Norwegian University of Life Sciences

Master's Thesis 2020 30 ECTS
Faculty of Landscape and Society (LANDSAM)

Biological Control of Salmon Lice: A Critical Analysis of Knowledge Production and Development in the Norwegian Cleaner Fish Industry

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Abstract

The lumpfish and four species of wrasse have become important resources for cleaning salmonids of sea lice in Norwegian aquaculture. Cleaner fish's delousing effectiveness and mortality rates in salmon cages vary dramatically due to environmental conditions, disease, and husbandry practices. While cleaner fish are portrayed as an environmentally friendly product, no post-cleaning use is made of their body parts. Thus, researchers and animal rights organisations have questioned whether the wrasse fishery and large-scale lumpfish aquaculture is justified and ethical. This case study analyses themes derived from qualitative interviews focussing on the history, knowledge production, and contestation of cleaner fish practices using a critical political ecology approach. The results suggest that despite rapid growth in their use, cleaner fish are an impermanent delousing solution. Perceptions of cleaner fish use are changing from optimism to scepticism and their use is characterised by uncertainty due to efficacy and welfare challenges. I argue that producing and using cleaner fish in Norway is contradictory in nature and constitutes a 'socioecological fix' of capitalism. This helps explain how salmon aquaculture's inherent vulnerability to lice creates an opportunity for behaviour in cleaner fish to be produced, exploited, and profited on. At the same time, this process both produces and 'fixes' social, economic, and environmental externalities. This provides grounds to critique the legal and regulatory context in Norwegian aquaculture, which I argue amplifies profitability goals while underemphasizing fish welfare.

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Introduction

Aquaculture is Norway's second most important industry after petroleum in terms of revenue, and a key focus of the country's research and development. Production of salmonids (Atlantic salmon [*Salmo salar*] and rainbow trout [*Oncorhynchus mykiss*] – referred to collectively as salmon hereafter unless specified) comprises 99.8% of total production weight (FishStatJ, 2020), but several other species are also farmed. Norway is now the world's largest exporter of farmed salmon and thus, the industry is important for generating regional employment and revenue (Johansen et al., 2019; Norwegian Government, 2019). Nevertheless, ownership of salmon production and its value chain has been consolidated into the hands of fewer and larger companies (NOU, 2018: 18). In 1996 the ten largest companies sold 19% of total sales, while in 2018, the ten largest companies sold 67% (Directorate of Fisheries, 2020d). The industry has indeed changed character from being small-scale in its 'pioneer days' in the late 1960s and 1970s to now being an industrial farming system dominated by publicly traded companies (Hovland & Møller, 2010; NOU, 2018: 18).

Salmon farming's reputation has also been tarnished by various environmental problems often criticized in Norwegian media (Olsen & Osmundsen, 2017). For example, excess waste emitted from farms negatively influences surrounding marine ecology (Norwegian Environment Agency, 2017). Additionally, the expansion of salmon aquaculture has correlated with a large decline in wild salmon populations (Torrissen et al., 2013). Studies have found that escaped farmed salmon hybridize and negatively affect the genetic uniqueness of wild salmon populations (Skaala et al., 2019). Sea lice infestation in farm cages is also common and lice of farm origin are known to increase wild salmon mortality and are considered a threat to wild populations (Grefsrud et al., 2018; Torrissen et al., 2013; Vollset et al., 2016). The salmon louse *Lepeophtheirus salmonis*, and to a much lesser degree *Calligus elongatus* (hereafter referred to commonly as lice), are parasitic copepods occurring naturally in the northern hemisphere, but aquaculture provides high numbers of salmon for lice to exploit. Lice infection damages the epidermis of salmon, increasing vulnerability to other illnesses, and if infection is severe enough, can lead to mortality (Hjeltnes, Bang Jensen, Bornø, Haukaas, & Walde, 2019). Pharmaceuticals have been widely used for treating lice infection in aquaculture, but these pollute surrounding areas and harm other crustaceans that provide valuable coastal fisheries (Olaussen, 2018).

Despite these environmental concerns, in 2013 the Norwegian Government adopted an ambitious goal for growth in the industry. Under optimal conditions, it was predicted that growth in salmonid aquaculture in Norway could increase production volume by around five times to 5 million tonnes by 2050 (Ministry of Trade, Industry and Fisheries, 2013). However, growth in farmed salmon sales has stagnated. After producing 1.2 million tonnes of slaughtered fish in round weight for sale in 2011, production has averaged approximately 1.3 million tonnes since then (Directorate of Fisheries, 2019a). The problem with sea lice has persisted and become so critical to the growth and reputation of the industry that lice density now governs whether production is allowed to increase (Jackson, Moberg, Djupevåg, Kane, & Hareide, 2018).

To achieve 'sustainable growth', the so-called "traffic light system" was introduced by law on 30th October 2017. The system issues a 'green light' for businesses to expand provided wild salmon mortality caused by salmon lice infection is kept below 10% of the population in a region (Olaussen, 2018; Vollset et al., 2017). In this way, the government claims that they will "use environmental sustainability as the most important issue to consider, when regulating further growth in the industry" "[benytte miljømessig bærekraft som den viktigste forutsetningen for å regulere videre vekst i oppdrettsnæringen"] (Ministry of Trade, Industry and Fisheries, 2015, p. 12). However, using one indicator to govern the industry's environmental sustainability is unavoidably problematic. Firstly, the terms 'environmental sustainability' are inevitably vague and subjective. Secondly, while average lice levels in salmon cages seem to be declining, wild salmon mortality linked to salmon lice remains a problem in regions with high density of salmon aquaculture (Grefsrud et al., 2018). Indeed, without isolating salmon production from environmental exposure by moving production into land-based facilities, lice will likely always negatively affect salmon farming.

Meanwhile, during the period that the traffic-light system was debated and implemented, several fish species became widely applied to consume lice from salmon in a form of biological control in aquaculture throughout Norway. This has resulted in the rapid and ongoing domestication of two new species for this purpose, and an intensive summer fishing period for several other species.

1.1 Biological Control and Salmon Lice Treatments

The lumpfish (*Cyclopterus lumpus*) and four species of wrasse of the family Labridae are used to graze on lice from salmon in aquaculture. The wrasses used are ballan wrasse (*Labrus bergylta*), goldsinny wrasse (*Ctenolabrus rupestris*), corkwing wrasse (*Symphodus melops*), and rock cook (*Centrolabrus exoletus).* All are opportunistic carnivores inhabiting rocky and algal habitats in coastal areas of Europe (Costello, 1991) and are mostly fished in shallow waters using traps (Blanco Gonzalez & de Boer, 2017). Lumpfish are opportunistic omnivores with an uncommon life-history strategy whereby their early stages are spent in coastal habitats before they migrate into pelagic habitats (Ingólfsson, Kristjánsson, & Schaefer, 2002). While a market exists for lumpfish caviar, in Norway lumpfish are only fished for aquaculture broodstock (Kennedy et al., 2019). Since 2016, the number of juvenile lumpfish produced has exceeded that of rainbow trout (*Oncorhynchus mykiss*), making lumpfish the second most farmed fish in Norway in terms of number of individuals (Directorate of Fisheries, 2020d). Efforts to farm ballan wrasse are ongoing, but the species is proving more challenging to farm than lumpfish (Brooker et al., 2018).

In addition to cleaner fish, many farmers combine methods in an integrated form of pest management. Different methods may include: lice skirts and snorkel cages that isolate salmon cages from zones of the water column where lice numbers are higher; laser technology that kills lice attached to salmon using light pulses; mechanical systems that spray lice off of salmon; thermal baths that expose salmon and lice to warm water causing lice to detach; and five different chemotherapeutants used in bath treatments and feed additives that cause lice to detach or die (Overton et al., 2019). During the 1990s and 2000s, formaldehyde, hydrogen peroxide and several chemotherapeutants were also used widely as delousing agents, but lice adapted resistance towards several of these, thereby reducing their efficacy and use (Denholm et al., 2002; Torrissen et al., 2013).

Research and development into lice treatments has become an industry in itself in Norway. This is to be expected when maintaining lice levels below certain thresholds governs whether the industry can expand. Also, researchers estimated that salmon lice infection led to production losses equivalent to 8.7% (US$436 million) of production in 2011 (Abolofia, Asche,

& Wilen, 2017). Thus, with salmon production growth stagnating since 2012, and growth restricted under the traffic-light system, the lice problem arguably represents the industry's greatest bottleneck. Adding to this problem is that lice treatment methods may vary in effect and have negative characteristics. Thermal, mechanical and chemotherapeutant treatments are stressful for fish. They stunt fish growth and often lead to higher mortality, thereby costing farmers money and reducing fish welfare (Hjeltnes et al., 2019; Nilsson et al., 2019; Overton et al., 2019).

However, trends in treatment methods are changing. Overton et al. (2019) found that treatment with chemotherapeutants has declined from 79% in 2015 to 13% in 2017, with the difference taken up mostly by thermal and mechanical methods which comprised 75% of all delousing treatment events in 2017. Cleaner fish are now considered an important part of salmon lice treatment strategies in Norway (Jackson et al., 2018). In 2018, around 49 million were released into salmon cages in Norway (Directorate of Fisheries, 2019b). This represents a large increase over the course of one decade (Figure 1).

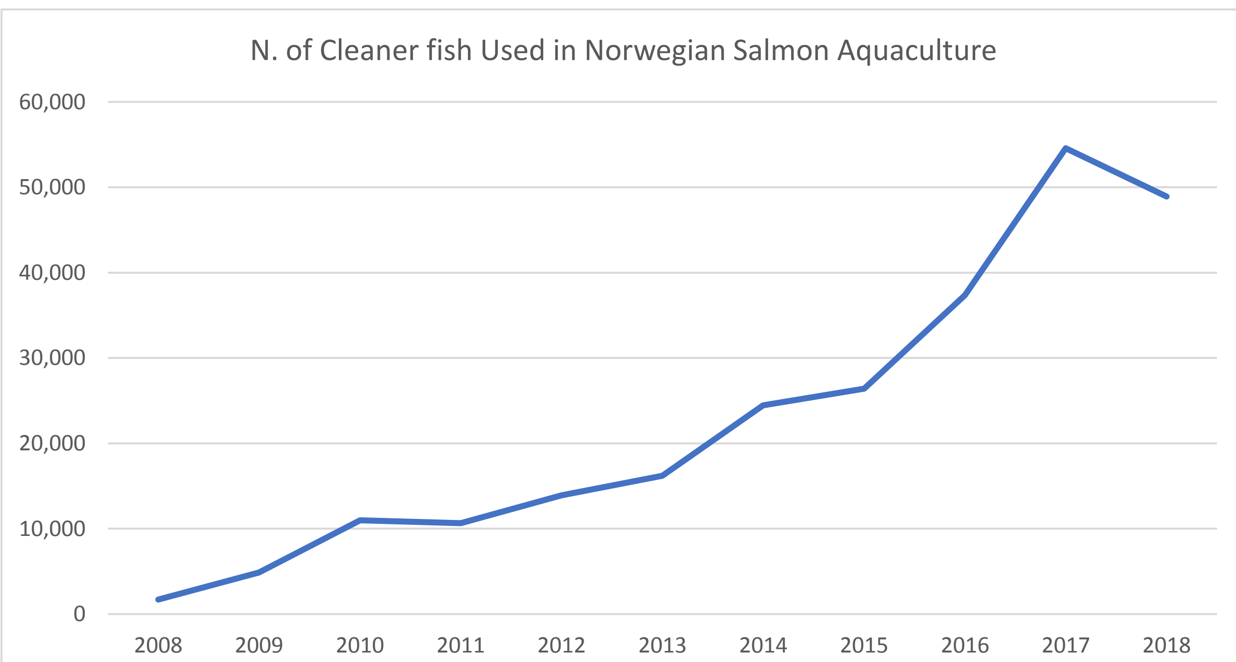

Figure 1. *Increase in number of cleaner fish used (number in 1000 individuals). Data from Directorate of Fisheries (2019b)*

1.2 Scale and Use of Cleaner fish

Of the approximately 49 million cleaner fish released into Norwegian salmon farms in 2018, 18 million were wild caught wrasse, approximately 30 million farmed lumpfish, and one million farmed ballan wrasse. These numbers greatly exceed production of other marine species such as Atlantic halibut (*Hippoglossus hippoglossus*), Atlantic cod (*Gadus morhua*) and Arctic char (*Salvelinus alpinus*). Total juvenile production for these three species since 2014 has only averaged around 2 million individuals (Directorate of Fisheries, 2020a). Nevertheless, the total weight is far less than the total weight of salmonid production. In comparison, around 341 million salmon juveniles, and 23 million rainbow trout juveniles, were released from hatcheries into sea cages for outgrowing in 2018 (Directorate of Fisheries, 2020d). In 2018, the total value of fish traded from cleaner fish aquaculture was just over 700 million NOK, whereas in 2012, it was only around 7 million NOK. At the same time, production licences for cleaner fish have almost tripled with fifteen held in 2012 and 42 held in 2018, while the number of companies farming cleaner fish increased from five to 25 producers during the same period (Directorate of Fisheries, 2019b).

While there is no clear number of how many salmon aquaculture locations use cleaner fish, a recent industry wide survey received 286 replies from company representatives. These representatives may be responsible for several locations and there may have been more than one respondent per company (Amundsen & Storkensen, 2019). Correspondingly, in 2018 there were 174 companies operating 1160 licences in Norway (Directorate of Fisheries, 2019d, p. 27). Another study assessing cleaner fish efficacy narrowed their sample down to 488 sites (to suit their statistical analysis), of which 70% reported stocking some cleaner fish. The mean number of cleaner fish stocked per site was 90 300 cleaner fish (Barrett, Overton, Stien, Oppedal, & Dempster, 2020, p. 4).

Since their importance to the salmon industry has grown, research into the aquaculture of lumpfish and ballen wrasse, along with the wrasse fishery, has exploded. Although the species were relatively obscure, they are now heavily researched (Treasurer, 2018a). A fishery has long existed for lumpfish roe, particularly in Iceland (Davenport, 1985), but their prevalence for salmon delousing has only arisen since 2012 in Norway with the first scientific documentation of their effect published in 2014 (Imsland et al., 2014; Powell et al., 2018). Wild broodstock are fished to supply lumpfish farmers with roe for their aquaculture. This has raised some concern that the harvest may be unsustainable in the long term since specimens are destroyed after their eggs are stripped (Powell et al., 2018). Lumpfish are also listed on the IUCN Red List as ‘near threatened’ (Lorance et al., 2015), however, the species has not been assessed since 2013 and details of this evaluation are unclear. A more recent study suggests there is little concern for lumpfish populations in Norway where they are more abundant than management targets (Kennedy et al., 2019). This implies that there is little concern from authorities for wild populations.

Conversely, wrasse have been known to perform cleaning in certain conditions for much longer, with the first scientific testing conducted on salmon by Bjordal in 1988. There is a strong will to replicate the aquaculture success of lumpfish with ballan wrasse since they are believed to be the most robust and effective. Ballan wrasse broodstock are also wild caught but can survive in hatcheries over several spawning cycles (Brooker et al., 2018). Nevertheless, since wrasse species have been poorly studied in the wild and fished heavily with few restrictions, researchers are also concerned about the long-term effect of the fishery. Wrasse are fished most heavily in Western Norway where there is a high concentration of salmon farms. Research in this region has shown that catch per unit of effort is lower than in the other two regions, as are average fish lengths. This is to be expected when larger fish are targeted for the salmon industry (Halvorsen et al., 2017; Halvorsen, Sørdalen, Larsen, Rafoss, & Skiftesvik, 2020).

Since 2016, the quota of 18 million individual wrasse has been fished annually for approximately three months from the end of summer into autumn. Until the quota was allocated per vessel and access divided into different groups (open group, closed group, recreational group, youth quota) in 2018, the fishery proved difficult to restrain. In 2017 the catch peaked with almost 28 million wrasse fished during the season, in comparison to 2008 when only around 1 million were caught (Directorate of Fisheries, 2018, 2019c). The fishery is divided into three zones with the coast north of 62° allocated 4 million fish, the western zone south of 62° to Varnes Lighthouse allocated 10 million, while the southern zone is allocated a further 4 million fish. The quota is not species specific, thus the title ‘leppefisk’ in Norwegian refers collectively to all wrasse species. All wrasse species enter fish traps and fyke nets (a type of trap with nets leading fish into a trap area) which makes it difficult to select which wrasse species are targeted. Additionally, species vary in abundance but also in their efficacy at consuming lice, and survival in salmon farm conditions (Blanco Gonzalez & de Boer, 2017; Brooker et al., 2018; Skiftesvik, Durif, Bjelland, & Browman, 2015). Generally, corkwing and goldsinny wrasse are the most abundant, followed by ballan wrasse and rock cook which are much less abundant (Directorate of Fisheries, 2019c; Skiftesvik et al., 2015). Therefore, regulators struggle to find regulations that suit the life-history traits of the different species.

Although the method is seen as a positive alternative to chemical use and is harmless to salmon, there are serious concerns for cleaner fish welfare and some question whether their use is justified (Norwegian Food Safety Authority, 2020).

1.3 Cleaner fish Efficacy and Contestation

Veterinarians and groups lobbying for animal rights are increasingly criticising the use of cleaner fish due to the poor welfare they experience in salmon cages (Berglihn, 2019; Trana & Sandmo, 2018). Indeed, all cleaner fish ultimately die, but most do not survive more than one salmon production cycle. A recent national survey found that mortality ranges from 42% for all species on average nationally, and only between 68% and 81% survive after three months in salmon cages (Stien, Størkensen, & Gåsnes, 2020). The survey also found that many farmers' report far less deaths than the number of fish released. This is because many cleaner fish are also preyed upon by salmon, die from disease, or die due to environmental stress and disintegrate before being collected (Norwegian Food Safety Authority, 2020; Stien et al., 2020). This implies that *at least* 20 million fish, and likely many more, died before a salmon cycle was completed in 2018.

