mortality.

The export value of farmed salmon exceeds the total value of the wild salmon; the export value in 2014 was 14.6 times larger than the total value of the wild salmon. Note that this is just the export value; spillover effects associated with the industry is not included. In addition, the treatment cost are 6.1 times larger than the economic damages done by sea lice. This implies that treatment cost is much higher than the value it intends to preserve. Even if the total value of sea trout was included, it is unlikely that the economic portions had changed significantly. Paradoxically, this implies that the current regulations are "over charging" the industry. The economic ponderation of these two findings goes in favor of the "over charging" of the industry. The total economic value of the salmon farming industry make the theoretical possible external effect small when comparing the two.

The current regulation may be reasonable if the reputation effect is taken into account. For instance, if a negative environmental reputation caused price decrease of two to three NOK, then the current treatment cost would seem reasonable. However, there is little knowledge about the size of this this effect.

The viewpoints on the external effects from Norwegian aquaculture differ a lot. Christiansen (2013) divide the different views into four groups and define how they want to handle a negative external effect. At each end of the spectrum we can observe extreme point of views, where the main standpoint is for instance a wish for no regulations or no farming activity. The two views are represented respectively by a few individuals in aquaculture sector and a marginalized numbers of individuals in environmental organizations. Christiansen (2013) also define a middle ground groups such as technology optimist that views technology advances as a solution to the external effects. As public opinion affects policymaker's stand in the issue of regulatory practice, it is possible that current regulation is an attempt to compromise the different point of views. Notwithstanding, the heated debate about aquaculture regulation will with great probability continue.

6.4 Implication for further growth

If the current regulatory practices continue, closed cage salmon farming may contribute to future growth. Furthermore, if actors succeeds in developing closed cage production that are reliant and reduces the environmental impact this growth may become significant.

The aquaculture industry is reliant on access to new location to be able to grow. Future growth with open net-pens will lead to a greater density of facilities, which in turn can increase negative production-production external effects like disease and sea lice levels (Tveteras & Battese, 2006). The closed-cage production might contribute to solve these problems. Moreover, the closed-cage technology might offer further growth potential in areas that already have high open net-pen activity. The contribution in growth may also occur in areas with lower levels of water exchange, where the surrounding are not suited for open net-pen aquaculture (Iversen et al., 2013).

Additionally, closed cage production might affect competitiveness of the Norwegian industry, since it not overly reliant on natural conditions. Iversen et al. (2013) states that the closed-cage production effect on the Norwegian competiveness is dependent on whether or not the technology is meant for protected locations. If the closed cage technology is reliant on protected location, the Norwegian coast will still retain its competitive hegemony. On the other hand, if the technology can be deployed in unproduced sea areas the Norwegian competitive advantage may be weakened. It is important to distinguish between the notion of developing closed cages and imposing regulation that demand closed cage production. Researching and collecting knowledge about the production technology do not necessarily weaken the Norwegian competiveness. On the other hand, imposing special Norwegian regulation that requires the industry to use the more expensive production technique would most likely be devastating for the Norwegian competitiveness (Teknologirådet, 2012).

6.5 Conclusion and Future Research

The closed cage technology is a new production method in the Norwegian salmon farming industry. The closed cage aquaculture are currently under development, due to environmental problems in the salmon farming industry's open net-pen production method. This technology may have an economic advantages on open net-pen aquaculture in terms of lower sea lice treatment cost and a price premium, which combined add up to 8.33 – 9.11 NOK per kilo produced. The actual profitability can be revealed when big scale testing of closed cage production is completed.

When data are available from big-scale-testing, it might be interesting to conduct a cost-benefit analysis of different facilities. A cost-benefit analysis may reveal interesting results about the economic viability and environmental parameters of closed cage salmon farming. Then, it will also be possible to compare the results from the analysis with similar analysis from net-pen aquaculture. The findings from this thesis can contribute in such a cost benefit analysis.

Regulations of Norwegian aquaculture are in place to conserve wild fish stock and environmental surroundings. The wild salmon stock is one of the greatest economic values the regulations intend to preserve. The total annual value of the wild salmon stock is 2.86 billion NOK, and its possible economic loss due to sea lice induced mortality is 572 million NOK. Compared with the total annual value of the salmon farming industry and it cost associated with lice treatments, which is 42 billion and 3 - 4 billion NOK respectively, the wild salmon stock economic value is small. The current regulation still may be viable due to the reputation effect.

