Analysing the Sustainability of Both Ocean and Land Based Salmon Farming on a Global Scale.

Introduction.

One of the targets within Sustainable Development Goal 14 is to rectify destructive fishing practices, and a major area of this is the Salmon industry. Due to vast overfishing, the stocks of Salmon *Salmo salar* in global waters were declining from before the 1980s and took a larger dip in the early 1990s (Noakes, Beamish, and Kent, 2000) and so open net pens were introduced to safely breed more salmon in the 1970-80s (GSA, 2021), keeping up with global consumption, reducing levels of fishing malpractice, and not forcing salmon into endangerment. This essay will explore how and why salmon farming is making the move to land and the different outcomes it will have when expressed in world-wide terms, this means that there will also be some entanglements with other sustainable development goal fulfillments throughout. This essay will go into more detail on what the adjoining poster represents: firstly, it will cover the ocean pollution that open net pens bring and the effects it has, secondly, the topic of sea lice is discussed and how it disrupts the oceans ecosystem and how eradicating sea lice is beneficial but also adds to ocean pollution. Next, the focus will move to how much electricity and carbon outputs both land and ocean salmon farming have by using a study on the US and Norway. Finally, the last section will cover specifics of location independent land farming and the pros and cons it brings to the environment and the economy.

Environmental impact deriving from Open Net Pen Farms.

In Norway as of 2020, 986 active sea-based localities have been registered for salmon farming along the Norwegian coast (Sommerset et al., 2020). With such a large quantitative production of salmon with 1 400 117 tonnes produced during the same year (Sommerset et al., 2020), it is important to acknowledge what kind of ripple effects such mass production of salmon has on the global environment. Throughout the history of the Norwegian salmon industry, artificial selection has been carried out in order to cultivate the best imaginable salmon individual for mass production. Due to this artificial selection of the original wild salmon stock, it has resulted in a significant genetic difference between farmed salmon and wild salmon (Glover et al., 2019), where farmed salmon have undergone selection based on human ideals, selection of wild salmon has mainly been based on survivability in natural environments. What is feared with escapes is that the genes from the farmed salmon, through introgressive hybridization, can cause unfavorable genes intended for optimized breeding to be integrated into the gene pool of wild salmon populations all over the world, resulting in worse fitness (Glover et al., 2019). In addition, as the facilities are directly connected to the ocean, nutrients like phosphate and nitrogen are released directly into the environment due to fish excretion and waste mineralization (Yakushev et al, 2020), resulting in eutrophication of water masses, causing an unnatural increase in algae and other aquatic plants which could have the ability to not only affect local and global ecosystems (Sofie Grefsrud et al., 2021), but also the salmon itself. In 2019, an estimated 8 million salmon died due to a bloom of the poisonous algae *Chrysochromulina leadbeaterii* in the regions of Sør-Troms and Nordre-Nordland (Sommerset et al., 2020). All these factors represent how open net pen systems can be detrimental to the health of salmon in our ocean, but also the health of the global water system. This is because of the artificial genetics and nutrients that are being used in ONPs around the world can easily speat with ocean movement and wild salmon repopulation.

Effects of Sea Lice.

The most important metazoan parasites of farmed Atlantic salmon are the sea lice *Lepeophtheirus salmonis* and Caligus elongatus (Pike, 1989). Marine salmon farming has been correlated with infestations of these parasites and the simultaneous decline of the worlds wild salmonids (Costello, 2009). The strong evidence that sea lice can be a major cause of mortality in wild salmonids near farms provides a challenge for controlling lice within them (Costello 2009). By moving production to land, there will be a more controllable environment for the regulation and prevention of salmon lice, as floating sea cages allow free movement of pathogens between farmed and wild fish. This also connects to SDG6 as removing possibilities for lice to grow aids the movement towards a clean and sanitary water cycle. Parasite infection is not only an environmental and health problem, but also causes large economic losses and can cost the global salmon industry $480 million per year and 6% of the value of the product (Costello, 2009). This is also represented through how the sea lice problem caused an estimated loss of 436 million dollars in Norway alone in 2011 (Abolofia et al., 2017). Furthermore, the most common treatment for salmon lice today is aggressive chemicals and, although this treatment has been effective in controlling outbreaks of the parasite, it has negative effects on the environment and on the fish, reducing their appetite and growth (Osterloff, n.d.). These factors show the further benefits for the global salmon farming industry to move to land as the land is an easier controllable space against externalities of the natural environment, and appears to benefit not only the economy, but also the world's oceans through avoiding chemical use and benefitting the health of salmon.

<u>Electricity Usage and Carbon Output</u>

With the rising use of land based closed containment recirculating aquaculture systems (LBCC-RAS) instead of the traditional open net pen farms found in our oceans and seas around the world, it is interesting to analyse which salmon farming technique is more sustainable on a global scale by looking at their electric use and carbon footprint output. By looking at Figure 1 from the poster (Liu et al., 2016), LBCC-RAS's use a large amount of electricity to run, this is because the farms need to always be kept at a cool temperature, around 8-14 degrees Celsius (Global Salmon Initiative, 2021), as that is the temperature of water in which adult salmon are healthy and thrive in. But if those same farms gather their energy from hydropower instead of general power grids, the CO2 output is significantly less and therefore more sustainable. This is also a perfect example of intertying SDG9 as industry, innovation and infrastructure are reflected in how farms were recreated on land with perfect biological conditions for salmon production whilst not being in their natural habitat, while also being sustainable. Moving on to open net pens, as they are set up in the ocean where biological and temperature conditions are just right for salmon health, they use a lot less energy to maintain, also meaning less CO2 output – until it is exported. Upon exporting salmon from the likes of open pen farms on journeys like Norway to the US for example, by just freezing the salmon and shipping it emits slightly less than that of LBCC-RAS's that use hydropower, but this also means the salmon is slightly less fresh. To import the freshest salmon airfreight is used as it is the quickest mode of transport but is also the highest emitter of CO2, and any singular transatlantic flight will emit more than double the CO2 than that of the LBCC-RAS's that use the electric grid.