Yet, the use of cleaner fish as a sustainable method for lice control is also contested on environmental grounds. Researchers have voiced concerns about the lack of post-salmon farm use of cleaner fish (Brooker et al., 2018; Nøstvold, Kvalvik, Voldnes, & Jentoft, 2016), and the practice of translocating cleaner fish regionally across Norway. Fish from the west coast of Sweden are often translocated as far north as Trondelag County along the central Norwegian coast (Norwegian Scientific Committee for Food and Environment, 2019). Ironically, this practice has already caused escapee cleaner fish to influence local genetic composition in some areas (Blanco Gonzalez et al., 2019; Faust, Halvorsen, Andersen, Knutsen, & André, 2018) in a similar way to how farmed salmon escapees have affected wild salmon (Skaala et al., 2019). At the same time, using cleaner fish for controlling salmon lice is also framed as an "environmentally friendly alternative to chemical treatments" (Institute of Marine Research, 2019, p. 5). Additionally, recent studies began questioning the entire evidence base that has so far portrayed cleaner fish as efficient delousers.

In early 2020 several studies assessing the efficacy and extent of cleaner fish use were published. Firstly, Overton, Barrett, Oppedal, Kristiansen, & Dempster (2020) questioned the evidence base of cleaner fish effectiveness by reviewing literature where cleaner fish were tested in cages with salmon. They found that few studies fulfilled quality standards related to scientific validity or tested the scale and conditions cleaner fish experience in a commercial salmon farm. The authors highlighted the importance of filling knowledge gaps by using studies with high scientific validity to justify using cleaner fish since poor cleaner fish welfare and high mortality rates in aquaculture are widespread (Brooker et al., 2018; Norwegian Food Safety Authority, 2020).

Secondly, Barrett et al. (2020) concluded that cleaner fish use is 'suboptimal' considering they found only "a weak and short-lived general effect averaged across the industry" (2020, p. 9). Still, some salmon farmers can document sea lice reductions from using cleaner fish with high survival rates (Norwegian Food Safety Authority, 2020). However, with high mortality and poor welfare of cleaner fish documented (Amundsen & Storkensen, 2019; Stien et al., 2020), the studies by Overton, Barrett and colleagues arguably help weaken the justification for cleaner fish use. Proving cleaner fish's effect is important since the Food Safety Authority should ensure that methods and equipment used in aquaculture facilities should be documented as suitable for fish welfare according to Paragraph 20 in Norway's Regulation on Operation of Aquaculture Facilities (2008). Nevertheless, when a fishing and aquaculture industry now exists to produce cleaner fish for salmon farms, regulators now risk disrupting many peoples' livelihoods should they prohibit use of cleaner fish in salmon farms.

After farmers were surveyed on how cleaner fish are used in relation to regulations, the Food Safety Authority now threatens to restrict cleaner fish use unless the industry documents an improvement in cleaner fish mortality (Norwegian Food Safety Authority, 2020). Therefore, cleaner fish paradoxically occupy a curious role as ‘martyrs’ for the salmon industry, as a ‘green’ delousing method, as a profitable commodity stemming from fisheries and aquaculture, and have become some of the most studied fish in the north Atlantic (Treasurer, 2018a) in the span of approximately one decade. Visible here are discursive portrayals of wild and produced fish with important economic values embedded in one of the world’s most lucrative industrial farming systems. Such a case is an inevitable focal point for the discipline of political ecology, which is often appraised as considering “ecology and a broadly defined political economy” (Blaikie & Brookfield, 1987, p. 17) with additional focus on relationships between language, meaning, and power (Forsyth, 2003; Robbins, 2012). Nevertheless, no studies to my knowledge have addressed cleaner fish using a political ecology lens.

Studies on cleaner fish have focussed overwhelmingly on the species’ delousing potential and welfare problems. The Food Safety Authority’s recent ‘Cleaner Fish Campaign’ provides useful data in relation to cleaner fish use and regulations, but its summary reports avoid critical reflection into the Authority’s own role in allowing or preventing the externalities that have emerged since cleaner fish use has increased. Other studies attempt to explore the development of cleaner fish use, but their approaches are apolitical or only address the topic briefly. Blanco Gonzalez & de Boer (2017) mapped the development of the wrasse fishery descriptively and only highlight the challenges of using wrasse in aquaculture and the rapid increase in wrasse fishing, however, the paper was largely uncritical. Brooker et al. (2018) reviewed the literature and problematize many of the challenges mentioned in this introduction. They point to several research gaps that need to be filled to enhance cleaner fish aquaculture “to meet the urgent demands from the salmon sector and to protect wild stocks from overfishing” (2018, p. 9). Therefore, there is little critical analysis of how cleaner fish use has become so prolific considering poor scientific justification of the practice.

Norway is interested in producing more species in aquaculture for food in the future (Ministry of Trade, Industry and Fisheries, 2020). However, the most recent attempts to domesticate lumpfish and ballan wrasse, along with the novel practice of using fish as biological lice control, are plagued with contradictions and have resulted in social and environmental externalities. Thus, to help improve understanding of the domestication process in this context, both of new species and the ongoing domestication of salmon, this thesis explores the drivers and consequences of cleaner fish use, production, and fishing using a critical political ecology approach. To do this, I will also analyse the socioecological context of the salmon industry more broadly using Ekers & Prudham's (2015, 2017, 2018) theory of how capitalism can produce, subsume and proliferate new relationships between animals, humans, and the environment to solve inherent contradictions that may arise systemically. This provides an alternative and more nuanced picture of why salmon delousing methods are changing and why the use of cleaner fish is increasingly contested.

1.4 Objective and Research Questions

This thesis aims to explore the drivers of cleaner fish use, production, and fishing using a critical political ecology approach. A thematic analysis of semi-structured interviews with salmon farmers and key actors in the development, contestation, production, and regulation of cleaner fish aquaculture and use in salmon farms will be conducted. With these aims, the following research questions have guided the data collection and analysis:

1. How has knowledge about lumpfish and wrasse species as delousing agents in salmon aquaculture been produced and contested in Norway?
2. How does this influence management?

2 Methods

2.1 Research Design

A case study approach is a common research design in political ecology. Bryman (2016) outlines a variety of different case study designs all aiming to suit research of change and the nature of social phenomena. A case study can be difficult to distinguish from a cross sectional study. Indeed, any study can be considered a case study if you consider the term in a literal sense. Bryman writes that the case in question should be "of interest in its own right" (2016, p. 61), and its objective should be to explore its uniqueness.

One might wonder why a case study is useful here when cleaner fish are used in several other countries. This fact could make another approach that compares the different countries' experiences more useful. Firstly, comparing cases may require more focus on the comparison itself than exploring the context and nuance of a unique case (Dyer & Wilkins, 1991 as cited by Bryman, 2016, p. 68). Secondly, it also requires the researcher to structure their research to allow for adequate comparison, which may narrow the study focus at the outset and leave the research less open to explore findings that emerge during the research process (Bryman, 2016). Bryman writes that the location of a case study can often be of little significance, but here, the Norwegian context is intrinsically associated with the introduction of cleaner fish to salmon aquaculture. Indeed, the first tests on this cleaning symbiosis were carried out in Norway, Norway is the world's largest exporter of farmed salmon, and the salmon lice problem is intrinsically tied to the governance of aquaculture in Norway. Therefore, the case of cleaner fish use in Norway is considered a unique case.

The research strategy for exploring this case draws on several approaches for gathering data. It is partly cross-sectional since most respondents were interviewed once, thus the data only captures a snapshot of the respondent's experiences and reflections at that time. However, there is also a longitudinal element in that three follow-up interviews aimed to reveal changes in perceptions before and after the release of the Cleaner Fish Campaign results. Additionally, in the Discussion Chapter, themes in the literature are analysed with a longitudinal perspective. Both of these characteristics reflect case study designs highlighted by Bryman (2016, Chapter 3). Nevertheless, this thesis is in the qualitative tradition and the relationship between theory and research is inductive. Therefore, the theory this thesis generates in relation to answering the research questions asked are not generalizable to other contexts. However, cleaner fish are used in several other salmon farming nations and other fish may indeed be domesticated again in the future. It is hoped then that the findings could provide a useful comparison if cleaner fish use expands in another country as it has in Norway, or if other cases of fish domestication occur in the future.

Considering this context, conducting qualitative interviews is a useful data collection method. Qualitative research is often concerned with exploring the "experience of something" (Bryman, 2016, p. 56) rather than focusing on aspects of measurement, validity, and replicability as in quantitative research. Methods used to conduct quantitative research are often somewhat formal or unnatural to the respondent. For example, surveys can be unnatural to fill-in if topics are rarely discussed or thought about in this format, and questions may limit the degree to which a respondent can answer a question. Therefore, I used semi-structured interviews which allowed me to follow-up ideas and points I felt were important. More importantly, when I observed or felt the respondent was passionate or felt strongly about a certain topic, it was easy to direct the conversation and allow the respondent to elaborate.

2.2 Sampling Approach

This study used a generic purposive sampling approach. This approach suits the nature of a case study because it allows the researcher to choose the most pertinent and knowledgeable interviewees in relation to the research questions (Bryman, 2016). This required that respondents could convey in-depth knowledge and understanding from a broad array of systems involved in the development of cleaner fish use. This includes aquaculture of ballan wrasse and lumpfish, fishing of wrasse, salmon aquaculture, research, and resource management. This is a form of non-probability sampling, which contrasts to a probability sampling approach where the goal is to acquire a representative sample of a given population and thus, allow for generalization by using statistical method (Bryman, 2016).

Interviewees were contacted for an interview request mostly by telephone and some by email. My supervising professor arranged three interviews for me with relevant researchers and one from a government agency. Two of these contacts helped me arrange further interviews at the Directorate of Fisheries and with other researchers and a fisher. A lumpfish farm manager interviewed also assisted in arranging further interviews with a salmon farmer. Thus, snowball sampling was integral to gaining access to some of the most knowledgeable respondents.

2.3 Field Work

Since the case of cleaner fish use in Norway is unique, the context chosen for research was Western and Southern Norway where there is a high density of fish farming localities, fishers, and offices of governing institutions, research institutions and environmental organizations. Trade-offs had to be made considering practical constraints such as time, money, distance, and access to interviewees. Therefore, the regions around Arendal in Southern Norway, and Bergen in Western Norway, were visited over a two-week period during the last week of February and first week of March 2020. Follow-up video and telephone interviews were carried out during the last week of April in Oslo in Eastern Norway where I reside.

2.3.1 Interview Descriptions and Respondents

Twenty-two (n=22) semi-structured interviews were conducted in total. Twenty were recorded and transcribed. Of these, the average length was 51 minutes. The longest was 97 minutes, four interviews were only 20 minutes, while the shortest two interviews (not included in average time) were not recorded and were short telephone calls with a fish slaughter facility manager and a fisher. Some interviewees turned out to have less relevant knowledge than expected, or that the nature of the topic required a shorter discussion. Interviews conducted in person were mostly conducted at the respondent’s workplaces in an office setting.

Eighteen interviews were carried out in Norwegian while the remainder were in English. English is my mother tongue however; I have practiced Norwegian for nine years whilst living in the country and my ability is somewhere in between fluent and semi-fluent. My Norwegian ability when listening and reading is better than my spoken fluency, relatively speaking.

Three researchers from the Norwegian Institute of Marine Research (IMR), were interviewed. The goals were to obtain information about the development of the wrasse fishery and their use in salmon aquaculture. This included history, knowledge and experiences regarding their transport to salmon farming locations and relevant biology and ecology for fisheries management. One of these was Åsmund Bjordal, who published the first scientific articles on the use of cleaner fish in salmon farming. Consent has been given to cite his name directly.

Representatives from four salmon farming companies using cleaner fish were interviewed. As was one representative from feed company specialising in feed for cleaner fish. An interview was conducted with a ballan wrasse hatchery manager. A lumpfish farming facility was also visited, and the manager was interviewed and provided a tour of the facility. This provided insight into how cleaner fish in general are used and farmed. It also revealed the interviewee's perspectives concerning regulations and interactions with relevant authorities such as the Norwegian Food Safety Authority, the Norwegian Environment Agency, and the Directorate of Fisheries. Representing civil society, the Deputy Leader from Green Warriors of Norway was interviewed, as was a journalist who has openly criticised the salmon industry. Additionally, unsuccessful attempts were made to interview a representative from the 'Norwegian Animal Protection Alliance'. One professional fisher who owns a quota in the 'closed group' (a right to fish 48 000 wrasse per season with one boat) was also interviewed. This provided valuable insight into how cleaner fish are harvested, stored, traded, and transported, relevant regulations and the welfare concerns that arise during this process.

To gain insight into regulatory history and challenges, one group interview was conducted with three regulators from the Directorate of Fisheries. This interview was conducted with three employees with different responsibilities to do with regulating fisheries and aquaculture. These were considered to have expert knowledge on the wrasse fishery, salmon aquaculture and related environmental concerns. Two telephone interviews were conducted with regulators from the Food Safety Authority. These interviewees had expert knowledge about cleaner fish regulations and fish health. Also, another employee from the Norwegian Environment Agency working with wild salmon was interviewed.

Telephone interviews were also conducted with a representative from a fish slaughter facility to hear about their experiences of receiving cleaner fish, and a fisher from the Austevoll region where there have been reports of conflict and overfishing of wrasse. Also, an associate professor in aquaculture engineering was interviewed via Skype.

Three follow-up telephone calls were made at the end of April to one salmon farming representative, the lumpfish farm manager, and a Food Safety Authority regulator. Since the time of initial data collection, two important events occurred that were relevant to the study. Firstly, the results from the Food Safety Authority's Cleaner Fish Campaign were published, and a global pandemic triggered an economic crisis. The goal was to gain information about how the fish farmers' activities and outlooks were affected by the economic crisis, and about how they perceived the results and ultimatum to reduce cleaner fish mortality given by the Food Safety Authority based on the campaign. Since the Food Safety Authority regulator's follow-up call was the final interview, questions were asked to clarify and explain information gained throughout the course of the data collection, and about their perceptions of the industry's response to the Cleaner Fish Campaign results.

2.3.2 Questioning

Questioning was generally broad and open. Due to the diverse nature of the systems that supply cleaner fish to salmon farms and the variation in use of cleaner fish, there were only a few common questions posed. I asked all respondents to explain their perspectives on the history and future outlook of cleaner fish use. It was common to ask people working with cleaner fish about how they perceive regulations and whether they are effective and adequate. When interviewing regulators, questions focused more on the drivers and reasons for regulations, whether these are effective and how they have changed. Researchers received a greater mix of questions, but focus was mainly directed to their fields of expertise or experiences relevant to cleaner fish use. This approach demanded that interview plans were prepared. This was usually done the night before the interview. During the data collection period, I chose to think about and prepare for future interviews rather than transcribing and analysing data ongoingly during this process.

2.4 Data Management and Analysis

I used thematic analysis to analyse the data using chapters from Guest, MacQueen, and Namey (2012) as a guide. Guest et al. (2012) describe thematic analysis as a versatile approach to analysing qualitative data that is interpretive by nature. This means that the approach aims to analyse both explicit and implicit themes within the data. I take a 'phenomenological' approach to the data. This means that it is "participants' perceptions, feelings, and lived experiences that are paramount and that are the object of study”. However, these are also juxtaposed with themes and objective knowledge within scientific literature, grey literature and media, albeit in a less systematic manner than the transcribed data. I recognize that there exists both objective and relative knowledge and thus position this thesis within a critical realist epistemology.

All interviews were recorded on a portable voice recorder and twenty were transcribed in one Microsoft Word document. This was carried out when the initial data collection period was completed. Whilst transcribing, sections or lines were highlighted on the transcripts and notes were handwritten on an A3 chart. These notes included who stated the words and what stimulated my reason for writing it down, along with the page number from where the utterance or conversation lies in the transcription document. Broad sampling labels such as ‘farmers’, ‘fishers’, ‘authorities’ for example, were used to group data in the handwritten notes and initial concepts were drawn from these notes. This process reduced the data into groups of concepts, which were then connected and compared between interviews and written on a notepad. This generated a codebook and initial analysis which helped determine if more data should be gathered and who to contact for further interviewing.

After completing the codebook and initial analysis, primary coding was conducted in the word processing document using the highlighting and commenting tools. Again, notes were handwritten to helped refine the initial concepts. These were then analysed to generate patterns and were synthesized into themes. Sections of interviews that represented these codes were highlighted. To qualify as a concept, relevant data not only had to emerge several times, but the context in which the concepts were discussed in their respective interviews were assessed and compared. This is an effort to ensure that conclusions drawn from the data in the Discussion Chapter are congruent with the raw data, as described by (Guest et al., 2012, p. 12).

This process is like what Guest et al. (2012) describe as an ‘explorative’ approach, in that the themes were derived from the data. In contrast, a confirmatory approach is hypothesis driven, whereby a hypothesis may be actively searched for in the data material. Nevertheless, after themes were generated, the data was reanalysed using the concepts that comprise Ekers & Prudham’s (2015, 2017, 2018) theory of the ‘socioecological fix’. Thus, further interpretation related to this framework are visible in section two of the Discussion.

2.5 Limitations of the Study

The main limitations with this thesis are related to sampling, my own subjective interpretations, and that there is a weak engagement with more objective knowledge related to the study. Firstly, I believe that more relevant interviewees could have been accessed had I been more organised for the data collection process. Nevertheless, this thought emerged in retrospect after carrying out the analysis and was therefore, somewhat unavoidable. Perhaps I would try and access interviewees with more knowledge regarding the political economy of the salmon and cleaner fish industries. This would help verify conclusions based on Section Two of the discussion more thoroughly.

