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Atlantic salmon Aquaculture and Its Environmental Impacts

Introduction

With the increase in consumer demand for fish, and massive toll the commercial fishing industry has taken on ocean stocks, the aquaculture industry has seen a rapid expansion. According to Columbia University's Earth Institute, "global per capita fish consumption has almost doubled from the 1960s to 2012". While it is quite simple and materially efficient to farm herbivorous fish such as tilapia, carnivorous fish, such as salmon and tuna, have much larger demands. These fish require feed made from ground pelagic fish in order to grow and mature properly, and develop the omega-3 fatty acids in their meat that the consumers look for. Salmon farms are found across the globe, with the largest producer and exporter of Atlantic salmon being Norway. There are many issues found within the salmon aquaculture industry, however with an increase in new technology and farming methodology, the environmental impacts can be significantly reduced.

In 2009, the national government of Norway established five goals for the future of their aquaculture industry as well as a risk analysis for each item (Taranger, et al.). They split the list into concerns and possible ends that were of concern. This list includes—genetic interaction, salmon lice, viral diseases, organic waste discharge, and nutrient waste discharge. The goal of the list was to figure out and address the most common issues associated with farming salmon and to work towards eliminating them over time. Although the list was compiled by the Norwegian government, it can be used as a set of guidelines for salmon farms across the globe.

Literature Review

Genetic interaction between farmed and wild salmon can potentially have negative impacts on wild salmon. Farmed salmon can escape if the cages that hold them are damaged or during inclement weather, as the cages themselves are not designed to withstand rough waters. In Norway, Atlantic salmon have undergone rigorous selective breeding in order to maximize growth rate and size. However, there are also changes in traits that have not been targeted, such as predator awareness, stress tolerance, and gene transcription (Taranger, et al.). These changes, in addition to decreased genetic variation throughout populations of farmed salmon, can be detrimental to wild populations if the farmed fish are allowed to genetically mix.

Salmon lice are a type of naturally occurring, copepod parasite that consume the blood, mucus, and skin of both salmon and trout. In wild populations of salmon, lice are commonly found on adult fish in the ocean. However, during the salmon run, the parasites are shaken off by rapids the fish must swim through, keeping salmon fry safe from lice until they mature and make their way to the ocean (Carroll). In Norway, the top producing country of farmed salmon, data has revealed that there is a strong correlation between salmon farms and lice infestations on wild salmon populations (Taranger, et al.). In the close confines of a fish cage, salmon lice can multiply rapidly and easily infect all of its inhabitants, wreaking havoc and increasing mortality of the farmed fish. Due to the structural nature of the cages and the parasites' ability to live for up to three weeks without a host, any populations of wild salmon living near a fish farm are susceptible to infection. In addition, “it has been shown that 0.04- 0.15 lice per [gram of] fish weight can increase stress levels, reduce swimming ability and create disturbances in water and salt balance in Atlantic salmon” (Taranger, et al.).

In Hardangerfjord, Norway, farmers and scientists have been experimenting with using several different species of wrasse (*Labridae*) to clean salmon lice off of farmed salmon. Four species of wrasse, of which are native to the Norwegian coast, have been recruited for delousing purposes: the goldsinny wrasse, corkwing wrasse, rock cook, and Ballan wrasse (Skiftesvik, et al.). Chemicals have also been used to treat contaminated waters; however, the lice have developed resistance to the substances and continue to affect farmed salmon. The wrasses provide a solution for this, as they are a native fish whose delousing abilities cannot be protected against by the lice. Of the four, the Ballan wrasse (*Labrus bergylta*), is the most efficient species for delousing salmon (Solheim). On average, each wrasse can consume around 70 lice and can eat at lower temperatures than other types. While Ballan wrasses are generally harvested from the sea to be used as cleaner fish, it is not known how the harvesting of these fish will affect the local ecosystems. Thus, the Fishery and Aquaculture Industry Research Fund has put in around NOK 26 million into developing a system for commercially raising the wrasse to be used in the aquaculture industry (Solheim).

Viral and bacterial diseases, just like salmon lice, can spread like wildfire through fish cages and easily jump to wild fish. While the use of antibiotics to treat infection was prevalent throughout the 1980’s, scientists became wary of the overuse of antibiotics in farmed fish in fear that the medications would negatively impact the health of consumers (WHO). Additionally, heavy usage of antibiotics would increase bacterial antibiotic resistance, creating a vicious cycle of evolution and the development of new drugs. It could also result in the creation of a superbug, or a bacterium with an extremely high resistance to medicines, which would be difficult to stop in the event of an outbreak. In the late 1980's, scientists began developing vaccines that could be used to immunize fish, and by 1994, farms across Norway had switched over from antibiotic usage to vaccination (WHO). Through an automated process, the salmon can be vaccinated during their fresh-water phase, allowing for an efficient and cost effective method for preventing future disease-related deaths. As of October of 2015, Norway produces over 1 million tons of salmon annually. There are not vaccines against every virus however, as infectious pancreatic necrosis, pancreas disease, heart and skeletal muscle inflammation, and cardiomyopathy syndrome still afflict salmon farms (Taranger, et al.). As of late 2015, "Norway's people use roughly 50,000kg of antibiotics a year. In salmon, [Norwegians] are using only 1,000kg altogether to treat sickness, even though the salmon population has more than twice the biomass of human beings in our country" (WHO). Dr. Bjoørn Røthe Knudtsen, a fish disease specialist, notes that farmers already practice good hygiene, as many of them will periodically clear cages, and leave them empty, therefore cleaning and starting anew for the next generation of salmon. This technique, similar to crop-rotation, allows for only one generation at a time, preventing the spread of cross-generational disease or infection.

