Title

“Environmental Effects of Farm Salmon Aquaculture and The Sustainability of Wild Fisheries”

Objectives

The objectives of this paper are to understand the environmental impacts of farmed salmon aquaculture, as well as examine the sustainability of wild fisheries. First, the five main problems with farmed salmon are discussed: waste, parasites/disease, antibiotics, metals, and effects on wild salmon population. Each section will bring up environmental issues focused on nutrient cycles, non-targeted organisms, wild salmon populations, and humans. These issues will bring light to the decreasing biodiversity in the ocean and human food security. Secondly, the sustainability of wild fisheries and best choice for consumption will be examined.

Summary of Findings

According to the United Nations Food and Agriculture Organization, salmon is farmed in 24 countries. However, 80% of the total farmed salmon produced comes from Chile and Norway (FAO). Salmon aquaculture, production of farmed salmon, is known for producing highly valuable products to the growing fish market, a 3 billion dollar industry (Burridge et al., 2010). With continued human pressures on salmon fisheries, aquaculture is a promising alternative for increasing salmon production in the future. However, recently there has been great criticism because it appears to generate negative environmental impacts (Liu, Sumaila, and Volpe, 2011). Through increased waste, disease, antibiotics, metals, and escaping farmed salmon, the negative environmental impacts of aquaculture continue to rise. However, wild Alaskan fisheries are well managed and have low contaminants making wild salmon a great sustainable alternative.

Environmental Effects of Farm Salmon Aquaculture

Waste

Salmon aquaculture consists of large floating cages or pens of salmon are placed in semi sheltered coastal bays that are still connected to the open ocean. In order for the farmed fish to obtain all key dietary needs to grow strong, vitamins and supplements are added to their feed. When food pellets are placed into the pens, not all is consumed and the vitamins and supplements dissolve in the water. The remaining bits, as well as the feces from the salmon, accumulate under the cage and can be extremely detrimental to the surrounding environment (Maitland and Morgan, 1997).

Over time, this bioaccumulation of excess feces and feed is dispersed by the currents, increasing nutrients in the greater marine environment. These particles are quite soluble in water, allowing the ammonia content, a specific nitrogen based-nutrient, from the salmon to spread...
quickly into the surrounding environment (Maitland). In addition, decomposition of the feces and food waste have a high concentration of phosphorus, another type of nutrient (Munro, 1990).

Together these effects from feces and excess feed of farmed fish cause eutrophication, an influx of nutrients in the ecosystem, which in turn causes an increase in plant growth, an algae bloom. The plants consume all available oxygen in the system, thus depleting the area of life resulting in a dead zone. This chain of events makes it hard for other organisms to survive, ultimately decreasing biodiversity in the surrounding areas as well as making it harder to sustain population of wild fish in the area (Burridge et al., 2010). Excess nutrients is a huge problem facing our water systems today and if continues, marine life close to shore may disappear forever. Livelihoods of people dependent on fisheries will be devastated. (More information see Ord 2012) (Burridge et al., 2010).

Parasites/Disease

Salmon’s life cycle consist of hatching in a river, swimming downstream to the ocean and swimming back upstream to spawn. After reproduction, salmon die. When placed in a cultured system, this life pattern cannot be sustained. Instead, they swim in a confined area, overcrowded with fish (Munro). These conditions are perfect for high rates of disease and parasites to spread quickly across the population allowing cultured salmon to be more susceptible to an epidemic of inflectional bacteria, virus, parasites, and disease. These diseases can be extremely harmful and destructive to any given aquaculture system (Burridge et al., 2010).