Secondly, given the more interpretivist nature of this approach to qualitative research, my interpretations of the data are unique. Another person’s analysis and conclusions may have looked very different. Nevertheless, I consider this only a limitation, not a weakness. Whether it is a strength or not is perhaps up to the reader to reflect on based on the quality of research and the strength of conclusions drawn.

Thirdly, similar to much political ecology, this thesis is more focused on the political economic aspects of cleaner fish use and thereby, I consider my explicit engagement with ecology as weak. Had time, my own knowledge, and my own field ecology skills allowed, field work assessing the nature of cleaner fish-salmonid interaction in the wild, compared with how the interaction occurs in a salmon cage environment may have been useful. This is because the symbiosis is rarely documented, and its scale and importance are not well understood. A relevant research question might therefore be: does a reduction in wild wrasse populations influence wild salmonid’s ability to delouse in the wild? I also hypothesise that perhaps the cleaner fish diet within salmon cages, where attempts are made to encourage them to consume salmon lice, does not reflect their diet in the wild. Could this play a role in the poor welfare they experience in salmon cages?

Nevertheless, had some of these limitations been addressed, conclusions drawn from the current approach may have been stronger.

3 Theory

3.1 Political Ecology

Political ecology is a broad interdisciplinary and transdisciplinary research approach to studying humans and the environment. It is interdisciplinary because it draws on the theories and methods of multiple disciplines, and transdisciplinary because results are often combined and go beyond the norms in the fields political ecology draws from. Similar to how Choi & Pak (2006, p. 351) describe transdisciplinarity as combining "natural, social and health sciences in a humanities context, …[which] transcends their traditional boundaries". For those unfamiliar with the field, its name could be seen as merging two somewhat disparate entities. 'Politics' is a concept typically related to human processes of governing, while 'ecology' is often something humans find themselves amongst. That is to say, some may consider ecology as external, a system existing somewhere beyond the human-built environment. Crucially, political ecology rejects the human-nature binary and recognizes humans as a part of a system who depend on, degenerate, enhance, and appropriate different facets of the environment, albeit to varying degrees.

With human systems viewed as inherently integrated in ecological processes, the varying degrees that humans influence the environment is contested. This contestation is often the focus within political ecology research. A good example can be found in the early conceptions of 'sustainable development' written in the Brundtland Report. Not only did this report frame "poverty as a major cause and effect of global environmental problems" (World Commission on Environment and Development [WCED], 1987, p. 12), it also posited technology advancement and expanding economic growth as blanket solutions to poverty across the global south. Political ecologists have often critiqued such sweeping generalizations as unnuanced and impervious to the multiple environmental realities and ways of managing resources that exist. With this in mind, political ecology studies often emphasize the safe-guarding and enhancement of environmental and social justice (Blaikie, 2012; Robbins, 2012). Therefore, studies in the field are often explicitly normative.

Political ecology research often questions perceptions and normative statements about the environment and the way environmental resources are managed. There are usually multiple ways of relating to and using the environment. Therefore, preferences and politics should not always be inflexible and closed off from debate. Exemplifying this point is a landmark collection of political ecology research by Blaikie and Brookfield (1987). The collection of articles in their book Land Degradation and Society are founded in the standpoint that people usually only consider land as degraded relative to how they use it. This relativist standpoint is not to play down the importance of maintaining a certain degree of environmental quality. Rather, it is to ensure that sweeping generalizations such as those expressed in the Brundtland Report are questioned and that counter-narratives from less powerful actors or organizations are also considered and accepted.

With this objective, the philosophy of science known as critical realism is foundational in political ecology and this has implications for research strategies and methods. With plural perceptions of nature and how to manage it, Blaikie & Brookfield (1987) analyse land management in different contexts, how people interact with their resources, what problems they face, physical change in their environments, and importantly, the economic context in which this occurs. Therefore, scientific approaches to measuring biophysical change are drawn upon, but the results are considered in relation to each case's political and economic context. This builds a more complex approach to analysing cause and effect that they term 'chains of explanation'. Forsyth's describes this epistemology as critical realism; an attempt to integrate "realist biophysical prediction with social and political constructions" (2003, p. 2). Unique in political ecology is how it integrates approaches to research typically associated with positivism and constructivism. Two epistemologies often considered incompatible (Forsyth, 2003; Robbins, 2012).

Since the 1990s, the field has exceedingly adopted postmodernist approaches (as in social constructionism and critical discourse analysis) and this has provoked critique. Most notably, and still relevant are the series of papers by Walker. Firstly, Walker (2005) points out how scholars of different disciplines can feel that the 'political ecology' title is not worthy if both fields (*politics* and *ecology)* are not engaged with meaningfully. He also suggests that the term ecology is often too loosely applied. This is contradictory considering the discursive focus on language and meaning are emphasized in political ecology. As the field begins to sprawl in many directions, Walker warns that researchers must display a careful understanding and appropriate use of ecology to ensure that further interdisciplinary political ecology is taken seriously. Walker (2006) also argues that political ecology's interdisciplinarity with complex mixed-methods approaches can be densely theoretical and burdening for readers. Walker claims that this complicates the extrapolation of the field's research implications for policymaking which paradoxically, is a core prescription in political ecology. Additionally, Walker believes that generally the field has been overly critical and that this has allowed narratives that political ecology has critiqued, such as neo-Malthusian discourses (for example, visible in Ehrlich, 1968), to gain a more popular foothold than counter-narratives produced and favoured in political ecology (for example that of Fairhead & Leach, 2006).

Perhaps the most recurring and evolving theme in political ecology is the field's engagement and critique of capitalist processes. Studies have often focused on environmental changes that can stem from transplanting capitalist models of economic development into areas with different systems of production (Blaikie & Brookfield, 1987; Peet & Watts, 2004). This is often summarized in Blaikie & Brookfield's words as a combination of "ecology and a broadly defined political economy" (1987, p. 17). Although not exclusively, case studies characterize political ecology's research approach, mostly at a local and regional level studying politics and its relationship to change in biophysical environment, but this is often juxtaposed with economic and discursive processes with a broader spatial scale (Zimmerer & Bassett, 2003). In this light, more recent directions the field has explored include conservation, urban development, market environmentalism and neoliberalism, to name a few. Inherent to political ecology on such topics is also a focus on power and inequality. Therefore, theories of Karl Marx have been widely cited and synthesized in political ecology.

3.2 Political Ecology and Marxist Theory

Political ecology has drawn upon Marx to explain uneven human influence on the environment and between humans themselves. For example, Harvey's theory of 'accumulation by dispossession' takes Marx's concept of 'primitive accumulation', which is an explanation for the origins of capital (understood generally as wealth) as being derived from a process of enclosing common property resources and redistributing them back to the populace using private property relations, and applies it to the modern era. The contradiction is that more resources must be brought into capitalist relations of production (meaning production and exchange generating surplus value) to continue expanding the avenues for surplus value to be invested profitably, and that inequality and environmental degradation subsequently increases (Harvey, 2003). This has also been applied to political ecology analyses of conservation areas (Büscher & Fletcher, 2015) and relates to political ecology's rejection of the human-nature binary. For example, conservation areas, and the politics and discourses that help establish them, have sometimes sealed off areas of the environment that people may depend on for their well-being and livelihoods (Benjaminsen & Bryceson, 2012; Cavanagh, Vedeld, & Trædal, 2015).

Marx pointed out inequalities in the capitalist system and analysed them in relation to the nature of production and value (Marx, 1990). He described value as comprised of 'use values', which are inherent and based on a commodity's function, and exchange value, which is a representation of use value and purely quantitative. For Marx, value is the product of 'socially necessary labour time'. This includes the time used to produce the product *and* the labour put into making it possible for the worker to go to work. Thus, exchange value for Marx is a representation of immaterial social relations (for example, home keeping and factory labour) that change material (for example, wood) into commodities (perhaps a table or chair).

From Marx's perspective social relations exist and have consequences which become embodied in commodities. However, under a capitalist mode of production these are considered inherently unequal based on the relationship whereby labour is underpaid to produce surplus value for the owner. In this arrangement, labourers who have only their labour to sell for a wage from capitalists (owners of the means of production; such as a factory), must do so to enable them to live, or 'socially reproduce', themselves. However, capitalists must pay their employees and themselves in addition to the costs of machines, inputs and for investing in subsequent rounds of production. Thus, it is always necessary to generate a surplus and pay workers less than the total value they generate.

This leads to several contradictions in the system. Marx also noted that under this system, goods produced for profit tend to be produced in excess. Thus, capitalists are compelled to look for new markets, innovate, and generally cut production costs to lower prices and incentivize more consumption. To continue this process, they must also accumulate more and draw more things and people into the production process. Marx (1990) described this process as the ‘metabolism’ of capitalism. He also hypothesized that this exploitative system would result in conflict between the working and owning classes but also highlighted how this systems exploits environmental resources. This explains how economic growth is always necessary and the system is self-reinforcing, and why it has been problematised in relation to biophysical limits to growth (Fletcher & Rammelt, 2017; Gómez-Baggethun & Naredo, 2015).

Harvey (2003), has theorized the point where capitalism is forced to expand as a crisis of overaccumulation. Rather than letting surpluses build up as capital, new avenues are needed to absorb surpluses and to perpetuate production and consumption. The mechanism of inflation in a capitalist economy is an important factor here. As the economy grows, consumers usually purchase more goods and services and governments must gradually increase the money supply. This usually forces sellers to increase their prices to cover the costs of producing more goods and services. Note that this is a structural dynamic (as in the economy over time), as opposed to a local or temporal dynamic (for example, a collapse in a fishery or crop damage from drought). Thus, if people or firms ‘over accumulate’ money (capital) as savings, as the cost of living or ‘reproduction’ increases, there exists an incentive to invest capital into more productive outlets (provided inflation outweighs interest rates). Harvey has linked this dynamic to imperialist expansion, globalization, and neoliberal governance throughout recent history (2005).

This is the basis of Harvey’s theory of the ‘spatial-fix’, or ‘spatio-temporal fix’ (2003, p. 139). The term ‘fix’ represents fixing capital in the form of built objects and infrastructure, but also creating new, or cheaper avenues for expanding production (Ekers & Prudham, 2017). Harvey (2003) writes that expanding what and who is brought into different facets of production can help stimulate consumers demand for goods, which in turn can stimulate new production for investing surplus capital. In other words, it is theory describing how capitalism ‘insatiably’ tries to “resolve its inner crisis tendencies by geographical expansion” (Harvey, 2001, p. 24). This is provoked by a tendency for capitalist production to overproduce since they do so for profit, rather than to meet a social demand, and do so based on the unequal relationship between worker and owner (Ekers & Prudham, 2017). In addition to expanding market opportunities, reducing the cost of inputs (such as land, material and labour) can also help increase the incentive to expand. This was seen in the fallout from the 2007-2008 financial crisis where ‘cheap’ land in certain areas of Africa was purchased by companies in order to generate profits from productive land as food prices soared and demand for biofuels increased (Borras, Hall, Scoones, White, & Wolford, 2011; Fairhead, Leach, & Scoones, 2012).

3.3 'Socioecological' Fix

Based on Harvey's theory of 'spatial fix' of crises of capitalism, Ekers & Prudham (2015, 2017, 2018) advance a theory of a 'socioecological' fix. Their first article on the topic states the aim to fill gaps in Harvey's theory of the 'spatial fix'. Ekers & Prudham note that Harvey's more recent work has moved towards 'socio-spatial' fixes; that is the expansion of capitalist processes in commodifying and exchanging social goods and services (such as water access, social welfare provision [Harvey, 2005]) with a focus on urban settings. Ekers & Prudham (2015) claim that Harvey's 'fix' theory diverged from adequately addressing capitalism's relationship with nature. Thus, they explore how nature and space can be 'produced' together through using different facets of the environment, modes of production and exchange, and the continuation of this process with the aim of producing surplus value a 'fix' but occurring in a politicised context.

Of interest is how 'nature' is used as an accumulation strategy. A key theoretical tenant here is an understanding of nature as 'produced' by the way we use it. As in; "an artefact of the direct or indirect transformation of biophysical processes and entities by social labour" (Ekers & Prudham, 2017, p. 1374). This stems from Smith's (1990) book 'Uneven Development'. Using Marx's conceptions of value (comprised of 'use value' being the pure utility of a good, and exchange value being a good's value abstracted and represented in the form of money), Smith proposes that, producing goods only to generate an exchange value alienates workers from the nature that they are transforming. This, he argues, contributes to, and reinforces a false nature-society dualism. Capital and labour invested into infrastructure is also included as nature here, albeit in a modified and economically productive form. Therefore, Ekers & Prudham (2017, p. 1380) quote Smith stating, "nature becomes a universal means of production in the sense that it not only provides the subjects, objects, and instruments of production, but is also in its totality an appendage to the production process" (Smith, 1990, p. 49).

Ekers & Prudham refer to these 'appendages to the production process' as fixed or 'sunk' capital and characterise it as 'socionatural'. 'Socionature' is nature, just in a form adapted, or produced, through the labour process and termed socionature to avoid dualistic human-nature terminology. Socionature, such as a factory might, be fixed to different degrees with different investment objectives over time. Ekers & Prudham (2017, p. 1376) equate such productive investments with grape vines, for example, as “fixed capital, producing grapes on an annual basis but with life cycles perhaps decades long.” Of course, this is not to say that agriculture is a ‘socioecological fix’, but it is the way that environmental processes are contested politically and how these “shape the formation and reformation of crises and corresponding fixes” (Ekers & Prudham, 2017, p. 1382) that constitute a ‘socioecological fix’. Therefore, Ekers & Prudham note that there is both a subjective and political nature to a sociological fix as well as a material, biophysical one. This too reflects a critical realist epistemology.

Concerning the biophysical nature of socioecological fixes, Ekers & Prudham cite O’Connor and his theory of ‘underproduction of nature’ (O'Connor, 1988, 1998). Although at face value this term seems incongruous in this context, it relates to the environmental externalities of production. That is the negative effects of production such as pollution or land degradation. Nature can be considered ‘underproduced’ if the conditions for further social reproduction and capital accumulation are undermined by the process itself and not repaired or reinvested in. Importantly, Ekers & Prudham (2017) note that this may be relational. Take the example of grape vines as a productive investment over a given period. Soil erosion from the vineyard might negatively affect a neighbouring farm. This is known as a negative externality. If there is no coercion for the vineyard to stop the erosion, it may be allowed to continue. At the same time, soil erosion may undermine the soil quality and thus, negatively affect further production of grapes. This could be considered an ‘underproduction of nature’. At one point or another, one party may pay another to fix the problems. In this way, another firm specializing in reducing soil erosion or mitigating the negative effects on grape production may see the externality or ‘underproduction of nature’ as a business opportunity. Therefore, according to O’Connor there is a tendency to ‘underproduce’ nature. Although to overcome the underproduction of nature, there is also a tendency to relocate or expand if externalities begin to undermine profitability. This dynamic has also been noted in relation to industrial aquaculture in other contexts (Beymer-Farris, Bassett, & Bryceson, 2012).

3.4 Summary

Ekers & Prudham (2015) justify their endeavour to theorize the ‘socioecological fix’ as important given that, in the last decade, environmentalism has often been equated with, or used as an accumulation strategy. In other words, capitalism has recently been posited as both the problem and the solution to environmental problems but with uneven social outcomes (Büscher & Fletcher, 2015; Fairhead et al., 2012). The last of Ekers & Prudham’s (2018) three articles, therefore, shifts the focus towards capitalism as hegemony. They note that understanding political and cultural influences as a foundation for legitimacy must be examined as an element of a socioecological fix (Ekers & Prudham, 2018). Because the term ‘hegemony’ represents a state of control or even oppression, and usually refers to relationships between countries, it risks portraying those subject to or participating in the process of a socioecological fix as politically bounded. This may be unproductive if wishing to nurture and engage in dialogue to change political and cultural influences as a foundation for legitimacy. Therefore, I argue that the term is less appropriate for this context and adopt the term ‘predominance’ instead. Its definition is more anthropic and less determinant and therefore, recognizes that there are plural understandings and acceptance of the contexts surrounding socioecological fixes.

Although the authors note that this theory of socioecological fix is relevant to large scale land transformation to infrastructure, this thesis uses it to examine a relationship between so-called ‘cleaner fish’ and salmon. It is relevant considering the stagnated growth experienced by the industry, which is partly attributed to the salmon lice problem, and constraints placed on growth in the industry by authorities based on salmon lice numbers as an indicator. Economic growth is considered predominant in terms of the salmon industry based on the stated goal of the laws governing aquaculture in Norway. The Aquaculture Act (2006, § 1) states, “the purpose of this Act is to promote the profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and contribute to the creation of value on the coast.” This will be discussed below along with other facets of the socioecological fix as presented in this section. These include the value embodied by commodities, ‘fixed’ productive capital embedded in landscapes, the ‘production’ and ‘underproduction’ of nature, and the politics and contestation of the development of cleaner fish use and aquaculture. These will be discussed using critical political ecology as a lens.

4 Results

4.1 Origins, Uncertainty and Impermanence

Two overarching themes emerged from the data concerning the history and development of cleaner fish use, namely *uncertainty* and *impermanence*. This section explains how the themes are interrelated using examples of how knowledge surrounding the fishing and aquaculture systems that supply cleaner fish use in salmon farms have developed. Firstly, however, a finding regarding the origins of cleaner fish use is presented.

The first few interviews immediately revealed a history that conflicted my background knowledge of cleaner fish use. One company was sighted by other farmers in the same region where field work was conducted as being one of the earliest salmon farmers to use cleaner fish. Based on this insight, a request was made to the owner of this company who willingly put forward evidence that his father had used ballan wrasse for delousing salmon many years before the first scientific tests. The owner showed a letter (Figure 2) from the Institute of Marine Research (IMR) from 1976 addressed to his father, who started the company. The letter, from an earlier Research Director at the Institute, states that he had read a newspaper article mentioning that the farmer 'Karstensen' had used ballan wrasse for salmon delousing. Karstensen's experiences could be useful to IMR since they had conducted some small-scale tests with fish for delousing salmon. Figure 3 is the newspaper clipping that the letter from IMR refers to.

