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Chilean Salmon Aquaculture: Delicious or Dangerous?

Currently, there are about 2.3 billion people worldwide experiencing moderate to severe food insecurity (Chavez, "Food Security"). However, there is enough food produced every year to feed 9.1 billion people, which is more than the amount of people who currently inhabit the Earth (Chappell 18). Therefore, it's clear that the food system needs a redesign, which can be achieved through systemic change. Salmon aquaculture produces much of the world's seafood, and thus is important to consider when looking at points for fixing the food system. In an analysis of economic, environmental, and nutritional impacts of the Chilean salmon aquaculture industry, I will determine the level of sustainability for the industry. Looking at a case study of Chiloé, Chile, it's clear that the problems of the industry need to be addressed one way or another due to its creation of dead zones, pollution, and mass antibiotic use. Following an analysis of various mitigation techniques, a determination on the feasibility of a sustainable and just salmon aquaculture industry in Chile is made.

History and Structure of the Industry

The salmon aquaculture industry in Chile emerged in 1979, becoming the second largest producer of farmed salmon worldwide by 1992 (Bjørndal & Aarland 238). The long, rugged coastline of Chile, around Puerto Montt and Chiloé Island, produces "...sheltered sites with ideal water temperatures and salinity" (Bjørndal & Aarland 239) for the salmon habitat. The production of farmed salmonid in Chile has expanded quickly since the mid-1980s (Bjørndal &

Aarland 239). Because Chile is in the southern hemisphere, they have opposite seasons compared to Norway, the leading producer of farmed salmon (Bjørndal & Aarland 238). This provides a competitive advantage for Chilean salmon farms when selling to fresh salmon markets in the northern hemisphere, because the major producer is "off-season" when Chilean farms are harvesting (Bjørndal & Aarland 239). Interestingly, Chile depends heavily on the importation of salmon eggs from foreign suppliers (Bjørndal & Aarland 239). This means the industry is not autonomous, as it outsources its salmon eggs. The institutional framework for the Chilean aquaculture industry is set by the regulations under the General Law of Fisheries and Aquaculture (Bjørndal & Aarland 242). There are four main areas of regulation that the General Law covers: the import of hydrological species, the transfer of aquaculture concessions and authorizations, the operation of aquaculture concessions or authorizations, and ocean ranching (Bjørndal & Aarland 242). Food industries are often regulated by the government, so they play a huge role in determining the impacts the industry has on areas like the environment or the economy.

In terms of research and development, the salmon aquaculture industry is looking for ways to better itself, especially in terms of sustainability. One of the biggest areas of research is centered around the use of antibiotics. Compared to other major producers of farmed salmon, like Norway, Chilean salmon farms use mass amounts of antibiotics in their production (Bjørndal & Aarland 243). Industrial farms, like these aquaculture farms, are more susceptible to disease, so the use of antibiotics attempts to curb this threat. This is detrimental to the industry because antibiotics facilitate the evolution of resistant bacteria, which pose an even larger threat as it increases the likelihood of pathogens moving from animals to humans.

The degree of concentration in salmon farms in Chile demonstrates a "strong tendency towards vertical integration in the production of salmonids" (Bjørndal & Aarland 244). Vertical

integration is an attempt by companies to own more than one step of production in their product. Thus, vertical integration in the salmon aquaculture industry would look like owning the processes of feed production, both stages of growing the salmon, harvesting, and selling of the product to consumers. Chile also has a very limited domestic market, because they have a population of about 15 million people, who are not known for being big fish consumers (Bjørndal & Aarland 247). From the start, Chile's salmon aquaculture industry has been export-oriented. Despite having food insecurity in its own country, Chile is sending its food to the Global North rather than focusing on the food injustices faced by its own people.

Areas of Analysis

There are three areas of analysis that will be examined to determine whether salmon aquaculture in Chile is a feasible source of food production: economic, environmental, and nutritional. By analyzing the impacts of the industry under these main sectors, the benefits and harms that salmon aquaculture in Chile creates are highlighted.