One of the most common problems facing farmed salmon today is sea lice. Sea lice reproduce quickly and all year round, making rapid spreading of such organism hard to control. This ectoparasite (outside the body) eats away at the skin of the fish. As the skin erodes, the salmon become more vulnerable to sub-epidermal hemorrhaging, uncontrollable bleeding under the skin. When a fish starts to bleed, the blood spreads quickly in the water, allowing the sea lice to disperse efficiently across the population. If these parasites go untreated, the salmon farmers could be at risk of losing the entire population, because of the high risk of secondary infections and osmotic stress. The best control of these parasites is simply to bath the fish in an insecticide called dichlorous, commonly known as an Aquaguard (Burridge et al., 2010). Although this kills the sea lice, it can be detrimental to the skin of the farmed salmon. The water of the bath is released into the surrounding areas even though it still contains insecticide dissolved in it. Sea lice therapeutants have the potential to negatively impact sensitive non-targeted organisms in nearby areas, as well as disrupt the population structure of surrounding environments. This devastation can result in tremendous economic losses for the aquaculture company (Burridge et al., 2010).

In order to have less effect on the surrounding environment, farmers must dilute the contaminated water leaving the aquaculture system 2000 times the current volume. Since the feasibility of the dilution is not likely, Canadians in 2009 switched over to adding Emamectin Benzoate (EB) into the feed of the fish. To date, EB is has not been found to be lethal to non-targeted organisms; however, it has been noted that ingestion of EB induced premature molting of lobsters. Overall, risk seems limited to small numbers and widespread population effects are
unlikely. Yet, overuse or over-reliance of any antibiotic or drug can spark the development of resistance to the compounds in parasites (Burridge et al., 2010). Although many vaccines and treatments have been developed to control these rapidly spreading diseases, many strains of the viruses and parasites are quickly mutating to become resistant and harder to control. These diseases can be deadly, killing an entire population of farm or wild salmon. Because of the resilience of parasites and viruses, the wild populations of salmon have been deeply harmed. Wild salmon lack human intervention of antibiotics to save them from these parasites (Burridge et al., 2010).

New diseases continue to appear, making it harder than ever for science to keep up with the eradication process. Scientists have a double pressure to find eradication strategies that save the cultured salmon, but that do not harm the surrounding environment. This is a hard task and often times the environment is placed on the back burner.

**Antibiotics**

With diseases and pathogenic bacteria spreading rapidly across farmed fish populations, an increase in demand for antibiotics as a source of protection arises. Antibiotics are carefully designed to kill the pathogen without harming the host species (salmon). In theory the antibiotic is a stable compound that breaks down quickly once inside the salmon so it doesn’t harm the host while eradicating the virus; however, more often than not, the antibiotic remains active in the salmon long after the disease is eradicated. Compounds will then be excreted via stool or urine and enter the environment. In addition, if not all the feed is consumed, the antibiotic placed in the food will dissolve in the water, entering the surrounding environment once again. Once in the water system, the antibiotics can become extremely dangerous to non-targeted organism, affecting the biodiversity of crucial keystone species such as phytoplankton and zooplankton communities. Being on the bottom of the food chain, these species have the potential to affect the larger health of animals and humans because the food web is all interconnected. This can even be detrimental to the salmon aquaculture industry itself (Burridge et al., 2010).

Currently, antibiotics are apart of the growing problem of active medical material circulating in the environment. An increase in antibiotics can lead to an influx in the selection of antibiotic resistant bacteria, resulting from spontaneous mutations. In turn, the development of resistances makes the antibiotics progressively more useless. As new bacterial strains emerge and become resistant to several antibiotics simultaneously, scientists are forced to continue to develop drugs to combat the new strains. If the mutations get out of hand, the dangerous pathogens can eventually acquire resistance to all previously effective antibiotics and give rise to uncontrollable epidemics (Burridge et al., 2010).

The residual antibiotics in farmed fish can directly affect human food safety. In 2007, for example, the FDA temporarily blocked the sale of five aquaculture products from China, because they contained residues of salmonella, nitrofurans, and fluorquinolones. As well, antibiotics used in aquaculture can reach wild fish and shellfish populations collected for human consumption, in turn affecting our food safety. The antibiotics are not highly regulated, thus one could eat a wild salmon or shellfish and have no idea that there is antibiotic residue (Burridge et al., 2010).
Metals

Metals enter the marine environment via antifoulant paints or fish feed. In the feed, metals are either added as nutritional supplements or are part of the original make up of the pellets. Copper and zinc have been shown to be the most elevated byproducts near aquaculture sites (Burridge et al., 2010).