Despite the article's title, the body of the text says nothing explaining the use of cleaner fish. Karstensen's son believed his father got the idea from a local fisher and stated that his family's salmon farm has used wrasse species ever since, except for a short period during the 1990s when chemicals were effective against lice. Other salmon farmers in the area also believed this to be the case. This documentation is of interest because it *precedes* the first formal studies conducted by Bjordal (1988), and Bjordal's own knowledge of IMR working on the topic, by approximately 10 years. Bjordal believes that since the use of cleaner fish was not adopted by more farmers until after he proved the method scientifically, that it is likely that Karstensen was unsuccessful. He also believed that the then Research Director from IMR who wrote the letter would have followed up the case had successful results been documented.

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(BES OPPGITT VED SVAR)

Fiskeoppdretter Erling Karstensen
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Vi har nettopp lest om Deres oppdrett av laksefisk i Fiskaren, datert 27.9. d.m. under overskriften "Lakseoppdrettar i Batalden brukar små-berggylte for å plukke fisken rein for lus".

På Havforskningsinstituttet har vi gjort en rekke forsøk med sikte på å holde lakselusen under kontroll med fisk som spiser lus. Vi er derfor meget interessert i å høre nærmere om Deres forsøk. Bl.a. om hvilken berggylte som brukes og hvor mange berggylter som nyttes i forhold til laksemengden.

Vi ville være takknemlige om De kunne gi oss et ord.

Vennlig hilsen

Dag Møller

Figure 2. *Scanned letter from the Directorate of Fisheries to salmon farmer requesting more information regarding their use of wrasse for delousing salmon.*

Lakseoppdrettar i Batalden brukar små-berggylte for å plukke fisken rein for lus

Erling Karstensen i Batalden er av dei mange som har satsa pa oppal av edelfisk. Det ser ut for oss som om han har gjort det pa rette maten. Han har starta varsamt opp med rimelege anlegg og får bra overskot når prisane er gode, og held hovudet over vatnet når dei er darlege.

Pa ettersommaren eller til hausten får han «slakteferdig» laks og regnboge-aure, og det blir ei spenande tid framover. Korleis blir prisane?

I mirane har han gaande ca. 10.000 regnbogeaure som er mellom 1 kilo og 1.5 kilo, pluss ein stad mellom femten hundre og to tusen laks av noko varierande storleik. Det er ikkje alle som veks like fort, sjølv om dei startar likt. Karstensen sette ut 12.000 regnbogeyngel og 2000 med laks, men 10—20 prosent svinn ma ein rekne med. Svinnet kjem pa så ymse matar. Det kan vere sjukdom større eller mindre huell, og sa greier fuglen å nappe seg ein fisk no og da — trass alle «sikringstiltad».

Hegren er nask etter laksen. — Oddvin Karstensen fortel at han ved eit tilfelle kom til a sjå korleis det gjekk til. Ein hegre kom og sette seg i nota. Han spilte vengene utover nettet og stakk halsen gjennom maskane og strakte seg til han vart «halvanna meter lang», som Karstensen sa. I alle fall har han aldri sett ein så lang hegrehals, og sanneleg kom han opp med ein pen liten tert.

— Kor stor skal fisken vere før den er salsvare?

— Det vanlege er ei foringstid pa halvanna til to år, og det kan vere så ymse med vekta, seier Karstensen, og fortel at første gongen han tok opp fekk han laks på 4—5 kilo etter to ar og regnbogeaure pa opptil 3.6 kilo pa halvanna år. I år ser det ut til at fisken på jamnen blir ein god del mindre.

No er det slik at sommaren er den beste vekst-tida og fisken kan kome seg svært mykje. I sunda langs Fandya samlar straumen opp raudate i store mengder og den hjelper godt på foringa.

Elles kjem Karstensen stort sett rimeleg til føret. Det blir brukt mykje fiskeavfall som han delvis skaffar til veges sjølv og ein stor del får han med dei som driv og fiskar i Batalden, i staden for å hive avfallet på sjøen, så går det på fryseriet til Karstensen. Det har begge partar nyte av. Når det ikkje er sjóver, får dei til gjengeld sette inn linene sine så agnet ikkje blir øydelagt. Den eine tenesta er den andre verd, heiter eit godt og velkjent ord.

Å drive med fiskeoppdrett blir rekna som ei nokså sjanseprega næring. Sjansane er i alle fal store for at det skal gå skeivt. Sjukdom på fisk som går så tett saman, er vel største fåren. Karstensen driv som nemnt eit billeg anlegg. Dessutan er det bra utsikter til å unngå epidemiar på fisken i dei dkupe sunda der reine sjøen straumar frisk igjennom.

Dessutan har han funne fram til eit par «triks» for å hjelpe seg mot snyltarar som er nesten uunngåeleg i slike tette kulturar. For ei tid sia fekk han mykje lus på laksen.

Figure 3. *Article from 'Fiskaren', 27 September, 1976 with heading 'Salmon farmer uses small ballan wrasse to clean the fish of lice'. Accessed online from the National Library of Norway.*

This history suggests that the idea for using cleaner fish had existed within small-scale testing in the early era of salmon farming in Norway. Nevertheless, the scale and success of their use at this stage is unclear. Cleaner fish use was later tested by scientists and adopted at larger scales by salmon farmers. This progression was a reaction to the intensification of salmon production, whereby challenges with salmon lice and how to address the problem became more acute.

Bjordal, who conducted the first scientific trials of Labridae for salmon delousing, was inspired at the time by research on biological pest control in agriculture and the possibility of reducing chemical use to delouse salmon. Chemical use in Norwegian salmon farms was common at the time, and the researcher mentioned the negative effects that chemical use is thought to have had on lobster and crab larvae. Knowledge arising at that time about the stress induced on salmon by performing chemical delousing was also cited as an incentive to test cleaner fish as a delousing method. Thus, reducing these side effects by using cleaner fish as a biological control that could graze on lice persistently in salmon cages without human handling or chemical inputs was seen as positive. Bjordal realises that many more problems have emerged since the first cleaner fish tests were conducted in the late 1980s.

Similarly, regulators from the Directorate of Fisheries acknowledged the problems with cleaner fish welfare and the rapid growth in the scale of the fishery. Cleaner fish use was initially thought to only be a temporary solution to the industry's lice problem. There was almost a blind faith in the salmon industry to solve the lice problem without chemicals due to the strength of their resources and history of innovating. One advisor working with the wrasse fishery believed that fishing pressure on wrasse species would quickly go away, assuming that the salmon industry would find something else to solve the lice problem. Although, it was then stated,

> "but then it became apparent, as time passed, that they [salmon industry] didn't find anything else. The solution didn't lie as close as we had thought. For us who deal with wild fish, then if we had just found a solution very fast, the fishing pressure would have declined."
>
> ["Men så viste det jo seg etterhvert som årene gikk at man fant ikke noe annet. Altså løsningen lå ikke så tett som vi hadde tenkt. For oss som driver med vill fisk så ville det jo vært sånn at om vi bare hadde funnet en løsning veldig raskt så ville jo på en måte fisketrykket avta"].

A regulator from the Directorate of Fisheries also stated,

> "At the same time, it was seen the effect of using chemicals on prawns and lobster molting. There were examples where people thought it might be chemicals, or is because of chemicals and then it became even more important [to use cleaner fish]. […] we thought it would be temporary because the salmon industry is so capital strong and big

that they will find another solution, and they should because they have a lot of money for it. Then they don't find it. Exactly the opposite – Chemicals don't work anymore."

["Samtidig så man også effekter av bruk av legemidler med skallskifte på reker, hummer, man hadde tilfeller der man trodde at dette er jo legemidler, eller det er legemidler, og da ble det enda viktigere. … vi trodde jo at dette skulle være midlertidig, for laksenæringen er så stor og så kapitalsterk at de finner nok en løsning og det skal de gjøre for de har penger til det. Men så finner man ingen løsning, tvert imot – legemidlene virker ikke lenger"].

So, while decisions from regulating institutions such as the Directorate of Fisheries should 'knowledge-based' in Norway, it appears that in the case of cleaner fish an exception was made in order to help the salmon industry with its lice problem. However, this was seen as an impermanent alternative. The Food Safety Authority aim to provide cleaner fish with the same welfare status as salmon under the Animal Welfare Act (2009), but in the eyes of regulators from the Directorate of Fisheries, this was outweighed by optimism for cleaner fish's potential for reducing chemical use. For example, regulator stated,

"this with lice was a very big problem [...] and then this was biological delousing, and that was the 'solution for everything' (exaggerates voice tone – as if to say 'this saves the day again') yes, great! So, there was no one that considered how people fished completely uncritically. […] people only thought about solving this problem with lice and less chemicals, that also after a while stopped working. So, people pretty much forgot to think about cleaner fish because that was 'biological control' and that everyone was happy with it. Then suddenly someone began to raise critical questions about extraction, welfare and health of these fish and so yes. It reversed everything a little bit."

["dette med lus var jo et stort problem, kjempestort problem … Og da var dette på en måte biologisk avlusning og det var «the solution of everything» på en måte. «Ja, Flott!», liksom sånn. Da var det ingen som tenkte på dette med at man fisket helt ukritisk, … man tenkte kun på å løse dette problemet med lus, og mindre legemidler, som også etter hvert begynte ikke å virke, sant. Så man glemte rett og slett å peke på rensefisken fordi det var biologisk avlusing og det var alle fornøyde med. Og så plutselig begynte noen å stille

> kritiske spørsmål både ved bestandsuttak og velferd og helse til den fisken og det og reverserte på en måte alt littegranne"].

This portrays the fact that cleaner fish were a 'biological control' as having helped reduce critical reflection towards cleaner fish use. A change in perception from optimism to scepticism of the practice is also visible here. Similarly, the interviewee from the Norwegian Environment Agency also stated that using cleaner fish looked like a relatively more environmentally friendly method in the beginning but also raised doubts towards the efficacy and welfare of the practice. For this interviewee, the legitimacy of cleaner fish use was challenged due to welfare concerns more than due to wasteful resource use.

Interviewees from the Food Safety Authority also insisted that cleaner fish mortality rates must be improved if they are to allow the practice to continue. This too is evidence of the theme of impermanence. For example, one Advisor from the Food Safety Authority stated that "the Authority has been very clear that it [the salmon and cleaner fish production industry] cannot continue with current mortality rates and limited oversight of [fish] losses" ["mattilsynet er jo veldig tydelige. Har jo vært veldig tydelige nå på at dette kan ikke fortsette med den dødeligheten og mangel på oversikt over svinn"]. This statement and the context of cleaner fish campaign in general refer specifically back to the laws governing animal welfare. It was stated by another working for the Authority on the campaign,

> "salmon and cleaner fish have exactly the same protection under the law. There is not a difference between a salmon and cleaner fish life. And they have the same protection as other animals. But in practice, we accept some things for fish that we would not accept for other animals."
>
> ["i utgangspunktet så har jo laks og rensefisk akkurat samme beskyttelse i lovverket. Det er ikke noen forskjell på et rensefiskliv og et lakseliv og de har egentlig samme beskyttelse som andre dyr. Men så er det sånn at i praksis så aksepterer vi en del ting for fisk som vi ikke aksepterer for andre dyr"].

4.1.1 Cleaner fish Use in Salmon Aquaculture

Based on experiences of the interviewees, this section illuminates how cleaner fish are used. Data relating to the practical challenges of holding cleaner fish together with salmon mortality in salmon farms is presented and connected to uncertainties regarding efficacy and welfare.

Cleaner fish are considered a technology for lice treatment. However, under the law they are assumed to be sentient and are thus subject to the same welfare regulations as salmon. This is well understood by farmers, but it was generally accepted that using cleaner fish is “in a way a trade-off, because when we use cleaner fish we expose salmon to much less stress, so we get better welfare for salmon, but it is maybe a little bit at the cost of cleaner fish.” [“Så det er på en måte en litt sånn oppveiing der, fordi at når vi bruker rensefisk, så utsetter vi jo laksen for mye mindre stress og da får vi jo bedre fiskevelferd på laksen, men det går kanskje litt ut over rensefisken”]. Nevertheless, interviewees who use cleaner fish stated their will to improve the welfare for cleaner fish and, for the most part, to comply with the regulatory demands set by the Food Safety Authority, especially in regard to reducing mortality during their time in salmon cages.

One salmon farmer interviewed with a small farm (two licenses) documented a saving of around 3 million NOK during one production cycle from savings in thermal treatment costs. For them, using cleaner fish was cheaper. It also helped them avoid other delousing methods which temporarily halts salmon growth which also increases production costs. The farmer noted the set out of cleaner fish correlated with a decline in lice number and reduced the number of delousing treatments to be expected here, but the farmer was careful to attribute the effect directly to cleaner fish. This farm used a 1:5 (20%) salmon-to-cleaner fish mixing ratio with a mix of around 15% farmed lumpfish and 5% wild-caught wrasse. Supply was expected to alternate seasonally with wrasse released after the fishery opened and the water was warmer in mid-July, while lumpfish would be released when the water gets cooler and wrasse become less active. At the end of each of these cycles it was assumed most fish would be dead, while the remainder would be anaesthetised. For this reason, an interviewee from the Food Safety Authority characterized cleaner fish as ‘consumer products’, reflecting on what could be considered a ‘use and throw away’ relationship.

At the same time, cleaner fish are considered an investment that need maintenance, or ‘care’ to keep them healthy and to maximise their function as lice-eaters, but this demands extra work from farmers.

> “They cost a lot of money and we only fish once a year, so we want to ensure that they survive. We use a lot of time to make sure they get food and protection and to fish them out, and if we have [salmon] treatments, it is very important with careful handling of cleaner fish” (salmon farm representative).

> [“de koster mye penger og vi fisker jo bare en gang i året så vi er veldig opptatt av at den skal overleve. Vi bruker mye tid på det her med å følge med på rensefisk og fôring og skjul og. Også det med utfisking. Og hvis vi har behandling så er dette med skånsom behandling av rensefisken veldig viktig”].

Companies interviewed use money and time providing, testing, and cleaning shelters for cleaner fish, and providing them separate feed. A medium sized company stated that “a third of the workforce is there because of wanting to maintain good fish welfare and look after lumpfish and wild caught wrasse.” All the interviewees used different systems to provide shelter for cleaner fish. Different methods were used and their practical qualities in relation to cleaning and effectiveness were mentioned. One farmer stated that lumpfish hides were important and noted that the model ‘Sea Nest’ that they used had been proven through research as effective for lumpfish. All submerged equipment at salmon farms needs to be washed routinely for growth of marine organisms. Two interviewees that had worked for many years with cleaner fish (one producer and one feed salesperson) stated that many workers dislike the extra work. For example, it was stated that salmon farmers “are meant to work with salmon, this is what makes money. That’s is why lumpfish loose the fight […] because it is so much work. Farmers - they don’t have time” [“de (oppdrettere) er pålagt å jobbe med laksen, det er de som skaper pengene. Derfor så taper rognkjeksen i kampen …. De har ikke tid til det”]. Indeed, using cleaner fish is a management burden because they must be provided with suitable conditions which differ to those suitable for salmon. Yet this type of maintenance work is important for cleaner fish efficacy. For example, if growth on submerged nets and cleaner fish hides is excessive, cleaner fish tend to graze on marine organisms here, instead of on salmon lice.

Although, a bigger problem for farmers is the variation in effect and temperature tolerance of cleaner fish. Salmon farmers mentioned how “lumpfish become less effective over 10 degrees and then at around 18 degrees, they begin to struggle. They do not tolerate this well.” [“rognkjeksen blir mindre effektiv over 10 grader og rundt 18 grader – da sliter den. Det tåler den ikke godt]”. It was generally noted that this was a large problem that results in higher mortality. In addition, those that survive until water temperatures are suitable again may become too large to be effective, and thus become more of a burden. One farmer stated that

> “lumpfish are too big when they are half a year old and this is part of the ethical challenge here – what do we do with them? They have no use but become more of a problem when we get further into the production [cycle]. This I feel is in a way, very important with this.”
>
> [“rognkjeksen den er egentlig for stor når den er et halvt år gammel og det er en del av den etiske utfordringen her også – hva gjør vi med den? For den gjør ingen nytte, men blir mer et problem når vi kommer utover i produksjonen. Dette føler jeg er på en måte.. er veldig viktig opp i dette”].

At the end of a salmon production cycle farmers are, therefore left with less useful cleaner fish that can be fished out and anaesthetised or temporarily kept and transported to another farm or location if or when one becomes available – a possibility usually only realistic for larger companies with many locations to rotate cleaner fish between. Salmon farmers are also reluctant to transfer cleaner fish between cages for reuse since they may pose an infection risk.

Additionally, separating cleaner fish from salmon is difficult. Some companies fish them out with traps before harvest, or some well-boats can sort cleaner fish from salmon. One company used a net with a certain hole size and shape which allowed smaller fish to swim through including “a good part of the cleaner fish” [“en god del av rensefiskene”]. Another stated that many localities have such high mortality, that when it comes to harvest, there is no cleaner fish left. It was also noted that fishing out cleaner fish is extremely difficult, especially with lumpfish. The shape and size of lumpfish also lead to problems with the sorting system on well-boats. This means that many cleaner fish end up with salmon in delousing treatments since well-boats are also used for this function. This too reportedly increases mortality among cleaner fish, especially the practice of raising and crowding wrasses, a practice carried out before pumping them through well boats. This is because raising wrasses too fast induces a form of decompression sickness. The examples above of practical challenges for salmon farmers generated by cleaner fish husbandry are important because they demonstrate the need for support or service businesses and research to optimise these methods and equipment.