Due to the creation of jobs and available profit, the Chilean salmon aquaculture industry is beneficial to the local economy. The cost of production of Atlantic salmon is 51 cents higher per kilo in Norway than in Chile (Bjørndal & Aarland 247). Therefore, because Chile is able to produce their product at a lower cost of production, they are able to make more profit off their salmon if they are selling in the same markets as Norway. Moreover, this advantage allows Chile to become a competitive player in the market for salmon aquaculture, as they have the upper hand in profits compared to long standing salmon markets like those based in Norway. Although Chilean salmon farms are able, on average, to produce their product at a lower cost, they should be making a larger profit margin than they are with how low their labor and inputs cost are. This is likely due to the inefficient logistics of their production, which, if improved, has the potential

to further increase their profit margin (Bjørndal & Aarland 246). This room for improvement can drastically increase the economic gains that come from this industry. The rise of this industry has also generated employment for local Chileans on the coast, but there is more about its economic implications than meets the eye.

Although there are beneficial economic motives for salmon aquaculture in Chile, there are also harmful economic effects that come out of this industry—most of which are centered around the local economy. The main justification for the environmental degradation that comes from this practice would be the improvement of the local economy, but there is very little evidence that demonstrates this. Although there has been a slight increase in employment from the industry, "it has also led to tension between salmon farmers and artisan fishermen" due to declining fish populations along the coast of chile—a direct result of the intensive salmon farming needed to support the salmon industry (Bjørndal & Aarland 247). In response, artisan fishermen are losing their livelihood, further attributing to the negative environmental impacts of the Chilean salmon aquaculture industry. This has led to local fishermen retaliating by attempting to catch fish that escape from cages, or even provoking the fish to escape said cages (Bjørndal & Aarland 247). As mentioned previously, this industry is export-oriented, so there is an "extreme dependency on the US and Japanese markets [which] makes the Chilean exporters vulnerable to international economic trends and trade policies" (Bjørndal & Aarland 248). Overall, it seems as though, even economically, the industry is not very strong due to internal obstacles, despite being the second largest producer.

Unlike the other two areas of analysis, the environmental effects of Chilean salmon aquaculture are purely negative—there are no redeemable environmental effects. One major effect of salmon farms on the environment off the coast of Southern Chile (the region known as Patagonia) is experiencing eutrophication. Eutrophication is defined as the excess of nutrients in

a body of water, which causes dense growth of marine plants, depriving the water of oxygen, making it an uninhabitable space for marine life. Essentially, anaerobic conditions result from this phenomenon. Because these fish farms increase the amount of organic matter on the seafloor (uneaten food, waste excreted by fish, etc.), they are the cause of the eutrophication seen along the coast, as the accumulation of said organic material supplies the oxygen depriving algae with the nutrients needed to proliferate (Quiñones 379). This is clearly very detrimental to the environment as it eradicates the coastal marine ecosystems. Moreover, the harmful algal blooms (HABs) that result from localized eutrophication around and under salmon farms are detrimental not only to the environment, but the industry as well (Quiñones 383). This is due to the mass mortality of the farmed salmon because of the aforementioned anaerobic conditions caused by these HABs.

Another major effect that the salmon aquaculture in Chile has on the surrounding environment is due to the excessive use of antibiotics and chemicals (pesticide, antifoulants, disinfectants, etc.) in their production. Chile has one of the highest rates of antibiotic use in salmon production in the world– using 1700 times the amount of antibiotics used per ton in Norway (Navarro 11:17-11:30). Exorbitant application of antibiotics results in “the emergence of new bacterial strains that are resistant to several antibiotics simultaneously” (Burridge et al. 9). If animals are infected by these types of hyper-resistant pathogens, it’s much more challenging to treat, leading to increased death and complications (Burridge at al. 9). Plus, the more that salmon farmers utilize antibiotics and the more resistant the fish are to pathogens, the more that pathogens will evolve in tandem. As pathogens become more resistant to antibiotics, farmers will run out of effective antibiotics to combat the issue of disease. In simpler terms, this phenomenon leads to a biological arms race. Chemical insecticides, like synthetic pyrethroids, are used to treat salmon for sea lice. Although the extermination of sea lice is important to successful yield on

salmon, the chemical insecticides applied to the waters are highly toxic to crustaceans (Burridge at al. 12). If released into the surrounding environment, these insecticides could decimate local crustacean populations, reducing biodiversity and harming the ecosystem. There are also negative effects from other chemicals used in salmon farms (cypermethrin, deltamethrin, etc.) on performance of Chilean rock crab (*Metacarcinus edwardsii*) larvae (Quiñones 386). These are harvested by artisanal fishers, which furthers the tension between them and salmon farmers. Once again, although there is the economic benefit of local jobs from the industry, the environmental impacts subsequently decimate the livelihoods of local artisan fishers.