Copper-based antifouling paints are applied to salmon cages to avoid growth of attached marine organisms. The build up of such organisms can reduce the water flow through the cages, thus decreasing the dissolved oxygen, leading to a reduction in durability of the nets, and ultimately reducing their floatation (Burridge et al., 2010). The applied paint reduces the need for replacement of the nets, but is harmful to the environment. These metals from the paint leach into the water system and exert toxic effects on non-target marine life in the water and sediments below the cages. Chemicals tend to accumulate in sediments, elevating the organic carbon and sulfides, which bind to copper. Once the copper binds, the risk of harm to non-targeted organisms dramatically decreases. However, if the copper doesn’t bind, it can be toxic to algae, mollusks, and crustaceans (Burridge et al., 2010).

Elevated levels of zinc have also been found in sediment build up. Zinc is often found as a supplement in salmon feeds and binds to organic compounds in the sediments. However, it is much less toxic than copper when not bound in water. Today, the amount of zinc placed in the feed, exceeds dietary requirements for farmed salmon, thus increasing its presence in marine ecosystems. Marine algae are particularly sensitive to zinc, therefore, it has a remarkable disruptive effect on the algae in the surrounding environment (Burridge et al., 2010).

Increase levels of copper and zinc along with other metals are extremely harmful to the surrounding environment. These metals can also leach into wild populations, in turn affecting organisms that humans consume, resulting in a trace of harmful metals in human bodies (Burridge et al., 2010).

Effects on wild populations

It is estimated that 2 million farmed salmon escape into the wild each year causing 20-40% of wild caught Atlantic salmon to actually be farmed raised. These escapes occur through regular, low level “leakage” as well as periodic events such as storms (Naylor and Burke, 2005). Because of the contained, closed population of farmed fish, the genetic difference between farmed and wild are significantly different. Thus, once a farmed fish escapes and interbreeds with a wild population, the ability for the wild salmon to survive dramatically decreases (Munro, 1990). Once farmed and wild populations interbreed and the hybrid offspring reproduced the purity of wild salmon is lost (Naylor and Burke, 2005). A study by Fleming at. al 2000 showed that genes from farmed populations are more often expressed than that of the wild gene pools. Thus there is a direct gene flow taking place, resulting in a decrease of wild salmon genes (Fleming IA, 2000). Overtime, all wild genes will be lost and the oceans will only be left with hybrid and farmed salmon. Fleming also found that hybrid offspring are not as fit to compete in
their environment, increasing the infant mortality rate of these salmon populations. With a high infant mortality rate, interbreeding might be driving vulnerable salmon populations closer to extinction (Fleming IA, 2000).

Also, once the farm salmon escapes they compete for space and food with wild populations, resulting in killing eggs and young. As the farmed and wild populations mix, the bacteria and viruses that farmed fish have become immune to can dramatically hinder a wild population. Wild salmon do not have the same resistance build up as farmed salmon (Maitland and Morgan, 1997).

Farmed juveniles are typically larger than wild juveniles even in nature, demonstrating artificial selective growth. The genetic variation selected for in farmed populations is shown in the clear difference of behavioral traits. Farmed raised salmon have a size advantage as well as a competitive edge over wild juveniles. Mortality and growth of wild populations are affected by the addition of cultured salmon. The increased aggressiveness of cultured escaped juveniles can severely stress the wild salmon causing them to shift towards poorer habits, thus increasing their death rates (Naylor and Burke, 2005). In a study by Fleming, it was found that wild juvenile salmon populations were suppressed by more than 30% in the presence of farmed juveniles (Fleming IA, 2000).

Sustainability of Wild Fisheries

If so many problems are associated with farmed salmon, is there an alternative that is good for humans and the environment? The answer to this question is mostly yes. Wild salmon populations are dramatically decreasing because of overfishing, yet the rate of consumption is rapidly increasing. This combination is a recipe for unsustainable industry. However, there are some sustainable commercial fisheries working hard to protect salmon habitats and prevent overfishing, though balancing economic growth with these restrictions is quite difficult.