Despite the burden on workers and management in keeping more than one species in their farms, cleaner fish can potentially save salmon farming companies money. If cleaner fish delouse efficiently, it is believed that using them can reduce the number of additional delousing treatments, which are costly. To try and keep cleaner fish consuming lice effectively, it is important to keep nets and hide areas clean to reduce growth of marine organisms which the cleaner fish may also graze on. However, cleaner fish are often also provided a specialised feed. Additionally, other common delousing methods, such as mechanical or thermal treatments, require that salmon are starved for a short period prior to treatment. This increases the stress tolerance of the salmon but disrupts the salmon's growth. Therefore, considering that these treatment methods may also induce additional mortality, the more they are avoided, the faster it is possible to grow more fish to send to slaughter and sell.

Nevertheless, there was a clear uncertainty around how effective cleaner fish will be. Uncertainty regarding lice numbers during the season was also mentioned since some years there are more lice than others. Thus, other lice treatments are usually necessary depending on lice pressure. One farmer stated,

> "if we go over [the threshold] then we have to do something and then it is 'thermolicing' (use of thermal delousing treatment) - that is the way out. So that's why we want to use cleaner fish as much as we can to avoid unnecessary treatment."
>
> ["hvis vi kommer over der, så må vi gjøre noe. Og da er det «thermolicing» som er utveien. Så det er derfor vi har lyst å bruke rensefisk så mye som vi kan for å unngå unødvendig"].

Another farmer aimed to have a 'recipe' for how to manage lice numbers and stated,

> "I know what I am going to do, and the salmon we put into the sea now [beginning of March], they will have wild caught wrasse in the middle of July, and then you will have farmed lumpfish at the end of November. If it is still warm in the sea, we won't put the lumpfish out, we just accept that we have to delice. We have to treat the fish."

This is an attempt to gain a degree of certainty and plan how to use cleaner fish and reduce losses. This farmer could release lumpfish pre-emptively when the water is still warm anticipating that the water temperature will fall, but many may die.

> "there is always a great deal of variables. Some years it seems the currents just miss our localities; they don't bring masses of lice with them. Other years there is just horrible amounts. So, nothing is decided, apart from our intentions […to produce fish]."

Thus, in planning how to use cleaner fish with uncertainty related to lice and seasonal temperature change, other delousing treatments are often unavoidable.

Visible in this section is uncertainty surrounding the efficacy and survival of cleaner fish when used for salmon delousing from farmer's perspectives. Efficacy depends on environmental factors and the nature of keeping cleaner fish and salmon together in the type of facilities used. However, most still consider cleaner fish use as a step away from chemical use, and therefore, a step in a positive direction. It was also generally believed that more time is needed to improve difficulties currently experienced with welfare, even though cleaner fish are suffering disproportionately now. It was stated, "I think these things will be solved but we are in an early phase here. Fish welfare is actually very important for us and actually for everyone" ["jeg tror at disse tingene vil bli løst, men vi er in i en tidlig fase her. Fiskevelferden er jo veldig viktig oss og egentlig alle sammen"].

4.1.2 Uncertainty in Cleaner fish Aquaculture

A concept that was coded in interviews relating to aquaculture production of cleaner fish, fishing, research and with regulators was that of 'trial-and error' testing to gain knowledge and experience. Such examples were coded and helped generate the theme of 'uncertainty'.

Lumpfish and ballan wrasse farmers test different light regimes, feed compositions, grading and grouping in different tank sizes, and this may vary according to location. For example, it was stated that parameters such as quality of sea water pumped into a facility, equipment used, and the lay out of the facility all influence production methods.

Ballan wrasse production was noted to be more complicated than that of lumpfish. Small ballan wrasse in land production are vulnerable to high mortality rates and it is difficult to predict and control production parameters. For example, over time it was learnt that moving the fish between different tanks as they grow was a critical factor, one that did not lead to physical injury but caused severe stress and mortality. It was also stated that,

> “...there are a many unknown factors. If you are going to make a plan, then you must predict a few things that you don’t quite have the answer for… growth rates… this varies a lot, we actually do not have very good numbers. Also feed consumption… and mortality vary a lot.”
>
> [“…det er så mange ukjente momenter, sant. For hvis du skal lage en plan så må du jo forutsette en del ting som du kanskje ikke helt vet svaret på. Sånn som veksthastigheten og sånn det er litt, det varierer veldig, så det har vi ikke egentlig så veldig gode tall på. Og fôrforbruk og litt sånne ting også.. Og dødeligheten varierer veldig mye også og ja. Det er nok å ta hensyn til”].

Several different live feeds are also used. Rotifers for example, require an additional production within the facility because they must be cultured to attain suitable nutritional qualities and must be controlled for infectious bacteria. The interviewee considered a new feed of cryo-preserved nauplii as being potentially revolutionary for marine fish production because it is simpler to revitalize and has less infectious bacteria present. Important here is how producing live feed represents a whole extra production of different species within this ballan wrasse facility. It also demonstrates how producing and optimising cleaner fish feeds are another so called ‘spin-off’ industry emerging to support ballan wrasse production. This also helps explain why, as more knowledge is gained, certain technology or innovations may become obsolete.

A lumpfish farm manager interviewed also explained how farming new species requires trial and error experimentation. The lumpfish farm manager explained how there are 50 years of experience and research with salmon farming and only a few years with lumpfish. The manager also expressed discontent with the languidness of research institutes to generate knowledge relevant to them and gave examples of their anecdotal testing through trial and error.:

The inevitable outcome, however, is that tests may go wrong or that unexpected factors reduce fish welfare or increase mortality. For example, regarding their initial trials with lumpfish production here it was stated,

> "we started buying juveniles from a producer for on-growth, and this was disappointing because the fish had Pasteurellosis [a bacterial infection] and all the fish died. When they were gone, we destroyed everything. Tanks, pipes… everything, and started again with our own hatching."
>
> ["vi startet med å kjøpe yngel fra en yngelprodusent for påvekst, og det var en veldig nedtur fordi fisken hadde pasteurellose. Så all fisken døde. Da vi hadde den fisken ut av anlegget, så rev vi vekk alt, kar, rør… alt, og startet på nytt med egen klekking"].

Of note here is how trial and error production forces new aquaculture operations to experiment and innovate to improve results. However, at the same time fish welfare and mortality is a crucial regulatory indicator being used to force the industry to improve even though there is great uncertainty about how successful these new aquaculture operations may be. Thus, there is a tension between regulators and farmers trying to improve their production.

This was most visible in one example related to vaccination of lumpfish. Some lumpfish farms do not anesthetize lumpfish at vaccination, and these were considered in breach of regulations during the Cleaner fish Campaign. When asked about the Food Safety Authority's recent regulatory campaign, the lumpfish farm manager explained how they do not provide anaesthesia before vaccinating lumpfish because they believe this decreases the survival rates of the fish.

> "The only thing we disagreed with was this with anaesthesia for vaccination. We refused and we got a warning there. But we will never anesthetize a lumpfish because you extend the stress. If you take a salmon unanaesthetised on a table, it will kill itself or kill you, right. Or, you will prick yourself with a needle, or you miss the spot on the salmon. It is

impossible to vaccinate a salmon without anaesthesia in a safe and good way. So, you have to unanaesthetised them."

["Det eneste som vi egentlig var uenige med mattilsynet om det var bedøvelse ved vaksinering. Og der nektet vi å… Altså, vi fikk avvik på det, men vi kommer aldri til å bedøve rognkjeksen. Fordi at du forlenger stresset. Altså laks.. hvis du tar en laks ubedøvet opp på bordet.. enten så dreper den seg selv eller så dreper den deg, ikke sant, eller så stikker du deg selv med vaksinesprøyten eller så feilstikker du laksen. Altså det er helt umulig å vaksinere en laks uten bedøvelse på en trygg og god måte, så der er du nødt å bedøve"].

However, they argued that lumpfish have a different stress response to handling whereby they freeze and become lethargic. The belief stemmed from handling responses at their farm and other examples such as how if a lumpfish ends up out of the tanks and on the floor, they can lie there for up to a half hour and rejuvenate when submerged in water again. Nevertheless, interviewees from the Food Safety Authority referred to this example as anecdotal knowledge of individuals and not documented scientifically. If the Authority was to approve this practice, it was considered the industry's responsibility to have a scientific institution document the response from lumpfish under vaccination without anaesthesia as responsible regarding fish welfare.

This example is important because should documentation for mortality causes, and efforts to rectify issues causing mortality not to be improved, the Food Safety Authority threatens to stop the use of cleaner fish as a delousing method. It is here that the theme of uncertainty connects to another overarching theme of 'impermanence'.

The cleaner fish coordinator from a salmon farming company who also produce their own lumpfish and the lumpfish farm manager were interviewed a second time to gain their impressions of the results of the cleaner fish campaign. Both were aware of the results, although had not read the reports, but had perceived the Food Safety Authority's conclusions as 'threatening' the future of cleaner fish use. After asking the cleaner fish coordinator about their situation amidst the economic crisis ongoing at the time, it was replied,

> "The biggest problem on the horizon is how to get cleaner fish to survive in a fish farming environment. If we can't solve the problems with poor cleaner fish survival, then the government will stop us from using them in the end."

The lumpfish farmer had also heard of what he referred to as "the massive pressure from the Food Safety Authority against the industry on fish welfare" ["det massive trykket fra mattilsynet mot næringen på fiskevelferd"]. Since the campaign's conclusion, he had heard of several farmers who had decided to increase their use of thermal and mechanical delousing methods instead of using cleaner fish. He believed that they perceived cleaner fish as easier to cease using since the practice is relatively new and less familiar that they would rather accept other methods as a "necessary evil" ["nødvendig onde"].

Nevertheless, one interviewee pointed out the business opportunity created by producing lumpfish, but only as a temporary venture. This salmon farm manager described the owners of the company as, "very adept at taking advantage of the demand for lumpfish" ["veldig dyktige på å utnytte etterspørselen etter rognkjeks"], but assumed that in five years, use of lumpfish would not be allowed. However, in the meantime, he thought that his employer would exploit the opportunity "to earn a lot of money" ["å tjene grovt med penger"]. At the same, there is currently a large demand for farmed cleaner fish and production of lumpfish especially has grown exponentially in recent years. At two of the three cleaner fish production facilities visited, large new constructions were underway to expand production, while the third had recently completed a new facility lying beside the older one. All three of these facilities had earlier produced other species and gone over to producing cleaner fish. One had produced salmon smolt but the environmental conditions at the location were unsuitable, whereas cod were produced at the other two locations.

An interviewee at one of these locations described two 'waves' of effort to produce cod in 2001 and 2007 at this location. This location was then owned by other companies that the interviewee described as financial investors interested in profit rather than the in fish or the aquaculture industry. These operations went bankrupt and he was again employed here in 2013 when his current employer purchased the property and decided to attempt farming lumpfish. Similarly, the ballan wrasse facility visited also produced cod until pressure from financial crisis at that time contributed to a decline in demand for their juvenile cod. The company then decided to immediately invest in production of ballan wrasse and gave the team three years to try and increase production before re-evaluating its future. Visible here is the concept of ‘uncertainty’ but also in the way cleaner fish aquaculture began as an effort to rejuvenate production at certain locations.

For those selling surplus lumpfish externally, this is indeed a profitable business. Conversely, for ballan wrasse production, should production increase enough to sell surplus to other companies the manager there believed this would be highly lucrative. Several other interviewees also hoped ballan wrasse production would increase since they are believed to be the most effective and robust in salmon cages. Therefore, they require a lower ratio to salmon and could reduce lumpfish use and pressure on the wrasse fishery.

4.1.3 Wrasse Fishery

The most dominant themes in discussions with interviewees about the wrasse fishery were also uncertainty and impermanence.

One fisher interviewed had received their quota when the quota system was implemented in 2016. “It is 10 years ago that it became very attractive [to fish wrasse …]. Prices increased a lot, and the problem with salmon lice just got bigger and bigger” [“Det er ca. 10 år siden … da ble det veldig aktuelt. Prisen på leppefisk steg veldig og problemet med lakselusen ble jo bare større og større”]. Gesturing to the bay immediately outside the fisher’s residence, the fisher stated that he fished eel and wrasse here earlier but was not paid by a buyer on one occasion. He considered the fishery poorly organised at that time and thus decided to stop. However, since he could document a catch, the fisher fulfilled a prerequisite which allowed him to acquire a quota in the ‘open group’, thus gaining the right to fish 48 000 fish during the season. The fisher noted that this fishery is completely dependent on demand from salmon farms. Thus, it was seen as an impermanent undertaking that could disappear as fast as it arose. The reason given for this was due to the negative attention cleaner fish practice has received.

Regulators at the Directorate of Fisheries consider the wrasse fishery very important for coastal fishers, but also to the salmon farming industry. It was acknowledged that fishers can earn well from fishing for wrasse. The value of the wrasse fishery was compared to that of the prawn fishery in Southern Norway – 300 000 000kr. This is weighed heavily in the regulations considering that coastal fishers have had several other species restricted (coastal cod, lobster, eel) in the past. Therefore, it was stated,

> "we have had problems with many species, especially in the south [of Norway]. We have restricted fishing on many species… Coastal fishers needed a new income source, and this was in a way a win-win."
>
> ["Vi har hatt problemer med mange arter, spesielt på Sørlandet. Vi har strammet inn på fiske av mange arter … "Kystfiskerne trengte jo en ny inntektskilde, og dette var en slags vinn-vinn"].

Also, since ballan wrasse is the most valuable cleaner fish (approximately 30kr per fish) but the least abundant, the Directorate has overlooked the recommendation from the Institute for Marine Research for a minimum size restriction on the ballan wrasse that allows them to reach spawning age – referred to as a 'biological minimum size'. They have chosen a 'commercial minimum size' which was explained as a compromise at the hearing meeting to ensure there was enough ballan wrasse for salmon farmers.

This is an important concession to the salmon industry since the 18 million-fish quota for 'wrasse' is not species specific. Thus, ensuring that fishing pressure was not harder on ballan wrasse than on other species of wrasse was considered a key challenge. "We have to look out for that not everyone throws all the other species back and only takes ballen wrasse" ["vi må jo passe på at ikke alle hiver ut igjen alle de andre artene og bare tar berggylt"]. To select smaller wrasse than the recommended 27cm minimum size, but larger than the actual minimum size of 14 cm, from 2021 trap-entrance sizes will be regulated to 60mm to protect larger ballan wrasse (Directorate of Fisheries, 2020c). Thus, while the concession on ballan wrasse sizes will help supply the demand from salmon farmers, new restrictions being phased in will likely limit the fishing pressure on ballan wrasse later.

Regarding the beginning of the wrasse fishery, the regulator from the Directorate of Fisheries started from assessing the basic biology of the species and regulations have developed iteratively thereafter. Therefore, it was stated by the fisheries regulator that "there has not been fixed regulations right, we have kind of tested our way forward. What works and what doesn't" ["det har jo ikke vært en sånn fast regulerer på en måte sant, for dette har vært et nytt fiskeri så vi har jo prøvd oss frem, hva virker og hva virker ikke"]. There has been too little fishing in the past for there to have been any concern for wrasse populations earlier. Governing fishing of new species is the 'management principle' [forvaltningsprinsippet]. This states that one can start to fish if there is no regulation on a species, and management and research are mandated to assess with even intervals whether the harvest of the species is sustainable. 'Wrasse' collectively, are considered as 'data poor species' in a table with the status of fished species compiled by the Directorate of Fisheries, while IMR has the responsibility for commissioning research on species should the need arise (Gullestad et al., 2017).

A researcher from IMR explained that the fishery developed rapidly, and that this hindered the researchers' ability to understand the impact of the fishery on wild populations. Therefore, it was stated that the question about whether the fishery was sustainable was "hanging in the air". One side effect of what Halvorsen called "lagging behind the fishery" were complaints and conjecture they had heard based on peoples' experiences. It was noted that the "narrative is that the fishery is unsustainable". People had complained that wrasse in their own area were depleted and that therefore, wrasse are overfished.

The wrasse fishery in the area around Austevoll in Western Norway was suggested to be suffering "a sort of 'tragedy of the commons' type situation", where norms regarding even and dispersed fishing pressure on target species had broken down. An informal telephone conversation had with a fisher who had worked around Austevoll supported these claims. This fisher confirmed that fishing pressure was high and that there had been conflict between 'local' fishers and 'outsiders'. Similarly, one cleaner fish coordinator from a medium sized company operating in this region also discussed conflict between wrasse fishers who supply salmon farming operations. It was stated,

> "there are some areas around Austevoll where it is very difficult to catch enough fish to make money out of it. CPUE is very low. And there is a goodly amount of arguments and threats and destroying each other's equipment. When people from Austevoll come here… here we've got the older generation who have always fished wrasse and want to continue that, but these people come from outside… so there is a fair amount of conflict."

The Deputy Leader for ‘Green Warriors of Norway’ based in Bergen was also interviewed to gain their perspectives on wrasse fishing and cleaner fish use in the salmon industry. This environmental organisation has been a critical voice towards the salmon industry for many years. The interviewee, Ruben Mjelde Oddekalv, believed the wrasse fishery was not regulated strongly enough. While it was recognized that regulations had been strengthened in recent years, it was argued that these were not satisfactory. The acceleration in fishing pressure over the last ten years was also problematized by Oddekalv. From this basis, it was noted that it becomes more difficult to increase fishing regulations when many fishers depend on the fishery for income.

4.1.4 Cleaner fish Transport

Unlike most fisheries, the wrasse catch is to be sold and delivered as living fish. It is common that wild caught fish are translocated from Southern Norway to Western Norway, sometimes as far north as Northern Trondelag County (Norwegian Scientific Committee for Food and Environment, 2019). A researcher and wrasse fisher interviewed talked about fish transports with scepticism. As did one salmon farmer on the west coast which is discussed in more depth below. The practice has led to several companies specializing in the transport of wrasse between regions.