A third environmental impact of salmon aquaculture is the disruption of the local ecosystems surrounding the salmon farms. One way in which this occurs is because of the attraction of carnivorous birds and mammals because of high concentrations of fish in one area (Buschmann et al. 245). There is also the case of fish escaping from the cages, which could be slow on a daily basis, or massively in the case of extreme weather events destroying infrastructure. With the prevalent issue of disease in Chilean farmed salmon, which requires the massive use of antibiotics by the industry, there is risk of these escaped salmon spreading diseases to wild salmon or other wildlife in the surrounding waterways (Buschmann et al. 246). Damaging the wild salmon population is harmful in a multitude of ways: it can lead to its prey taking over, death of its predators from a lack of food source, etc. Salmon lice, for example, have traveled from escaped salmon from these aquaculture sites into wild populations of coastal fish, inhabiting them as their new hosts (Buschmann et al. 246). Once a disease is out into the natural ecosystem, it becomes much harder to control and can decimate the wildlife in those areas, even if it just wipes out one species, because of the interdependency of wildlife.

The final lens through which impacts of the salmon aquaculture industry in Chile can be assessed is nutritional. Specifically, looking at the benefits and harms of consuming salmon as a

main source of protein allows for a full understanding of the value of Chilean salmon aquaculture. The main benefit from consuming farmed salmon, from a nutritional standpoint, is the intake of omega-3 fatty acids (Foran et al. 2640). Omega-3 fatty acids are considered "essential" fatty acids because they play a critical role in the function of the human body, but they are not produced by the body (Donovan). Other nutritional benefits of eating salmon include it being low in saturated fat and good sources of protein, vitamin B12, potassium, iron, and vitamin D (Donovan). Among the various types of animal protein, fish are ranked the highest in nutritional value because they are a lean source of protein and considered the "healthiest" animal protein option (Birch). It is important to note the comparative health of various animal protein beause of the livestock industry's impact on climate change. Other sources of protein, like beef, are detrimental to the environment because of the use of large quantities of water, grazing land (requires deforestation), and methane emissions. From a nutritional standpoint, salmon is a beneficial addition to the human diet, especially when compared to other sources of animal protein.

Unfortunately, there are downsides to eating salmon, which mostly arises from the concerns from contaminants from the farming process (e.g. polluted water) and antibiotics use by the industry. There is potential risk to eating salmon from the potential of presence of carcinogens in contaminants such as PCBs, dioxin, and dioxin-like compounds (Foran et al. 2640). There is also a risk of ingesting mercury and microplastics because of contaminants in the water (Birch). This would have to be assessed on more of a case-by-case basis because different coastal regions have varying levels of contamination. However, it's important to note that in a risk-benefit analysis of consumption of salmon, it's argued that the benefits to human health outweigh the small risk of contaminants (Foran et al. 2642).

Case Study: Chiloé

Looking at the specific case of how the Chilean salmon aquaculture industry has impacted the island of Chiloé, which is off the coast of the Patagonia region of Chile, provides a localized context and real-world stories. In general, the people of Chiloé are unhappy with the presence of the industry in the area. In April of 2016, Ramon Navarro discovered that 9,000 tons of decomposing salmon had been dumped off the coast of Chiloé by the farmed salmon industry (Navarro 03:16-03:32). This led to marine life washing up dead on the shore; colored foam, mass strandings, dead fish, and dead birds were all observed on the beaches of Chiloé (Navarro 03:36--03:46). Local and regional governments were complicit in the actions by the farmed salmon industry, allowing them to bury the huge ecological problem they created (Navarro 04:17-04:35). When he went to investigate an abandoned salmon farm, Navarro found trash all along the seafloor and very little life in the water because of the eutrophication of the area that essentially created a dead zone (Navarro 07:50-9:52). One major aspect of the industry that is specifically highlighted in this case study is the amount of trash pollution that comes from the salmon aquaculture industry. Trash, ranging from huge buoys to small microplastics have found their way onto all 20 kilometers of beach the island has (Navarro 04:58-5:40). They also highlight the egregious amounts of antibiotics used by the Chilean sector of this industry. They have gotten to the point where they are on their last effective antibiotic, florfenicol (Navarro 11:45-11:52). When this is no longer effective, it's likely that there will be mass mortalities that are even worse than what was seen in April of 2016 because lack of antibiotics will allow for disease to spread much quicker. With an ever-growing industry, the salmon aquaculture in Chile is looking to expand into the Magallanes region, which is one of the most pristine and remote areas in the world (Navarro 18:29-18:48). This region holds fundamental and international

ecological value comparable to the Amazon rainforest, making the expansion of Chilean salmon aquaculture controversial (Navarro 18:49-18:56).