Additionally, as a case study, many open net pens in Norway are making the move to become completely electrically run and cutting out use of diesel and fossil fuels completely. According to Digges (2020), a medium sized open net pen that uses diesel generators can emit the same amount of CO2 as 70 cars, and if Norway cut the use of diesel in all their ocean salmon farms, it would prevent 300,000 tonnes of CO2 being released into the atmosphere. All these numbers are without export to the US so with export there will still be higher emissions but by ditching airfreight transportation the CO2 output can be cut drastically. But, if this number of emissions were cut by Norway alone going completely electrical, the amount of carbon production saved if other nations ONPs over the world made the transition to electrical would be incredibly substantial and a lot more sustainable overall.

In terms of the US salmon production carbon footprint, if the US keeps using their hydro powered LBCC-RAS's, it will be more efficient than importing salmon from a free-net aquaculture system (Liu et al., 2016). This is because transatlantic flights emit vast quantities of CO2, which is bad for the environment and generally unsustainable, while frozen imports and locally sourced salmon from hydro powered LBCC-RAS's use fewer fossil fuels and benefit the environment. This shows how by cutting down unnecessary flights and having nations source their own salmon from local land farms, it would assist the global effort of emissions reduction - reflecting how both open net pen and land farm systems are on equal terms when looking at electricity and carbon use if beneficial renewable decisions are made. This does however intertwine slightly with SDG10: Reduced Inequalities, as not all countries have the resources and money to build an on-land salmon farm and will continue to depend on importing it from other countries, meaning cutting out transatlantic flights all together is not in immediate possibility.

Benefits and Drawbacks of Land Based Salmon Farming.

98% of the global salmon industry is made up of five countries: Chile, Canada, Norway, Faroe Islands and Scotland (Iversen et al., 2020). One important competitive advantage is the lack of suitable environmental conditions in other nations (Iversen et al., 2020). Land-based marine aquaculture is site-independent which can introduce other countries to the industry and give potential for economic growth, positively contributing to SDG 8 on decent work and economic growth. As aquaculture is estimated to experience a growth of 30 million tonnes by 2030 globally, emerging nations like India and China can grow to be large export market for the Atlantic salmon (PwC Seafood Barometer, 2017). Spreading the production of salmon closer to the market will reduce transport by air freight and its large carbon emissions. Land-based marine aquaculture in the US is closer to the market and have a smaller carbon footprint than salmon transported from other countries (Liu et al., 2016). There is also reduced cost related to disease outbreak compared to traditional marine aquaculture (Iversen et al., 2020).

Having salmon farms on land will allow countries which do not have a coastline to produce salmon as LBCC-RAS's systems reproduce the perfect environment for salmon on land (Liu et al., 2016). Additionally, localizing salmon production helps cut down on transportation costs. This is beneficial to the global economy as it will not just be the five major countries in the salmon industry making all the money and wealth can be distributed globally. New employment opportunities, technological advancement and an increased self-sufficiency can empower nations that lacked marine natural resources. It will also contribute to the progress of SDG2 on ending hunger as the more salmon is produced, the easier it is to keep up with global consumption.

However, to summarize a few negatives of moving salmon farms to land that have already been briefly mentioned in previous paragraphs is how without using hydropower, land farms will use up a lot of energy and therefore have higher emissions, and as land farms are a relatively new development, making the transition to hydropower so soon will affect the rate at which countries across the world implement their own. Additionally, some countries may lack interest and may not have enough demand for salmon to warrant implementing their own LBCC-RAS, and some nations do not have the funds to set up their own land farms, and in both instances, it will be deemed more cost effective to continue to import. This conveys how for some countries across the world, importing salmon will be more sustainable for their nation, but will be less sustainable overall in a world-wide view as this will keep transport emissions high.

Not only this, there are many papers reaping the benefits of moving salmon farms to land, as seen throughout this essay, but very little on the negatives. This is because moving salmon farms to land is a very new concept so there is relatively little research on the topic overall; additionally, scientists that write about the negatives of open net pens have very limited knowledge to work on because of the small amount of land farms set up around the world, and simply do not have enough data to make an unbiased decision over which is best.

Conclusion.

In conclusion, the shift to land-based salmon farming is currently growing and will continue to do so in the future as it positively affects not only SDG14 but also other SDGs such as SDG2, SDG6 and SDG9. There is however a plethora of negatives with salmon farming moving to land like slightly largening the inequality gap as well as the possibility of countries with no interest in land farms. So, while the land-based project alternative seems more beneficial to the environment for reasons like, reduction of pollution and carbon footprint, raising global water sanitation, and welfare of wild species, there is simply a need for more research into LBCC-RASs to make a more balanced argument. With the research available at this current time, the conclusion is that land-based salmon farms will lead to greater accessibility to food in much of the world and to fresher fish, a lower carbon footprint, and less release of antibiotics and other pollutants into the environment; all of which are beneficial to furthering the sustainability of global modern living.

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