Two problems arose from the data regarding transacting live wrasse under this system. These are the amount of handling the fish may undergo, and a mismatch in power between buyers and sellers. The fisher interviewed stated that fishers in their area sold fish through transport companies who buy and sell cleaner fish between fishers and salmon farmers. Firstly, if fishers must wait for transports to arrive, fish may become stressed in the storage locations. It was stated that if pick-up occurs within four or five days then the fish are likely still in good enough condition. The fisher described this as a ‘little problem’ but that costs fishers a lot of time and effort.

Secondly, trucks may have limited capacity and must drive long routes. Pick-up location in relation to distance along the transport route was also mentioned as often contributing to whether the transports were full or not. The fisher explained that in the fishing season there are trucks that drive and stop along a ‘main route’ to meet smaller delivery trucks with fish picked up from the coast. The fisher was worried about the trucks' ability to regulate parameters like temperature under transport, although it was believed that generally, the quality of vehicles used for transport had improved with time.

One 'cleaner fish coordinator' from a medium-sized salmon farming company explained their experience with wrasse transports locally and from Southern Norway.

> "As long as I have been in charge of budget and buying fish [I have seen] it is a benefit for us to use local fishermen. There has been a great deal of development […] I got them to use oxygen, previously they have just used exchange water they are pumping as they move around.

However, this company stated they had received 5 transports from southern Norway and that they had been dissatisfied with all of them.

> "In 2017 and 2018 I tried buying fish from Southern Norway delivered on a lorry and a trailer. 25 thousand at a time. It was just hopeless… dramatically hopeless. The fish didn't survive. We got them in the sea and they just died!".

When questioned further about whether they depend on veterinary controls for quality, the interviewee elaborated:

> "No, because once we made an agreement that we will accept these fish, then they're delivered. We are not covered for disease, but if there is something wrong with the fish and they die, if we get veterinary report that explains why they died, then we should be able to get compensated. But the situation was that I just refused to pay for them. I said, 'sorry, more than half the fish are gone already in one week.. I'm just not going to pay for them'. I don't know why they accepted that, but a couple of bills I was able to get them adjusted, reduced. 60% had died and I reduced the bill by 60 %... so they had to accept that."

Perhaps the transport company was aware that they had delivered poor quality fish. However, considering the salmon farming company's buying power, it is logical that the transport company had less capacity to argue against the salmon farming company in this case.

The salmon company representative interviewed was unable to tell me which transport company I could contact to hear their side of this story.

5 Discussion

This chapter is divided into two sections with additional sub-sections. Section One and Section Two analyse and discuss the themes presented in the results section in relation to scientific and grey literature. The discussion is guided by the two research questions which ask: how knowledge about lumpfish and wrasse species as delousing agents in salmon aquaculture has been produced and contested in Norway, and how this influences management. Insight from critical political ecology is reflected on throughout in order to critically assess knowledge claims, to analyse power dynamics, and to ground the analysis in a critical realist epistemology. Cleaner fish practice is then contextualized within the salmon industry and analysed as a form of 'socioecological fix' (Ekers & Prudham, 2015, 2017, 2018). These provide the grounds for answering the research questions in the Conclusion.

5.1 Section 1 – History, Externalities and Change in Cleaner fish Use

The results of this study revealed an inaccuracy in the literature describing the history of cleaner fish use. Recognition is commonly given to Bjordal for conducting the first studies on wrasse species for delousing salmon with no acknowledgement of salmon farmers attempting this long before Bjordal's experiments which, according to him, started in 1987. Forsyth's (2003) claims that 'critical' political ecology should "increase both the social equity of science, and its relevance to environmental problems experienced within diverse social settings" (2003, p. 20). To do this, he argues that more people should be included in environmental science and participate in formulating it (2003, p. 273).

From my research, there is no mention in the scientific literature of cleaner fish being used by Norwegian salmon farmers before the first scientific experiments. According to the data gathered in this project, a salmon farmer used wrasse species for cleaning salmon of lice in 1976, which is twelve years earlier than Bjordal's pioneering experiments. While several highly cited papers concerning the use of cleaner fish credit Bjordal (1988) for *conducting the first experiments* (Skiftesvik, Bjelland, Durif, Johansen, & Browman, 2013; Treasurer, 2002), several other highly-cited papers (Deady, Varian, & Fives, 1995; Powell et al., 2018) credit Bjordal as being *the first to use* wrasse as cleaner fish in this way. Note the difference in wording in the two italicized phrases. The first alludes to the possibility that cleaner fish have been used outside of ‘science’, while the other is more categorical and portrays what is understood as fact. Also, in the book edited by Treasurer (2018b, p. 13), it is stated “if Bjordal had not thought of this idea would cleaner fish have been used over the last 25 years?”. Similarly, in reference to Bjordal, Chapter 4 states that “the use of wrasse in aquaculture as a green tool for sea lice control *started in 1989*” (Rabadan, 2018). Thus, results from this study suggest that these claims are inaccurate.

It is difficult to say what this inaccuracy implies for the management and development of cleaner fish use, and for the aquaculture of ballan wrasse and lumpfish. However, perhaps if scientists had worked with salmon farmers who used cleaner fish from 1976, one could reasonably speculate that the extra twelve years of experiential knowledge might have helped improve scientific research. Additionally, recognition should be given accurately where recognition is due.

This example provides a starting point for analysing the history and themes derived from the data in relation to relevant literature. It is by no means an attempt to discredit the work conducted by Bjordal or Treasurer and their colleagues, nor to re-write the history books, so to speak, but rather to demonstrate the importance of remaining critical of all knowledge. If credit was given to small-scale salmon farmers early in the industry’s development, it may perhaps serve only to broaden our understanding than have any real consequences. However, this example does reflect a norm within science whereby knowledge is often produced from the ‘top down’, and knowledge produced without orthodox scientific method is considered less reliable and has even been looked down upon (Bryman, 2016; Forsyth, 2003).

5.1.1 From Optimism to Scepticism

This sub-section argues that perceptions of cleaner fish use among interviewees and in scientific and grey literature have shifted from optimism to scepticism. The concept derived from the data of a so-called ‘environmentally-friendly’ perception among the interviewees is discussed together with how cleaner fish use is contested in public and in science.

Above, Rabadan (2018) is quoted referring to cleaner fish use as a ‘green’ method for delousing salmon. Similar terms have often been invoked to describe cleaner fish use in grey literature, scientific literature and media since the practice’s rapid expansion began in 2008. Still, as knowledge about cleaner fish and their use has increased, so has recognition of the welfare challenges and environmental concerns surrounding their use.

Earlier studies were more positive towards the use of cleaner fish for delousing salmon. This is logical considering that the concept was new and showed potential to help the salmon industry reduce its chemical use. Studies noted that it could therefore have a positive environmental effect; improve salmon welfare by avoiding other treatment methods; and potentially reduce expenditure on other more costly treatments (Bjordal, 1988; Deady et al., 1995; Treasurer, 2002). More recent scientific reviews, however, are more cautious in the face of new knowledge and contestation and they present the challenges related to cleaner fish use and aquaculture more explicitly (Blanco Gonzalez & de Boer, 2017; Brooker et al., 2018; Powell et al., 2018). Since several authors have now reviewed the scientific literature on these topics, this indicates that the knowledge level is now diverse, and the practice of cleaner fish use is not optimal and somewhat contested. Nevertheless, institutions such as IMR continue to frame cleaner fish use as an "environmentally friendly alternative to chemical treatments" (Institute of Marine Research, 2019, p. 5)

Arguably the word 'green' connotes a practice that is 'environmentally friendly' or 'sustainable'. Terminology used to denote such concepts are often vague and critiqued in political ecology, as have broad generalizations regarding various environmental realities. In the Rabadan (2018) article referred to above, the term 'green' is not elaborated upon. Yet, one could reasonably assume it refers to how cleaner fish have been said to reduce other forms of delousing, such as chemical treatments. These have been proven to negatively affect organisms in areas surrounding their use (Olaussen, 2018), and mechanical and thermal methods which trigger stress responses in salmon that may increase relative mortality (Hjeltnes et al., 2019; Nilsson et al., 2019). Also, in the opening chapter in the most recent book on cleaner fish entitled Cleaner Fish Biology and Aquaculture Applications, edited by Treasurer, it is generalized that "any reduction in the use of medicines and advent of reliable methods of controlling sea lice are seen as positive by the public, NGOs and environmentalists", and that "retailers see the use of cleaner fish as a positive marketing image" (Treasurer, 2018a, p. 15). Nevertheless, it is unclear where and when Treasurer is referring to here since no reference for these statements is provided. Additionally, regulators from the Directorate of Fisheries also explained their perception of the term ‘biological control’ as related to something with a positive environmental outcome. Regulators reflected specifically on how the term ‘biological control’ hindered critical thinking towards cleaner fish use.

A critical political ecology approach considers all knowledge as situated, but also that plural understandings of the environment represent peoples’ reality in their own contexts. In other words, knowledge is limited by what we do, and do not understand, but knowledge is also political in nature and often derived from one’s own interests (Forsyth, 2003). A good example to demonstrate this could be found in knowledge claims from an environmental organization. For example, in the report from Green Warriors Norway, claims that the wrasse fishery is ‘wiping out’ wrasse populations can be seen as vested in their interest to influence politicians to endorse higher degrees of environmental protection (Green Warriors of Norway, 2019). A claim that. . the wrasse fishery is wiping out populations is unnuanced considering that earlier studies have stated that data and knowledge regarding the wrasse fishery was lacking (Halvorsen et al., 2017; Skiftesvik et al., 2015). More recent evidence suggests that shallow water fishing grounds are being replenished in some areas by wrasse from deeper waters, and that in most places, the fishery is believed to be sustainable (Halvorsen et al., 2020). Thus, from this example, and the last concerning the perception of cleaner fish use as environmentally friendly, we see how people and group’s positions are influenced by their roles and understandings, and how this may change and be contested over time.

5.1.1.1 Social and environmental externalities

Perhaps the biggest ‘problem’ *per se*, stemming from the wrasse fishery is the way the fish are traded. In this subsection we see how fishing and transporting fish can lead to social externalities in the form of power imbalances, conflict, poor fish welfare and genetic pollution of wild fish populations. As these have arisen, they have also helped increase scepticism towards cleaner fish use.

The data revealed a theme of distrust among buyers and sellers and some examples of conflict among fishers, salmon farmers and transport companies. Firstly, salmon farmers with many localities have large buying power, and three salmon farmers mentioned how each season they may purchase a fishers’ entire quota of 48 000 fish. One case in the data revealed how a salmon farmer used this power to contest a purchase of transported fish where many had died after release in the salmon cage.by refusing to pay. While it is unknown why this was accepted, it is conceivable that the company would try to uphold their reputation to ensure a salmon farmer would seek out their services again. The fisher interviewed also told of one case where he was not paid for fish. Nevertheless, such conflicts are not mentioned in scientific literature or in Norwegian media. The same fisher also found the practice of translocating fish and the use of trucks for transport as stressful for fish and difficult to regulate and organize. Concern regarding high mortality rates and stress levels among cleaner fish at transport has also been addressed by Jonassen, Remen, Lekva, Árnason, and Steinarsson (2018).

Secondly, studies have showed how corkwing wrasse from Southern Norway have escaped on the west coast and that escapees can hybridize with local corkwing wrasse (Faust et al., 2018). This may negatively influence the genetic composition of local populations of corkwing wrasse (Blanco Gonzalez et al., 2019). Lumpfish too are farmed in large numbers and transported around Norway. Even though it is understood how the genetic uniqueness of wild Norwegian salmon is negatively affected by farmed salmon by escapees (Skaala et al., 2019), a similar risk is posed to wild populations of wrasses and lumpfish. One report also states that wrasse are imported from Sweden and approval has been given to import from Denmark (Grefsrud et al., 2019). In response, the Norwegian Environment Agency commissioned one study to assess the risk of this practice (Norwegian Scientific Committee for Food and Environment, 2019).

Thirdly, there are also reports of conflict between fishers in some areas along the west coast. When asked about this, the representative from the Directorate of Fisheries acknowledged that conflict has occurred, but it had no influence on how regulations for the wrasse fishery have evolved. There are also few media reports on the topic (for example, Lindbæk, 2014). Three interviewees described cases of territorial disagreements and equipment sabotage between fishers, however these were heard of through acquaintances rather than experienced. Demand for wild-caught wrasse relates only to their use in salmon farms, and the higher quota for the western Norway zone (10 million, as opposed to 4 million each for the northern and southern zones) was also stated by the Fisheries Directorate' representative as another concession to the salmon industry, who are densely concentrated in this region. Thus, conflict here among fishers should be seen as a social externality of the salmon industry.

In addition, I argue that cleaner fish use should be counted as an input into salmon production that contributes to the material footprint of the industry. Studies have argued that changes in salmon feed composition have reduced the amount of marine protein required to produce salmon feed (Aas, Ytrestøyl, & Åsgård, 2019). However, this study has not included cleaner fish as an input since it is not a salmon feed. Indeed, there is currently no use for cleaner fish after their lives cleaning salmon. Only one study has looked at the potential for using lumpfish as food (Nøstvold et al., 2016), but so far it seems their efforts have had no effect. Nevertheless, it is a biotic input of marine proteins and thus of the same nature and relevance as feed for any analysis aiming to shed light on the resource consumption, or wastes resulting from salmon production. While this is insignificant relative to total weight produced by the salmon industry, it is more relevant in relation to the total use of salmon waste products. One public research institute analysed the use of waste products from the aquaculture industry but only considered wastes from salmon and trout (Winther, Myrhe, & Nystøyl, 2019). This report claims that in 2018 only 10% (36 000 t) of the total waste from aquaculture was not utilized. However, based on their numbers, this percentage would differ had cleaner fish been considered as a waste material from the industry since an estimate of the weight of cleaner fish used in 2018 is around 18 000 tonnes (Figure 4).

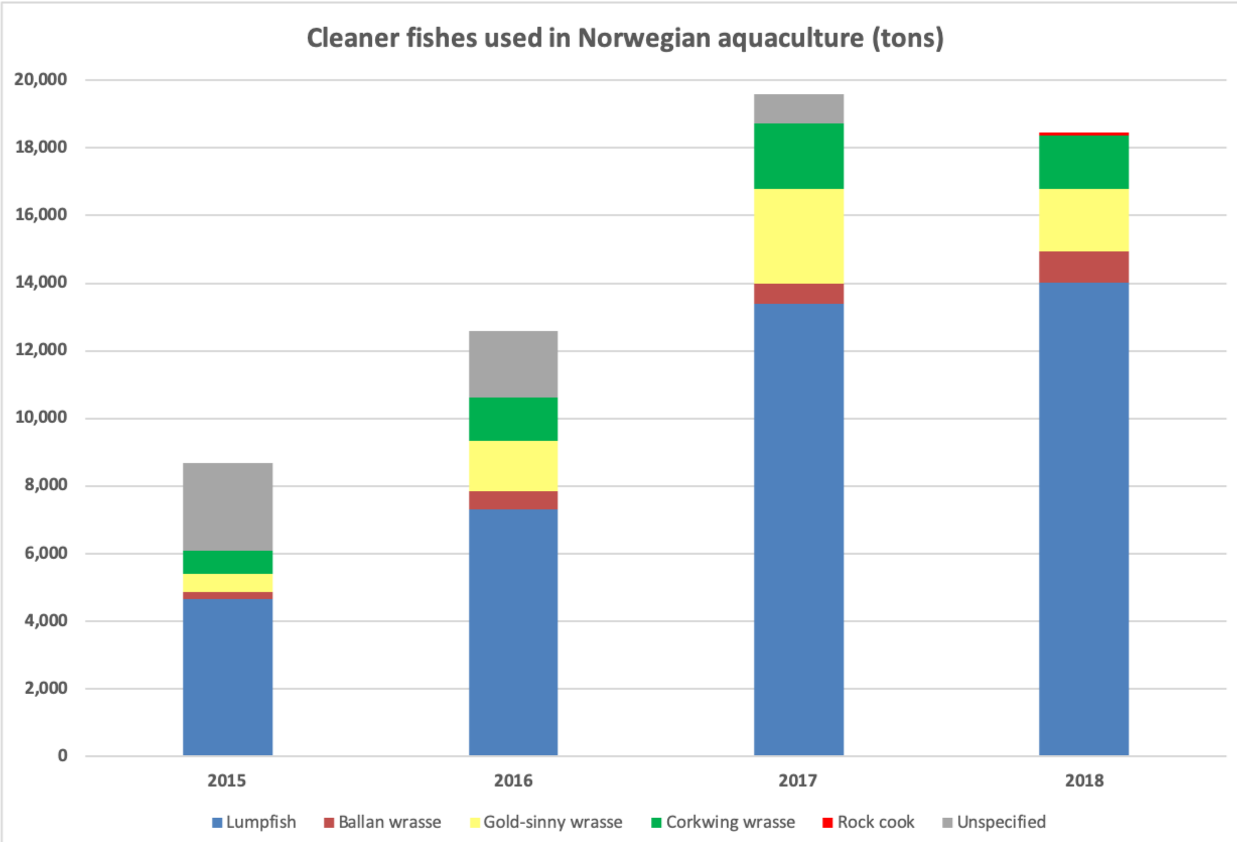

Figure 4. *Estimated weight of cleaner fish used in Norwegian salmon farms (2015-2018). Data from Directorate of Fisheries (2019b). Estimated weights at mortality: lumpfish - 0.45 kg, wrasse species - 0.25 kg.*

The examples in this subsection must be seen as externalities of using wild-caught cleaner fish. Namely, genetic pollution from escapee cleaner fish, conflict among buyers, sellers, and fishers of cleaner fish, and wasted marine resources since no use exists for cleaner fish other than for salmon delousing. I have also argued that cleaner fish should be included in any calculation of waste material from the salmon industry. The points raised in this subsection also strengthen reasons to premise the wrasse fishery on sustainable extraction rates that do not diminish wrasse population's, or ecosystem resilience. Finally, a relationship is highlighted whereby salmon farmers may exercise power through their economic positions to influence smaller companies providing services to them, and regulators who must try to balance the interests of salmon farmers with competing interests. While the implications of these externalities may be relatively small considering the scale of the salmon industry in Norway, there is little attention given to them. Considering the rapid growth in cleaner fish use it is important to acknowledge that they exist should the effect of any of these problems escalate.