The Wild Salmon Center’s (WCS) mission is to “make sustainable salmon fisheries more profitable, thereby rewarding fishermen whose operations meet strict sustainability criteria” (2012a). As a supporting third-party certification assessment of Pacific salmon fisheries, the WSC provides a road map to the sustainability and related fishery improvements through scientific, technical, and logistical assistance. Oversight and regulation is scarce, making it hard to enforce sustainable certification. However, recently, overharvesting of fish populations has decreased and habitat destruction is rapidly rising. Habitat loss is the largest problem facing wild salmon today and many think it might be irreversible. The incentive to conserve and manage, according to the WCS, is “if we manage our wild salmon wisely, they will continue to nourish human communities and ecosystems as well as provide long-term food and economic security for the nations of the Pacific Rim” (2012a).

Although the WCS is working hard to protect salmon fisheries and increase the industries sustainability, the Monterey Bay Aquarium states that the only real sustainable fisheries are in Alaska (2012b). Alaska salmon is only caught in tightly regulated areas within state waters up to three miles offshore. Every aspect of Alaska’s wild salmon fisheries are strictly regulated,
closely monitored, and rigidly enforced. The state of Alaska controls fishing areas, fishing licenses and fishing gear. Through regulating the fishing areas, the government can prohibit fishing too far offshore, as well as open and close areas available to fishing depending on the current number of the salmon population. The number of people allowed to fish commercially is limited by the state. Lastly, the state ensures there is a significant number of adult wild salmon that escape the fisheries so the population can continue to grow. The number of wild salmon released varies with environmental conditions and population size (2012c).

Along with regulation from the state, fisheries are ecologically sound in other important ways. All wild Alaskan salmon live in natural habitats of open, clean waters in the Pacific Ocean. Growth of the fish is at a natural pace while they eat only food found in the ocean. Throughout the salmon’s life they swim freely and return to their natal streams to spawn on their own schedule. Allowing this course of natural actions to occur forces Alaska’s fisheries to be seasonal, rather than year around. There is no farmed salmon in Alaska, ensuring no risk of interbreeding (2012c).

Salmon are an integral part of Alaska’s natural environment, thus closely managing the populations help the livelihood of fishermen as well as promote robust populations of bears, eagles and many other mammals and birds. No other region has been as diligent as Alaska in management. It was only until some species of salmon were listed as endangered other states started to care and promote conservation programs.

Recommendations and Conclusions

If you are so inclined to continue eating salmon, that’s great, but make sure to steer clear of farmed salmon. According to the Monterey Bay Aquarium Seafood Watch and the Environmental Defense Fund, Wild Alaskan Salmon is the best choice. California, Oregon, and Washington wild salmon is a good alternative, but farmed salmon is strictly recommended to avoid. Alaskan wild salmon comes from well-managed fisheries with low contaminants in the water due to the lack of salmon farms (2012b; 2012d). Monterey Bay Aquarium advises consumers to avoid farmed salmon because, “Waste from these farms is released directly into the ocean. Parasites and diseases from farmed salmon can spread to wild fish swimming near the farms and escaping farmed salmon can harm wild populations” (2012b). In addition, antibiotic resistant mutations are rising from farmed salmon as well as metals are leaching into surrounding water systems from the aquaculture sites (2012b). Together, all these harms are decreasing the spectacular biodiversity of our oceans and contaminating other food sources for human consumption, thus affecting our food security.

The good news is salmon farmers are working hard to change and improve their practices. As the demand for salmon grows, the farms have to keep up production practices while hopefully bearing the environment in mind, as well as the human demand. However, as of now Alaskan Wild Salmon is our best choice if salmon is a necessity for you (2012b).
Sources
2012a. Sustainable Fisheries Program. Wild Salmon Center, Portland, OR.
2012b. Salmon, Farmed including Alantic. Monterey Bay Aquarium Foundation, Monterey, CA.