For future research, it might be interesting to examine the reputational effect from the salmon industry. Different approaches may be taken to examine this effect. For instance, future studies can investigate how environmental reputation affects regulations, or how the industry's reputation may affect the salmon price. By applying hedonic modeling, knowledge about the reputation effect might be possible to acquire.

References

Aadland, C. (2015a). Nå skal de bygge anlegg med 20 lukkede merder. *Sysla.no*. Retrieved from http://sysla.no/2015/11/03/havbruk/na-skal-de-bygge-anlegg-med-20-lukkede-merder_65884/

Aadland, C. (2015b). Se alt de gjør for å knekke lakselusa. *Sysla.no*. Retrieved from http://sysla.no/2015/09/01/havbruk/se-alt-de-gjor-for-a-knekke-lakselusen_58625/?_ga=1.189301099.1987988068.1445609323

Aarhus, I. J. (2011). Rømming - en høyt prioritert utfordring for oppdrettsnæringen. *Norsk fiskerioppdrett nr. 8, 2011*.

Asche, F., & Bjørndal, T. (2011). Environmental Issues *The Economics of Salmon Aquaculture* (pp. 65-81). Chichester: Wiley-Blackwell.

Asche, F., Hansen, H., Tveteras, R., & Tveterås, S. (2009). The Salmon Disease Crisis in Chile. *Marine Resource Economics, 24*(4), 405-411. doi:10.5950/0738-1360-24.4.405

Aunsmo, A., Valle, P. S., Sandberg, M., Midtlyng, P. J., & Bruheim, T. (2010). Stochastic modelling of direct costs of pancreas disease (PD) in Norwegian farmed Atlantic salmon (Salmo salar L.). *Preventive Veterinary Medicine, 93*(2–3), 233-241. doi:10.1016/j.prevetmed.2009.10.001

Brandsler, S. (2016). Lakselusproblemet må gi kutt i oppdrett. *Gemini.no*. Retrieved from http://gemini.no/2016/01/lakselusproblemet-ma-gi-kutt-i-oppdrett/

Christiansen, E. A. N. (2013). Negative externalities of food production: Discourses on the contested Norwegian aquaculture industry. *Journal of Political Ecology, 20*(1), 180-198.

Det Kongelige Norske Videnskabers Selskab (DKNVS) and Norges Tekniske Vitenskapsakademi (NTVA). (2012). *Verdiskaping basert på produktive hav i 2050*. Retrieved from https://www.regjeringen.no/globalassets/upload/FKD/Vedlegg/Rapporter/2012/Verdiskaping-rapport-010812.pdf

Ellefsen, H. (2015). Utviklingskonsesjoner kan få store konsekvenser. *Fiskejuss.no*.

FAO. (2014). *The State of world Fisheries and Aquaculture* Retrieved from FAO, Rome: http://www.fao.org/3/a-i3720e/index.html

Fiske, P., Lund, R. A., & Hansen, L. P. (2006). Relationships between the frequency of farmed Atlantic salmon, Salmo salar L., in wild salmon populations and fish farming activity in Norway, 1989–2004. *ICES Journal of Marine Science: Journal du Conseil, 63*(7), 1182-1189. doi:10.1016/j.icesjms.2006.04.006

Hansen, H., & Onozaka, Y. (2011). When diseases hit aquaculture: An experimental study of spillover effects from negative publicity. *Marine Resource Economics, 26*(4), 281-291. doi:10.5950/0738-1360-26.4.281

Hersoug, B. (2015). The greening of Norwegian salmon production. *Maritime Studies, 14*(1), 1-19. doi:10.1186/s40152-015-0034-9

Heuch, P. A., Bjørn, P. A., Finstad, B., Holst, J. C., Asplin, L., & Nilsen, F. (2005). A review of the Norwegian 'National Action Plan Against Salmon Lice on Salmonids': The effect on wild salmonids. *Aquaculture, 246*(1–4), 79-92. doi:10.1016/j.aquaculture.2004.12.027

Håkansson, C. (2009). Costs and benefits of improving wild salmon passage in a regulated river. *Journal of Environmental Planning and Management, 52*(3), 345-363. doi:10.1080/09640560802703249

International Food Policy Research Institute. (2015). *2014 - 2015 Global Food Policy Report*. Retrieved from http://reliefweb.int/sites/reliefweb.int/files/resources/GFPR14-15_embargo_w.pdf

Iversen, A., Andreassen, O., Hermansen, Ø., Larsen, T. A., & Terjesen, B. F. (2013). *Oppdrettsteknologi og konkuranseeposisjon* (Nofima 32/2013). Retrieved from http://www.nofima.no/filearchive/rapport-32-2013-oppdrettsteknologi-og-konkurranseposisjon.pdf