By analyzing the salmon aquaculture through the lens of its impacts on Chiloé, it's clear that the Chilean salmon aquaculture industry is in need of drastic changes. The government complicity to the environmental degradation that is caused by these aquaculture practices is alarming. Unless people, like Ramon Navarro and Patagonia, had exposed the industry and government for their corrupt practices, they would continue to deplete the ocean's resources. With eyes on the industry, it's time for them to make systemic changes to become more sustainable. A localized context, like the case study of Chiloé, also provides insight to the thoughts, feelings, and concerns of the people that are directly affected by these environmental harms. An important aspect of analyzing food systems is to understand the stories of marginalized people and provide them a platform to educate those so far removed from the impacts, such as Americans. Seeing as the United States is the number one consumer of Chilean farmed salmon, there needs to be a realization by Americans on where their food comes from and the impact their food choices have on the environment.

Mitigation Strategies and Suggestions for Improvement

There is clear evidence that demonstrates the need for improvement in the salmon aquaculture industry of Chile. One main strategy that is suggested for sustainable development in the salmon aquaculture industry is to start using integrated multi-trophic aquaculture (IMTA). This is a process known as "the recycling of finfish (fed aquaculture) organic waste by filter feeders and seaweed (extracting species)" (Buschmann et al. 246). Specifically, in terms of Chilean salmon aquaculture, this would look like growing salmon, seaweed, and mussels together. The mussels and seaweed absorb organic and inorganic salmon wastes, which enhances

their growth and helps mitigate eutrophication seen in coastal ecosystems used for aquaculture (Buschmann et al. 246). This mitigation strategy not only addresses the common problem of eutrophication caused by the salmon aquaculture industry, but also provides a better harvest of the two added species (mussels and seaweed). This can lead to increased economic gains and diversification of revenue sources.

Another way to mitigate environmental impacts of salmon aquaculture would be to address the issue of sea lice in salmon, which causes harmful effects not only to the population of farmed salmon, but wildlife populations in the surrounding area. One possible technique is shielding, which involves closing off the entire aquaculture process from marine ecosystems to prevent the spread of sea lice (Moe Føre at al. 7). Another method is using inlet water, which is filtered and/or pumped in from deeper water (Moe Føre at al. 7). Alternatively, salmon farmers could treat the salmon by removing parasitic sea lice through the use of freshwater (Moe Føre at al. 7). Submergence is a fourth mitigation technique that submerges fish deeper in the water because it's known that higher levels of sea lice occur at upper water levels **(**Moe Føre at al. 7). A final technique is infection pressure, which is choosing a location that is expected to have reduced pressure of sea lice infection or the removal of sea lice in the water column by electricity, ultrasound, etc. (Moe Føre at al. 7). By using one of these variations of sea lice mitigation, the Chilean salmon aquaculture industry could proceed in a more sustainable manner through the reduction of their environmental impact.

Conclusion: A Food Justice Lens

Based on the information presented in this research paper, it's blatantly obvious that the Chilean salmon aquaculture industry needs to make systemic changes in order to promote sustainability within the market. The environment cannot wait idly as it continues to be

destroyed by this food production. The environmental and economic harms demonstrated by the industry heavily outweigh the economic and nutritional gains. If Chilean salmon aquaculture should continue, it needs to adopt the various mitigation strategies offered in this paper. Left unchecked, especially if the expansion into the Magallanes region occurs, the industry will continue to kill the ocean.

From a food justice lens, salmon aquaculture in Chile is not addressing issues of food insecurity in its own country. This industry, as mentioned, is export-oriented, especially because they don't have a population that typically consumes much seafood. Along with the improvements made to minimize environmental harm by the industry, they should shift production to focus on addressing local issues of food insecurity. Seeing as large salmon farms are also depleting the livelihoods of artisanal and subsistence fishers, they are contributing to issues of food injustice in the Global South at the expense of providing food to the Global North. Although there are a myriad of issues that currently result from Chilean salmon aquaculture, with a commitment to sustainability and food justice, the industry could shift to work towards making a better future, as opposed to its current role of actively contributing to the decimation of the planet's future.

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