It is likely that the diseases that cause trouble for the farmed salmon originated from wild fish and spread over to cages, readily taking advantage of the high density of the cages and expand (Taranger, et al.). New, exotic, viruses can originate from a fish that was raised in a hatchery in another state and continent. Farmers do not know how to deal with an increase in these diseases, as there are no vaccines yet that have been able to combat these nonnative, exotic viruses.

Organic and nutrient wastes easily leak from fish cages and can wreak havoc upon the waters surrounding them. These wastes, comprised of fish feed, feces, and other metabolic byproducts, of which contain very high concentrations of carbon, nitrogen, and phosphorus, can lead to eutrophication and thus, algal blooms. Calculations of carbon, nitrogen, and phosphorous discharged to the environment from fish farms in 2009 in Norwegian waters resulted in 70%, 62%, and 70% respectively (Wang, et al.). Algal blooms result in an anaerobic environment, making it very difficult for the organisms in the area to survive due to the lack of oxygen in the water. This in turn can cause massive die offs, decimating most of the aquatic life. While the amount of fish per cage can be reduced to alleviate the effects of the nutrient overloading, it would be less efficient for farmers to raise fish in such a manner. To address this issue, the company Open Blue, launched in 2007, has developed a system for open ocean mariculture, which would allow excess nutrients and waste to be swept away and cycled into the deep sea by stronger open ocean currents. The company claims that their "approach means a natural growing environment for our fish, lower risk of disease and no traceable impact to the surrounding ecosystem". These fully-submerged, bipyramidal fish pens are stationed approximately eight miles offshore and are not kept at maximum capacity to lower the risk of disease. While Open Blue's system is currently only being used to farm cobia, another type of carnivorous marine fish, the cages can be used to develop a similar system to farm salmon without fear of dumping excess organic and nutrient wastes into the water.

The food that the salmon are fed usually consists of fishmeal—dried and ground pelagic fish and fish processing byproducts that are compressed into pelleted food that is then sold and fed to both the salmon. This pelleted food commonly contains carotene substitutes to color the flesh of the fish, and fish oil, used to feed the salmon so that they may contain higher levels of omega 3 fatty-acids. The fish used in the production of fishmeal are predominantly sardines, menhaden, and horse mackerel, all of which are not commonly consumed by humans. Excessive farming of pelagic fish can put pressure on wild stocks of carnivorous fish, as their prey is fished out of the water. To combat this, a number of research groups are trying to find vegetarian alternatives to fishmeal in order to feed farmed fish.

AquAdvantage salmon is a genetically modified Atlantic salmon, and the first genetically modified animal that has been approved by the Food and Drug Administration, created by the company, AquaBounty Technologies. It was developed by splicing a Chinook salmon growth hormone gene and a promoter from an ocean pout with an Atlantic salmon, which causes the fish to develop twice as fast as the standard Atlantic salmon (AquaBounty). These fish are hatched and raised in inland water tanks, in a system known as recirculating aquaculture system (RAS), and grow up to twice as fast as Atlantic salmon. RAS is a type of aquaculture setup in which the water inside the fish holding tanks is continuously filtered and circulated. The fish waste and byproducts created by the growing process are then usable as fertilizer for agriculture. AquaBounty also claims that “fish grown from AquAdvantage eggs are all female and sterile, making it impossible for them to breed among themselves and with other salmon”. Furthermore, the fish are spawned and raised in Canada and Panama respectively, with each facility armed with a number of steps, such as nets and jump fences installed as well as a closed, chlorinated septic system that will kill any escaped eggs, to prevent fish from escaping (FDA). The FDA conducted an environmental assessment and ruled that the fish would have no significant environmental impact. In addition, there is no regulation that requires AquAdvantage salmon to be labelled, however, the FDA has recommended that food manufacturers do so. While the genetically modified salmon and their growing methods have much less environmental impact than that of traditional farming methods, the technology is still too new for the fish to be cost effective, and the general consumer population has yet to accept genetically modified plants and animals as something seen as safe for consumption.

Discussion

The consumer demand for fish only continues to skyrocket as the population increases and fish becomes popularized as a protein source. The farming of carnivorous fish such as salmon is highly complex and can vary in its environmental impacts, depending on the methods used to raise the animals. While currently, the practices in which most Atlantic salmon are farmed are not particularly environmentally conscientious, new technology is being developed and refined in order to reduce the strength of its environmental impacts. With money being put into the research of fishmeal alternatives by the National Oceanic and Atmospheric Administration and the U.S. Department of Agriculture since 2007, the betterment of fish farming technology is not a pipe dream.

The development and especially the FDA approval of AquAdvantage salmon is an extremely exciting development in the salmon farming industry. If it can propagate and take hold in the consumers' eyes as an inexpensive alternative to wild caught salmon or an environmentally friendly alternative to traditional, cage farmed salmon; it could potentially change the entire industry. The recirculating aquaculture system holds fish at a lower density in each tank than traditional cage farms, but the incredibly high turnover rate due to the rapid growth of the new fish would make the system more efficient, allowing more fish to be sold in the long term. Additionally, since the RAS systems are based on land, they could be used to provide locally grown salmon to inland areas without having to expend energy to ship the fish to consumers.

Conclusion

The Atlantic salmon farming industry is rapidly becoming more sustainable and placing less of an impact on the environment. As fish becomes more popular as a source of protein in consumer diets, the market may shift as the demand for other meats, which place a larger burden on the environment, may decrease. Advancements in technology will ultimately not only speed up the process of raising fish, but will reduce the market price to make fish more comparable and accessible to the mass market.

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