Iversen, A., Hermansen, Ø., Andreassen, O., Brandvik, R. K., Marthinussen, A., & Nystøyl, R. (2015). *Kostnadsdrivere i lakseoppdrett* (Nofima AS: 41/2015). Retrieved from http://nofima-326d.kxcdn.com/wp-content/uploads/2015/08/Rapport_nr_41-2015_-_Kostnadsdrivere_i_lakseoppdrett.pdf

Jensen, Ø., Dempster, T., Thorstad, E. B., Uglem, I., & Fredheim, A. (2010). Escapes of fishes from Norwegian sea-cage aquaculture: causes, consequences and prevention. *Aquaculture Envirionment Interactions, 1: 71–83, 2010*. doi:10.3354/aei00008

Lekang, O. I., Salas-Bringas, C., & Bostock, J. C. (2016). Challenges and emerging technical solutions in on-growing salmon farming. *Aquaculture International*, 1-10. doi:10.1007/s10499-016-9994-z

Lilleby, J. (2016). Dette egget kan revolusjonere norsk lakseoppdrett. *e24.no*.   Retrieved from http://e24.no/naeringsliv/marine-harvest/dette-egget-kan-revolusjonere-norsk-lakseoppdrett/23615684

Liu, Y., Diserud, O. H., Hindar, K., & Skonhoft, A. (2013). An ecological–economic model on the effects of interactions between escaped farmed and wild salmon (Salmo salar). *Fish and Fisheries, 14*(2), 158-173. doi:10.1111/j.1467-2979.2012.00457.x

Liu, Y., Olaussen, J. O., & Skonhoft, A. (2011). Wild and farmed salmon in Norway—A review. *Marine Policy, 35*(3), 413-418. doi:10.1016/j.marpol.2010.11.007

Marine Harvest. (2015). *Salmon Farming Industry Handbook 2015*. Retrieved from http://www.marineharvest.com/globalassets/investors/handbook/2015-salmon-industry-handbook.pdf

Mørkved, O. J., & Krokan, P. S. (2000). *Økonomiske analyse av villaksressrsene i nasjonale laksevassdrag* (Høgskolen i Nord-Trøndelag Utredning nr 24). Retrieved from http://www.nb.no/nbsok/nb/47cc99feb48780e24e090378eab57e3b.nbdigital?lang=no#2

Nikitina, E. (2015). *The role of "green" licences in defining environmental controls in Norwegian salmon aquaculture.* (Master's thesis). Retrieved from http://munin.uit.no/handle/10037/7747

Nodland, E. (2016). Rift om laksen som skal produseres i "Egget" *iLaks.no* Retrieved from http://ilaks.no/rift-om-laksen-som-skal-produseres-i-egget/

Norwegian Forest Owners Association. (2009). *Estimat for omsetning av jakt og innlandsfiske i Norge*. Retrieved from https://www.regjeringen.no/globalassets/upload/lmd/vedlegg/brosjyrer_veiledere_rapporter/jaktturisme_rapport.pdf

Norwegian Scientific Advisory Committee for Atlantic Salmon Management. (2015). *Status for norske laksebestander i 2015 [Status of the Norwegian salmon stocks in 2015]* (Nr 8). Retrieved from http://www.nina.no/archive/nina/PppBasePdf/Rapp%20Vitr%C3%A5dlaks/Thorstad%20Status%20RVitr%C3%A5d%20laks2015-8.pdf

Nærings- og Fiskeridepartementet. (2014-2015). *Forutsigbar og miljømessig bærekraftig vekst i norsk lakse-og ørretoppdrett*. Retrieved from https://www.regjeringen.no/no/dokumenter/meld.-st.-16-2014-2015/id2401865/?ch=1&q=

Nærings- og Fiskeridepartementet. (2015). *Forskrift om endring av laksetildelingsforskriften*. Regjeringen.no Retrieved from https://www.regjeringen.no/no/dokumenter/forskrift-om-endring-av-laksetildelingsforskriften/id2462545/.