5.1.1.2 Contestation

In Norway, veterinarians and environmental organisations are increasingly questioning the ethical grounds of cleaner fish use. This has correlated with the numbers of wild caught wrasse increasing and more details of cleaner fish's life and use cycles within aquaculture emerging. Those objecting perceive cleaner fish use as wasteful and morally unacceptable claiming that mortality rates are too high (Berglihn, 2019; Trana & Sandmo, 2018). One veterinary professor labelled the development an "animal tragedy without precedent (en dyretragedie uten sidetykke)" (Berglihn, 2019, para. 10) and claimed that mortality rates for lumpfish would never be accepted for farmed salmon. The environmental organizations Friends of the Earth and Green Warriors of Norway have called for cleaner fish use in salmon cages to be banned and argued that: regional transport of genetically unique wrasse, overfishing, and bycatch occurring within the wrasse fishery threaten wild populations, and that salmon farming must be moved on land to eliminate the lice problem in Norway (Green Warriors of Norway, 2019; Nilsen & Langeland, 2020).

Researchers too have recently raised doubts as to whether the effect of cleaner fish for salmon delousing justifies their use. A review paper questioned the scientific validity of the evidence base. They argue that this evidence base is comprised of experiments on cleaner fish efficacy as salmon delousers, which were mostly carried out in conditions that do not reflect the conditions cleaner fish experience in commercial salmon farms (Overton et al., 2020). While another study found that use of cleaner fish was 'suboptimal' since there are large variations in cleaner fish's effect when comparing data on set out events (number of cleaner fish released into a salmon cage at one time) and subsequent change in lice numbers which are counted and submitted to authorities weekly (Barrett et al., 2020). These studies were conducted based on scepticism arising from cleaner fish welfare concerns. Salmon farmers interviewed in this thesis were convinced that cleaner fish functioned well in delousing salmon, however they also recognized that mortality is too high. Indeed, it is sometimes 100% considering most farmers destroy remaining fish after a salmon cycle. Some fishers interviewed for this thesis were also sceptical towards cleaner fish use and acknowledged the uncertainty of their delousing performance. This was a key argument from Barrett et al. (2020), that it is difficult to demonstrate that cleaner fish are effective delousers when the interaction between cleaner fish and salmon is difficult to observe, when multiple species are used as cleaner fish, and when many other variables may confound results in the varying environmental conditions salmon farming occurs in along the Norwegian coast.

5.1.1.3 Response from Regulators

The results from Overton et al. (2020) and Barrett et al. (2020) generated new knowledge that supported the Food Safety Authority's reasoning to threaten banning cleaner fish use. Thus, the interviewee from the Authority stated that the Cleaner Fish Campaign was a response to poor knowledge about their effect and mortality in salmon cages, but also to letters of concern ('bekymringsmeldinger' in Norwegian) that the Authority received about cleaner fish welfare issues. Thus, it appears that discontent and better understanding of how cleaner fish are used has provoked a response from the Food Safety Authority. The culmination of these critical studies and the summary reports from the Cleaner Fish Campaign also resulted in widespread media coverage in February 2020, including on the country's most popular news satire television program ('Nytt på Nytt') (Udnæs et al., 2020) as well as damming articles in newspapers (Berglihn, 2020; Stranden, 2020). One could ask then why cleaner fish use has been allowed to increase without being grounded in a reliable evidence base?

I argue that this must be considered a concession to the salmon industry from authorities. It was stated by one regulator working with the wrasse fishery that the advice from IMR to set a minimum size of 14cm instead of the recommended 27cm on the ballan wrasse was neglected. This minimum size would increase the likelihood of individuals reaching spawning age. Additionally, while farmers interviewed in this research state that the ballan wrasse is the most sought-after wild wrasse from fishers, the quota will remain defined as 'wrasse' rather than being species specific, thus incentivizing a more selective fishery on the ballan wrasse. While Halvorsen et al. (2020) recently affirmed that wrasse populations seem to be tolerating a high fishing pressure since wrasses are abundant within their range, there are still uncertainties and some areas are fished harder than others. Thus, there is a sense that regulators are 'sacrificing' the ballan wrasse to a degree in the interests of supplying salmon farmers' demand.

It seems more focus was given to the potential that cleaner fish use provided for reducing chemical delousing methods. This was visible in the results where one regulator from the Fisheries Directorate commented, "… people pretty much forgot to think about cleaner fish because that was 'biological control' and that everyone was happy with it.." ["mann glemte rett og slett å peke på rensefisken fordi det var biologisk avlusing og det var alle fornøyde med"]. While this comment was made benignly, it demonstrates how cleaner fish may have come to be treated differentially in regard to welfare laws. Differential treatment of wrasse and salmon was a key issue that the Cleaner Fish Campaign aimed to address (Norwegian Food Safety Authority, 2020). Therefore, the Food Safety Authority's campaign was also a response to a lack of foresight from regulators who allowed the practice to begin with. This is problematic since the Directorate of Fisheries claim that its societal goal is to deliver "knowledge-based advice that contributes to develop and implement policy for aquaculture, fisheries and marine spatial planning" (Directorate of Fisheries, 2020b, p. 9). The Food Safety Authority is also responsible for ensuring that methods used in aquaculture are knowledge-based, or in other words, documented by a scientific institution as appropriate for fish welfare. However, the evidence gathered in this thesis provides grounds for questioning whether this goal has been overlooked since cleaner fish use has been allowed to expand in the absence of appropriate scientific documentation of their effect.

The political economic context should also be considered here since using cleaner fish aligns with the interest of the salmon farming industry and its drive for profit. Importantly, the cost of using cleaner fish as a method was described as substantially less than other treatment methods. Salmon farmers interviewed also described the practice of cleaner fish use as positive for reducing chemical use and for salmon welfare. This is because avoiding chemical, thermal and mechanical methods are costly and require temporarily starving the fish, thereby reducing growth rates and salmon welfare (Liu & Bjelland, 2014; Overton et al., 2019). These findings also support modelling of sea lice treatment strategy costs by Liu & Bjelland (2014) who found that wrasse as a biological control was the most economical method.

The intention here is to point out that when cleaner fish use has not been contested heavily in hearings and with letters of concern, the economic interests of the salmon industry are likely to reign supreme in authorities' evaluations and decisions. Authorities hold a certain degree of power in choosing which knowledge they base their decisions on but must consider public opinion. Hearings are conducted routinely for decisions regarding regulations in fisheries and aquaculture where civil society organizations, businesses, industry organisations, and the public may express their concerns towards decisions. The Directorate of Fisheries and Food Safety Authority, then evaluate scientific evidence and input from organizations and the public (those concerned enough to send their input), and then make informed decisions about how to set and enforce regulations. Oddekalv from Green Warriors of Norway rightly stated that there are few "standing on the barricades fighting for cleaner fish". Without stronger opposition from the public however, it seems that the response from regulators has prioritised the interests of the salmon industry as a trade-off for some of the externalities stemming from the cleaner fish industry discussed in this section.

In this section I have discussed how knowledge has been interpreted by certain employees within regulating institutions, by researchers, and by salmon farmers. This has revealed how the wrasse fishery and cleaner fish use have been favoured without reliable evidence. Although this was in the interest of reducing the use of chemicals for salmon delousing, it has inevitably contradicted the societal goals that these government agencies aspire to. I have also explained how fishers and small businesses may have significantly less power to wield than a large salmon farming firm. Also, initial optimism towards a novel practice of 'biological control' has shifted towards scepticism and pressure seems to be building on authorities to take regulatory action against cleaner fish use. However, I argue there should be a stronger focus on the resource input into cleaner fish production and use given the growth in numbers used by the salmon industry.

5.1.2 Section 2 - Cleaner fish as a Socioecological Fix

This section analyses cleaner fish use by relating themes from the data to concepts from Ekers & Prudham's (2015, 2017, 2018) theory of the 'socioecological fix'. The aim is to illuminate how even though salmon production is undermined by the salmon lice problem, the same problem creates a profitable opportunity for some. This provides grounds to critique the context of economic and production growth in salmon aquaculture based on the externalities it produces.

5.1.2.1 Spatial Fix

Since the theory of the socioecological fix considers how space and landscapes are altered to produce goods and to supply consumption, aspects of the data concerning cleaner fish facilities and related infrastructure will be analysed.

Ekers & Prudham (2017) explain Harvey's model of capital investment flows as having three circuits. These are reflected in infrastructure used in salmon and cleaner fish production. The 'primary circuit' is the costs of inputs during a production cycle. This may be fish feeds, labour costs etc. The 'secondary circuit' flows into infrastructure. Ekers & Prudham (2017) call these 'relatively enduring fixed assets' which may serve to generate surpluses over several production cycles. They note that what this type of asset entails varies depending on the sector. In this case, fixed assets are salmon pens which are an investment used over multiple production cycles. Also, in this category is land-based cleaner fish hatcheries where fish are hatched and grown until set-out in the ocean. Lastly, the 'tertiary circuit' flows towards "reproduction of capitalism and social reproduction more broadly, including scientific and technological research and development, education, health care, and so on" (Ekers & Prudham, 2017, p. 1376). While the need for research and development to increase efficacy is rather self-explanatory in this case, Lien's study (2015) and media have noted how salmon farmers may privately donate or assist in building social infrastructure, such as schools in rural areas (Helland & Svarstad, 2020). Similarly, funds from the salmon industry provide considerable income to municipal and county administrations (NOU 2019: 18, 2019).

Ekers & Prudham (2017) focus on the secondary circuit and how capital flows within it are facilitated by a broader social context. They write "we are concerned with how sunk capital leads not only to the production of space but also to the production of landscapes in a more holistic sense, and this to the production of nature as prevailing socioenvironmental conditions" (Ekers & Prudham, 2017, p. 1376).

Relevant here is sunk capital in fish production facilities, namely factories located in strategic positions along the coast, have been somewhat revitalized by cleaner fish production. Some have been used within different investment ‘waves’, as one interviewee put it, of aquaculture production of various species. These included halibut and two waves of cod production. Treasurer (2018a) also describes cleaner fish aquaculture as revitalizing marine fish aquaculture after cod production lost momentum around 2010. The acquisition of these facilities was not a transformation of the landscape directly, rather a redeployment of stagnated capital with a new agenda. While their locations may not originally have been strategically located for salmon farming, transport boat services have improved and coastal cleaner fish transport to salmon cages is normal practice. Iversen, Hermansen, Nystøyl, Marthinussen, and Garshol (2018) note the large amount of capital being invested in well boats in recent years. Indeed, well boats are important infrastructure since transporting cleaner fish from hatcheries and thermal and mechanical delousing treatments depend on them. With 45 licenses issued for cleaner fish aquaculture in Norway, there are also many more aquaculture facilities now built in the landscape that have allowed for large growth in production of lumpfish especially.

Iversen et al. (2018) also describe ‘significant’ investment into cleaner fish facilities and found that salmon farming companies own some of these, but there are more companies specialising in cleaner fish production alone (Iversen et al., 2018). These production facilities and infrastructure such as well boats are an important element of the socioecological fix because they support production, social reproduction, and consumption and produce surplus value over multiple production cycles. Salmon pens and well boats must also be considered as a form of fixed capital, since they also achieve this purpose, even though they are metaphysically less ‘fixed’ in the landscape than a factory, for example. As will be revealed more clearly below, salmon pens are also where the use value of cleaner fish materializes in their interactions with salmon. I will now discuss the production of farmed cleaner fish as a profitable commodity within the facilities discussed here.

5.1.2.2 Value, Costs, and the ‘Production of Nature’

Value in cleaner fish is derived from their ability to eat lice in large numbers. More similar to aquarium fish, cleaner fish species are bred or captured from the wild with the intention to survive with certain qualities, whereas salmon are raised to have certain qualities at slaughter, and thus with the intention that they will die. Of course, all animals will die eventually, but somewhat contradictorily, critics consider ‘high mortality’ as morally unacceptable (Berglihn, 2019). Several interviewees used comparisons with other production animals to demonstrate how unique this practice is, and to suggest that among animals other than fish, the same use of animals would never be accepted by the public. Indeed, keeping two mammals in the same situation would seem outrageous to most. Nevertheless, cleaner fish used for controlling salmon lice are perhaps the only vertebrate animal used commercially purely for controlling parasites on other vertebrates (Barrett et al., 2020). If so, the ballan wrasse and lumpfish are also the only vertebrates being cultured and domesticated with this purpose.

It is well understood that salmon lice in Norway costs the industry in production losses and in treatment costs. It has also been demonstrated that wrasses are generally a cheaper treatment method, however, their effect is more delayed and less reliable than mechanical, thermal or chemical methods (Liu & Bjelland, 2014). This is likely to also apply for lumpfish since they are now farmed in great numbers, and interviewees stated that there was a surplus in the market at the time. With a readily available cultured production of lumpfish and only a five to seven-month production time until reaching set-out size, one production manager of lumpfish explained how they are relatively cheap to produce and to purchase. Salmon farmers also demonstrated how using cleaner fish can help reduce costs since they are cheap to purchase and reduce the need for other delousing methods which temporarily stunts salmon growth. Nevertheless, while producing savings for salmon farmers, results from the Cleaner Fish Campaign suggest that cleaner fish experience poorer welfare than salmon (Norwegian Food Safety Authority, 2020; Stien et al., 2020).

The intention here is not to convey salmon farmers as purely economically rational with no regard for welfare. Lien’s (2015) ethnographic study of a salmon farm conveys worker’s compassion and empathy for the animals they keep. Through studying daily practice and record-keeping, Lien also reveals how fish, their welfare, and mortality are ultimately always translated into an economic calculation, also referred to as “biocapital” (Lien, 2015, p. 95). The intention here is to demonstrate that when traits such as opportunistic feeding among cleaner fish on parasites can be exploited and produced in aquaculture through the labour process and sold for profit, the same logic described by Marx applies. There is a drive to accumulate surplus and then ‘fix’ surpluses into new productive avenues to avoid overaccumulation. While some farmers produce lumpfish or ballan wrasse for use in their own salmon farms and therefore, produce a use value in cleaner fish for their own delousing efforts, many produce lumpfish for profit. However, once producing for exchange value in addition, a contradiction arises. The lice problem becomes a prerequisite for generating a surplus from cleaner fish production.

Paradoxically, cleaner fish are a profitable solution for the sea lice problem which arise from the nature of industrial salmon production itself. Salmon cages provide a high density of hosts for salmon lice (Kristoffersen et al., 2018) and thus, provide ideal conditions to apply cleaner fish to try and address or 'fix' this problem. Of course, cleaner fish are only profitable commodities for those owning the means of producing lumpfish or wrasse in their own aquaculture facilities. At the same time, it is often posited as a ‘green’ or environmentally friendly solution. This contradiction represents part of a ‘socioecological fix’ through what Ekers & Prudham (2017, p. 1382) describe as both the ‘production of nature’ (Smith, 1990) and ‘*underproduction* of nature’ (O'Connor, 1988, 1998). That is the appropriation of facets of nature through the capitalist labour process (for example, farming cleaner fish species) to address the externalities created by a related process – namely intensive salmon production.

Importantly, Ekers & Prudham (2017) highlight that this may also be relational and subjective. This affirms what was discussed earlier, that there are plural understandings of such economic relations and environmental outcomes. They write, “what constitutes underproduction from the standpoint of one firm might be another’s source of profitability. What looks like underproduction from the standpoint of environmental social movements will look quite different to the firms that profit from it” (2017, p. 1384). For example, companies are designing and selling various forms of shelter and adhesion surfaces for wrasses and lumpfish respectively (Treasurer, Noble, Puvanendran, Planellas, & Iversen, 2018). Another salmon farming company interviewed created a daughter company specializing in fishing out cleaner fish at the end of salmon growth cycles for reuse. Fishing out is not required by law, but some companies do so to get more use out of their fish and to improve the image of cleaner fish use. Despite efforts to fish them out, three of the salmon farmers interviewed described this as very difficult. Fishing out cleaner fish simultaneously creates an attractive service for other salmon farming companies to use. These two examples demonstrate how by ‘underproducing’ the conditions for adequate cleaner fish welfare ‘spin-off’ businesses have arisen around cleaner fish husbandry. Indeed, these are ripple effects that provide outlets to fix overaccumulation into new profitable avenues.

The wrasse fishery also represents a spin-off industry to salmon farming and a ‘fix’ for the industry’s lice problem, but with inherently different qualities and problems. Wild-caught cleaner fish are a good provided by the environment whose extraction is regulated by the Fisheries Directorate. This fact imposes scarcity on their supply to salmon farms. Conversely, farmed lumpfish are scarce only to the degree that aquaculture can produce them. While most salmon farmers would logically prefer to purchase fewer cleaner fish and use them more effectively for longer, physiological traits of wrasses and lumpfish reduce their activity levels in cold and warm water temperatures respectively (Brooker et al., 2018). However, seasonally alternating demand for cleaner fish species means there exists more opportunities to profit (for those owning the means to produce them) rather than less. Thus, introducing lumpfish for cold water delousing represents a ‘fix’ for conversely declining wrasse effectivity. From a profitability perspective, if a firm produces both species in aquaculture, the two different temperature tolerances can be seen as complementary.