Olaussen, J. O., & Liu, Y. (2011). On the willingess-to-pay for recreatioal fishing - escaped farmed versus wild atlantic salmon. *Aquaculture Economics & Management, 15*(4), 245-261. doi:10.1080/13657305.2011.624573

Olaussen, J. O., Liu, Y., & Skonhoft, A. (2015). Conservation versus harvest of wild Atlantic salmon. The cost of sea lice induced mortality. *Fisheries Research, 168*, 63-71. doi:10.1016/j.fishres.2015.03.022

Olesen, I., Alfnes, F., Røra, M. B., & Kolstad, K. (2010). Eliciting consumers' willingness to pay for organic and welfare-labelled salmon in a non-hypothetical choice experiment. *Livestock Science, 127*(2–3), 218-226. doi:10.1016/j.livsci.2009.10.001

Perman, R., Ma, Y., Common, M., Maddison, D., & McGilray, J. (2011). *Natural resource and environmental economics* (4th ed. ed.). Harlow: Pearson Education Limited.

Rosen, H. S., & Gayer, T. (2010). *Public Finance*. New York: McGraw Gill Higher Education.

Rødseth, G. I. (2016). Beregninger på fem milliarder i lusekostnader er bare deler av sannheten. *iLaks.no*. Retrieved from http://ilaks.no/beregninger-pa-fem-milliarder-i-lusekostnader-er-bare-deler-av-sannheten/

Seaman, T. (2015). Chile loses out with Costco to switch 2/3 of salmon contract to Norway. *Undercurrentnews.com*. Retrieved from https://www.undercurrentnews.com/2015/03/19/chile-loses-out-with-costco-to-switch-23-of-salmon-contract-to-norway/

Solås, A. M., Hersoug, B., Andreassen, O., Tveteras, R., Osmundsen, T. C., Sørgård, B., . . . Robertsen, R. (2015). *Rettslig rammeverk for norsk havbruksnæring: Kartlegging av dagens status* (Nofima AS: 29/2015). Retrieved from http://nofima-326d.kxcdn.com/wp-content/uploads/2015/08/Rapport_-_Rettslig_rammeverk_for_norsk_havbruksnaering.pdf

Son, J., & Rojas, E. M. (2011). Impact of optimism bias regarding organizational dynamics on project planning and control. *Journal of Construction Engineering and Management, 137*(2), 147-157. doi:doi:10.1061/(ASCE)CO.1943-7862.0000260

Statistics Norway. (2015). Akvakultur, 2014, endelige tall. Retrieved from http://www.ssb.no/fiskeoppdrett

Teknologirådet. (2012). *Fremtidens lakseoppdrett* (Report 1). Retrieved from https://teknologiradet.no/wp-content/uploads/sites/19/2013/08/Rapport-Fremtidens-lakseoppdrett.pdf

Thorstad, E. B., Todd, C. D., Uglem, I., Bjørn, P. A., Gargan, P. G., Vollset, K. W., . . . Finstad, B. (2015). Effects of salmon lice Lepeophtheirus salmonis on wild sea trout Salmo trutta—a literature review. *Aquaculture Environment Interactions, 7*, 91-113. doi:10.3354/aei00142

Tichy, G. (2004). The over-optimism among experts in assessment and foresight. *Technological Forecasting and Social Change, 71*(4), 341-363. doi:10.1016/j.techfore.2004.01.003

Toivonen, A. L., Roth, E., Navrud, S., Gudbergsson, G., Appelblad, H., Bengtsson, B., & Tuunainen, P. (2004). The economic value of recreational fisheries in Nordic countries. *Fisheries Management and Ecology, 11*(1), 1-14. doi:10.1046/j.1365-2400.2003.00376.x

Torrissen, O., Jones, S., Asche, F., Guttormsen, A., Skilbrei, O. T., Nilsen, F., . . . Jackson, D. (2013). Salmon lice – impact on wild salmonids and salmon aquaculture. *Journal of Fish Diseases*, *36*(3), 171-194. doi:10.1111/jfd.12061

Tveteras, R., & Battese, G. E. (2006). Agglomeration externalities, productivity, and technical inefficiency. *Journal of Regional Science, 46*(4), 605-625. doi:10.1111/j.1467-9787.2006.00470.x

van der Meeren, G. I. (2013). *Kasusstudie: Villaks og oppdrettslaks i et økosystemtjenesteperspektiv* (5-2013). Retrieved from Havforskningsinstituttet: https://www.imr.no/filarkiv/2013/06/fh_5-2013_til_web.pdf/nb-no

Whelan, B. (2006). *Assessment of the socio-economic value of aquaculture and sport angling for wild salmonids in northwestern Europe: implications for treatments for sea lice infestation*. Lillehammer ; Trondheim: Norsk institutt for naturforskning.

Whitmarsh, D., & Palmieri, M. G. (2011). Consumer behaviour and environmental preferences: a case study of Scottish salmon aquaculture. *Aquaculture Research, 42*, 142-147. doi:10.1111/j.1365-2109.2010.02672.x