More realistically though, the nature of capitalism tends to make firms compete to produce higher ‘quality’ cleaner fish that are more robust and more effective at a greater range of temperatures. Indeed, research is ongoing to do so (Brooker et al., 2018; Torrissen, Norberg, Naustvoll, & Svåsand, 2018). Additionally, with competitive research and development into new methods and equipment driven by the industry, privately funded research is also a spin-off industry from cleaner fish production and from salmon farming more broadly. This has both positive and negative sides which were visible in the data in the debate on whether to anesthetize lumpfish before vaccination. On one hand, demanding that salmon farmers must use research institutions to document equipment and methods as meeting fish welfare standards avoids public funds being used for the private interests of salmon companies. On the other hand, privatizing research for the purposes of industry always compromises the intended neutrality of research. This exemplifies a tension between aquaculture practice and the ‘knowledge-based’ decision-making goal that the Food Safety Authority and the Directorate of Fisheries aspire to. It seems this is an unavoidable contradiction within this system, but ultimately the Food Safety Authority must still assess during site inspections whether methods and equipment result in welfare outcomes that are satisfactory in relation to animal welfare laws.

Arguably, this dynamic drives technical innovation in the salmon industry. Stimulating competition between business for this purpose has been a hallmark of the centre-right government that has led Norway since 2013. While this could be relatively positive for the capitalist system, it also draws more ‘socionature’ into the economy, and often with negative social and environmental externalities, like those resulting from cleaner fish use explained in the last section.

5.1.2.3 Predominance

Fixed capital has also been analysed in the form of salmon farms and cleaner fish production facilities as sites where nature is ‘produced’ and profited on to help mitigate the salmon industry’s lice problem. This revealed a contradiction in that spin-off industries depend on the lice problem existing. This section analyses cleaner fish production and use against some of the overarching goals of the capitalist state they occur in. I argue that the drive for economic growth in Norwegian aquaculture is structurally inherent considering current laws and policies, and that this reflects a predominant ideology. How this plays out in Norway in relation to cleaner fish is relevant to this study in two ways. Firstly, in how Norway’s Aquaculture Law prioritizes profit and growth and frames welfare standards relatively vaguely. And secondly, in relation to incentives offered to the industry for more environmentally friendly technology development. The implications of this are briefly discussed before relating them to the broader context of the salmon industry and its role in Norway’s economy.

Aquaculture in Norway is governed with an ambition for growth and profitability but is moderated with a focus on sustainability. The concept of ‘sustainable development’, is omni-present in Norway and often referred to in the context of Norway’s ocean industries and economic growth (Norwegian Government, 2017, 2019). The ‘purpose’ (usually the first paragraph of Norwegian laws) of Norway’s Aquaculture Act (2006, § 1) states first and foremost that the industry “should promote the aquaculture industry’s profitability and competitiveness within the framework of sustainable development, and contribute to value creation along the coast” “[skal fremme akvakulturnæringens lønnsomhet og konkurransekraft innenfor rammene av en bærekraftig utvikling, og bidra til verdiskaping på kysten]". Similarly, in Norway's recent ocean strategy document it is stated that employers and employees should have a key role in aiming to maximize 'blue growth', and that Norway's ocean areas are the "foundation for one of the world's most sustainable seafood industries" (Norwegian Government, 2019, p. 6).

Indeed, economic growth is equated here with sustainability and the salmon industry, with all its environmental challenges, is considered 'sustainable'. The evidence in this study suggests that this is a broad generalization that must be criticized. Claims that the industry is sustainable may not seem unusual considering the enormous growth and profitability of the salmon industry, but they are grounded in ideology; that is to say a culmination of normative ideas that form political and economic policy. Thus, it must be emphasized that aquaculture localities and infrastructures reflect, and help legitimize, the ideological underpinnings of the society they exist in; which are noted by Ekers & Prudham (2018) as key premises of a socioecological fix.

In addition, the second half of the Aquaculture Law's Purpose also reflects an ideological underpinning of society but concerning animal welfare in this context. A researcher from IMR and the the Norwegian Veterinary Institute compared the 'purposes' of the different Norwegian regulations for food production and the language used within them (Stien & Gismervik, n.d). Visible is what they call semantically 'less loaded words' in laws and regulations regarding the welfare of aquaculture than those for poultry and so called 'production animals' more broadly, which *does not* include fish. These are translated and displayed in Table 1. (see Appendix for Norwegian original)

Table 1.

Semantically 'less loaded' words used in Norwegian regulations regarding animal welfare.

Regulation on Welfare for Production Animals (2006)	Regulation on Holding of Chicken and Turkey (2002)	Regulation on Operation of Aquaculture Facilities (2008)
§ 1. Purpose The regulation should contribute to good health and **well-being** among production animals.	**§ 1. Purpose** The purpose with this regulation is to facilitate the conditions for good health and **well-being** in poultry, and ensure that consideration is given to the animals' natural requirements"	**§ 1. Purpose** The regulation should promote the aquaculture industry's profitability and competitiveness within the framework of sustainable development and contribute to value creation along the coast. The purpose is also to promote good health among aquaculture animals and maintain **good welfare** among fish
§ 3. Prohibitions regarding keeping of animals. Animals should not be held for production purposes unless the animal's genetic predispositions (genotype) or (phenotype) suggests this can happen without causing damage to the animals physical or **psychological health** or welfare.	**§ 4. General** Poultry keeping will be operated, and equipment and inventory will be shaped, in a manner that safeguards the animal's welfare. The animal's instincts and needs shall be considered, and the animals shall be protected against **unnecessary stress, pain, and suffering**.	**§ 5. General demands for responsible operation** The operation shall be **responsible regarding** matters of **fish welfare** and health

Note. Adapted from Stien & Gismervik (n.d, emphasis in original).

The researchers suggest that words and phrases such as "good health and wellbeing" with "consideration" for "animal's natural requirements" have greater implications for attitudes towards welfare than the phrasing used for fish and aquaculture animals. As do references to "psychological health" and "unnecessary stress, pain and suffering" in other animals, compared to "responsible in relation to fish health and welfare". The alternative standard for fish is reflected in one comment by a Food Safety Authority advisor who stated, "in practice, we accept some things for fish that we would not accept for other animals." Arguably, less 'loaded' words here are more difficult to contest when knowledge regarding fish sentience and welfare is contested (Browman et al., 2018). Others have also argued that cleaner fish do not receive equal treatment to salmon, even though the same law applies (Berglihn, 2019). The results in this thesis also suggest that this is not occurring, but many within the industry are striving to do so. At the same time, growth in the use of cleaner fish is being incentivized in several ways.

Government efforts to improve technology development within the salmon industry have benefitted companies using and producing cleaner fish. For example, the Research Council of Norway in collaboration with the Norwegian Tax Administration have run a tax rebate scheme that has benefited projects for improving lumpfish breeding and production (Skretting, 2018; Soltveit, 2018). Another example is the so-called 'Green License' scheme which began in 2013. This program run by the Ministry of Industry, Trade and Fisheries and the Directorate of Fisheries, evaluated applications for new farming locations based on their use of new 'technological' or managerial solutions that address the environmental challenges stemming from escaped farmed salmon and the spread of salmon lice (Directorate of Fisheries, 2013). Out of 45 green licenses, 33 that were accepted used cleaner fish as a credential for acquiring a license (Furuset, 2014). However, findings from one report suggest the scheme was aimed more so at stimulating growth within the industry than environmentally friendly technology development. The same report found that most of the green licenses were accepted based on proposals that included technology, such as cleaner fish, that was widely used anyway (Vormedal et al., 2019).

This implies that cleaner fish are favoured by some regulatory institutions while their use is threatened by others. Additionally, when government institutions that should be 'knowledge based' incentivize solutions with a poorly documented evidence base, they seem to lack coherence. Also, Considering the efforts of businesses and researchers that have built careers on the use of cleaner fish, it can also be considered counter-productive that the Food Safety Authority is now threatening to end cleaner fish use should mortality rates not be reduced. The fulcrum of the Food Safety Authority's argument is the welfare troubles regarding high mortality that characterizes the use of cleaner fish (Norwegian Food Safety Authority, 2020). Yet the Food Safety Authority must also balance the interests of businesses and wealth creation more broadly, in addition to carrying out their duty to enforce animal welfare laws. Nevertheless, this balancing act is necessary since the primary goal of the Aquaculture Law is to ensure the industry is profitable in addition to its welfare goals.

In Norway, welfare concerns, environmental costs and inequality that fixed capital in the forms discussed above produces are often pitched against the benefits of employment and wealth creation (NOU 2019: 18, 2019). One example is provided in a recent proposal for a ‘ground rent’, or in other words a tax on the industry’s use of Norway’s common ocean space. The proposed tax of 40% tax on individual firms’ annual surplus profits was dropped due to opposition from the ruling parties in a re-evaluated 2021 national budget in light of economic down-turn (Norwegian Government, 2020). The tax was fiercely debated, and lobbying efforts pushed to have the proposal thrown out (Tveitereid, 2019). Data from this thesis and reports from other sources also suggest that a strong lobbying engagement from industry organizations, such as Seafood Norway and Salmon Group, influences political decisions regarding salmon farming (Sandvik, 2016; Tveitereid, 2019). This must be seen as a driver also favouring production of cleaner fish, and growth in their aquaculture and use for salmon delousing. Farming salmon in the ocean takes advantage of conditions favourable for producing salmon, but also releases wastes, leads to escape and genetic pollution, and leads to disease and parasite infestation. These are environmental effects that are not paid for by the industry. As we have seen in this analysis, some are turned into profitable business endeavours. While the effects of cleaner fish may be relatively small compared to the footprint made by salmon production in terms of wastes, this and other externalities mentioned earlier in this thesis could be compensated to a degree by such a tax.

This section has analysed how fixed capital becomes embedded in salmon and cleaner fish production facilities. It was argued that this mainly occurs due to growth goals being embedded in Norway’s Aquaculture Law, and through governmental programs that have incentivized and helped stimulate growth in cleaner fish use and salmon aquaculture more broadly. The process of growth in aquaculture is ‘metabolic’. Aquaculture facilities are fixed into the landscape and absorb resources to produce and distribute the products of labour and technology and, thus create the circumstances for this process to recur over multiple cycles. This simultaneously creates livelihoods for people which become normalized. Ekers & Prudham argue that this process “makes real ideological pillars of legitimacy, including notions of freedom, modernity, progress, and the like” (2018, p. 30), which then helps legitimize the predominant capitalist system. The Norwegian salmon industry with its cleaner fish industry as a subordinate should be seen as such a pillar.

6 Conclusion

In conclusion I will discuss the research questions before recapping the main arguments to help justify the answers.

Norway has pioneered the aquaculture of salmonids and now the use and production of cleaner fish. Based on the findings from this study, it seems likely that the idea emerged in Norway among small-scale salmon farmers as early as 1976. This pre-dates what is published in the scientific literature by more than a decade. Nevertheless, the degree to which they were used until the first scientific trials is uncertain and likely at a small scale. Cleaner fish use remained relatively obscure while chemical delousing treatments were popular in the 1990s and 2000s. Since then, they have become an important tool for Norway's salmon industry and their use has increased from around 2008 (Powell et al., 2018). Several other socioecological systems have grown to supply cleaner fish to the salmon industry including a profitable coastal trap fishery and aquaculture for ballan wrasse and lumpfish. In addition, a whole sector of spin off services relevant for cleaner fish production and husbandry now also supports employment and generates profits for companies along the Norwegian coast. Cleaner fish are now also used in other salmon producing countries, and research and development into cleaner fish is now broad considering the poor knowledge base that existed for these species before (Treasurer, 2018a). Nevertheless, the findings discussed in this thesis have tracked a change in perception towards cleaner fish use as the practice grew.

The researched questions asked broadly how knowledge about cleaner fish has been produced and contested, and how this has influenced management. Based on this thesis, knowledge has largely been driven by the industry through research into cleaner fish's potential and limitations for salmon delousing. This has been driven by changes in efficacy of other lice treatment methods, as found in other studies (Overton et al., 2019), but also by the profitable opportunities that culturing, researching, using, and fishing for cleaner fish present. Because the practice grew rapidly, authorities have lacked data on how cleaner fish were produced (through fishing or otherwise), what was happening to cleaner fish in salmon cages, and underappreciated the externalities this created. Therefore, based on the qualitative data and discussion in this thesis, I suggest that resource managers have given the salmon industry a concession to use more resources common to the Norwegian state and its constituents which has helped perpetuate the predominant economic system; one premised inherently on perpetuating economic growth.

In concluding this, I have discussed scientific and grey literature and compared them with themes derived from a thematic analysis of interviews with regulators, salmon farmers and knowledgeable industry representatives. I have argued that there has been a shift from optimism to scepticism regarding cleaner fish use in salmon farms from researchers, authorities and civil society. This culminated in several studies criticizing the efficacy and justification for cleaner fish use (Barrett et al., 2020; Overton et al., 2020), and in a national ‘cleaner fish campaign’ to investigate mortality and cleaner fish use. Nevertheless, while more are becoming aware of welfare challenges with cleaner fish, as one interviewee put it - there are few “standing on the barricades fighting for cleaner fish”. Also, several working in regulatory positions at the Directorate of Fisheries favoured cleaner fish use due to the potential it provided to reduce chemical treatments for delousing salmon. While this had good intentions, it emerged from the cleaner fish campaign that the scientific evidence base justifying cleaner fish use as effective was thin. Therefore, I argued that promoting cleaner fish as a useful technology for the salmon industry is contradictory to a norm in Norwegian regulatory institutions that activities concerning animal welfare and natural resource use should be ‘knowledge-based’. If aiming to farm more species in the future, these authorities should critically reflect on, and learn from this experience.

By using analytical concepts from critical political ecology (Forsyth, 2003) as a lens, several examples of social externalities, including conflict and unequal power dynamics within systems of cleaner fish use, were highlighted and discussed. Although the strength and seriousness of these seem relatively trivial with few similar reports, they are indeed serious phenomena for those experiencing them and noteworthy considering regulations are likely to adapt to future circumstances. From a resource use perspective, I have also argued that the input of resources, in terms of marine protein used to grow cleaner fish in aquaculture and fisheries extraction is underappreciated considering the fish have no further use after their time in salmon cages.

Norwegian salmon farming is inherently exposed to the threat of lice effecting their production due to the nature of intensive salmon farming within open coastal ecosystems.

Nevertheless, growing the industry to be as profitable and large as possible has long been a political goal (Ministry of Trade, Industry and Fisheries, 2013; Norwegian Government, 2017) that is also ascribed in the law governing aquaculture (Aquaculture Act, 2006). At the same time, externalities of salmon production have also generated growth in the industry since technology and spin off businesses are needed to help address these externalities. I have argued that cleaner fish use is such an industry, but that this creates an inherent contradiction in that, businesses depend on the lice problem they are trying to address in order to continue profiting and growing from it. This helped explain why themes such as impermanence and uncertainty were dominant in the data analysed in this thesis. To help explain this contradiction, I have analysed cleaner fish as a what Ekers & Prudham (Ekers & Prudham, 2015, 2017, 2018) call a ‘socioecological fix’.

More specifically, cleaner fish use represents the element of a socioecological fix related to Smith’s (1990) ‘production of nature’ theory and O’Connor’s (1988, 1998) ‘underproduction of nature’. Put simply, these help explain how salmon aquaculture’s vulnerability to lice creates an opportunity for a behaviour in cleaner fish to be produced, exploited and profited on. Also, by analysing how fixed capital becomes embedded in salmon and cleaner fish production facilities, this process becomes ‘metabolic’. These facilities absorb resources to produce and distribute the products of labour and technology and thus create the circumstances for this process to recur over multiple cycles. This simultaneously creates livelihoods for people which become normalized and support the legitimacy of the predominant economic system.

According to Forsyth (2003), one should consider all knowledge as political situated and to not accept all environmental ‘truths’ as given. The same could be said about social, political, and economic systems which are plural and vary across time and space, and as we have seen in this thesis, are inherently linked to the production of nature. The predominant economic system analysed as a socioecological fix in relation to cleaner fish and salmon aquaculture in this thesis is grounded in ideology; that is to say a culmination of social relations that form political and economic policy. This ideology could be described as one where money and material wealth are prioritized and equated to human welfare. Considering the inevitability of environmental change, efforts to explore alternatives should be prioritized.

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8 Appendix

Table 2.

Sammenligning av velferdsregelverket for oppdrettskylling og oppdrettslaks [Comparison of welfare rules for farmed chickens and farmed salmon]

F. om velferd for produksjonsdyr	**F. for hold av høns og kalkun**	**Akvakulturdriftsforskriften**
§ 1.Formål Forskriften skal bidra til god helse og **trivsel** hos produksjonsdyr.	**§ 1.Formål** Formålet med forskriften er å legge forholdene til rette for god helse og **trivsel** hos fjørfe, og sikre at det tas hensyn til dyras naturlige behov.	**§ 1.Formål** Forskriften skal fremme akvakulturnæringens lønnsomhet og konkurransekraft innenfor rammene av en bærekraftig utvikling, og bidra til verdiskaping på kysten. Formålet er også å fremme god helse hos akvakulturdyr og ivareta **god velferd** hos fisk**.**

§ 3.Forbud mot hold av dyr Dyr skal ikke holdes for produksjonsformål med mindre dyrets arveanlegg (genotype) eller egenskaper (fenotype) tilsier at dette kan skje uten skadevirkninger på dyrets fysiske eller **psykiske helse** eller velferd.	**§ 4.Generelt** Fjørfehold skal drives og utstyr og inventar utformes slik at hensynet til dyras velferd ivaretas. Det skal tas hensyn til dyras instinkt og behov, og dyra skal beskyttes mot **unødig stress, smerte og lidelse.**	**§ 5.Generelle krav til forsvarlig drift** Driften skal være helsemessig og **fiskevelferdsmessig forsvarlig.**

Note. From Stien & Gismervik, (n.d)

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