Title
Sustainable Salmon Farming Practices and Possible Mechanisms for Encouraging Their Practice

Objective(s)
The objective of this research and this paper is to examine what parts of salmon farming are most environmentally unfriendly and how we can alter farming techniques in order to make salmon farming more sustainable and healthy for the environment.

Summary of Findings
Salmon Feed

Feed for farmed salmon is one of the most scrutinized aspects of salmon aquaculture. Many farmed fish can be fed a plant-based diet that results in a net increase in protein. Salmon however are carnivorous fish that have many dietary needs that need to be met in order to ensure good health. According to Olivia-Teles, there are certain indispensable amino acids that salmon must eat because they cannot synthesize them on their own. In addition there are more amino acids that must be eaten in order to be converted into other important amino acids (Olivia-Teles 2012). Not all protein sources give salmon these required amino acids. Unfortunately, that means that the protein sources in salmon feed must be very specific. In the wild, salmon eat smaller fish, so the obvious choice would be to make salmon feed from these various “feeder” fish which are converted into fish oil and fish meal: the basis for salmon feed.

Fish meal and fish oil are processed fish products. Large industrial fleets fish for small herbivore species like anchovies and sardines. These are then sent to factories that process the fish into these products. One of the first inefficiencies of fish feed occurs here. It takes between two and five pounds of these forage fish to create one pound of fish meal (Weber 2003); Peter Tyedmers calculated that 22% of the wet fish weight ultimately becomes fish meal (called the yield rate). Even worse, it takes up to twice that amount of forage fish to create one pound of fish oil, 12% according to Tyedmers (Tyedmyers 2000). This is of course due to the fact that not every part of the fish can be used in making these products. It is important to keep this statistic in mind when considering certain feed conversion ratios that are the standard of evaluating the sustainability of salmon feeds.

Feed conversion ratio (FCR) is the ratio of weight of fish feed eaten to the weight gained by the fish. As mentioned earlier, this statistic is slightly skewed by the fact that the weight used is the weight of the fish feed, not the weight of the fish required to make these products. The Monterey Bay Aquarium has created a slightly different statistic that includes both the yield rate and the inclusion rate of each product in the feed in order to fully encompass how much of the fish in feed is converted into salmon. They call this the ratio of wild fish input to farmed salmon output or WI:FO and it is calculated by the following equation: WI:FO = Yield rate x Inclusion
rate (%) \times FCR. They use this ratio to evaluate the sustainability of different farming techniques (Gilbert 2009).

The one farming technique that they give a green rating is a freshwater salmon farm in Washington State run by the Aquaseed Corporation. For a variety of reasons that will be discussed, this farm is considerably more sustainable than other salmon farms that they have observed. With respect to feed however, this farm received a moderate conservation concern rating. They found that the WI:FO ratio was about 1.2 with respect to fish meal and 0.8 with respect to fish oil. The aquarium made its judgment based on the ratio with respect to fishmeal, though the 0.8 ratio with respect to fish oil would fall under the sustainable level. It appears that this number is below average due to the species (coho) of salmon that they farm. Coho can stay healthy with a lower amount of its protein from fish it eats (Gilbert 2009). These data suggest that we can choose species of salmon to farm that will require fewer marine inputs and therefore will be more environmentally friendly.

Other companies have looked into alternative manners of feeding salmon without relying so heavily on feeder fish. This change would require finding new sources of protein and fatty acids. It is difficult to provide salmon with the protein they need, so some level of fish meal will always be needed to provide the indispensable amino acids. Conceivably a more sustainable feed could be created using alternative plant protein sources like soybean meal or maize gluten meal (Olivia-Teles 2012). Great care must taken in crafting these diets though as fish do not perform nearly as well with free, unnecessary amino acids in their diets.

Fish oil is the main source of polyunsaturated fats in fish feed. These fats are necessary parts of the fish’s diet as well as ours. Without a well balanced supply of these essential fatty acids, fish will grow slower and will not use their feed as efficiently (Olivia-Teles 2012). Many people also eat salmon for the omega-3 fatty acids that it has which are purported to have great nutritional value. Neither humans nor fish can synthesize these fats; they must eat them. Unlike proteins, there is not as wide a variety of fatty acids that fish can use, so it is likely possible to get the fatty acids from a source other than fish oil and reduce the strain on marine resources.

One company has claimed that they have a solution. Verlasso “harmoniously” raises their salmon on a diet that includes genetically modified yeast that produce omega-3 fatty acids. That reduces their dependence on fish oil to the point where they claim that they raise one pound of salmon per pound of feeder fish (Verlasso 2011). Recent literature confirms that yeast have become a viable, safe source of these omega-3 acids (Leigh A. Belcher 2010). Though one cannot trust their statistics directly given that most of this information was found on their website, Verlasso does provide an example of using technology to reduce dependence on marine resources.

The Scottish government has also produced reports that indicate that other substitutes for fish oil are successful to a certain extent in fish feed. They have seen that rapeseed oil and soya oil have been successful at raising fish in a healthy and rapid manner. Unfortunately, these oils do not raise salmon with high quality meat, leading to consumer dissatisfaction. They have found that they can dilute these plant oils by feeding the fish a 100% fish oil based diet for six months prior to harvest. The meat then meets quality standards. For the twelve months or so prior to the switch in diet, the salmon are raised with considerably less strain on marine resources (Unit 2002).

It is clear that, with changes, salmon feed can become more sustainable. Scientists and nutritionists can formulate diets that include more indispensable amino acids from alternative
sources. There will always be a need for feeder fish, but with a finely tuned diet, it will be possible to lower this dependence. Other important parts of their diet can also come from alternative sources, meaning that in the future, salmon farming could reach a point where a normal farm has a WI:FO of less than one.

Containment

Most salmon are farmed in open water pens or cages. Farmers can reach the pens through docks set up along the pens or by boat. Often the fish are forced to live in crowded conditions. They create large amounts of waste and are subject to industrial pollution that leads to questions of whether people should be careful of eating too much farmed salmon. For a more complete analysis of these environmental issues please read Arielle Koshkin’s paper.

There are several ways to improve these environmental issues that result from current farming techniques. Given that salmon are especially susceptible to pollution, farmers should be more careful in choosing the location of their farms. Companies like Verlasso have moved to Chile, in particular Patagonia, where they are sure to be far away from many industrial pollutants. Chile, according to Hines, et al, is one of the cleanest places to raise salmon (based on PCB content) other than Alaskan wild caught salmon (Hites 2004). Though it may result in an increase in carbon footprint due to the need to transport materials and product across much longer distances, the increase in safety of product may be worth it.

Aquaseed Corporation has found a completely pollution-free place to farm their salmon: in freshwater pens. In such a pen they can control the water going in, meaning the water will certainly be free from industrial contaminants, resulting in safe salmon (Gilbert 2009). Inland pens can be placed anywhere and will not result in any increased transport costs.

It would appear to be difficult to improve the containment system itself. Verlasso claims that their double netting system limits the number of escapees, but that seems like dubious self-promotion. Even on their website they feel that they need to address their escaped salmon. They claim that, due to a lack of wild populations in the areas where they farm, escaped salmon do not have as large an impact on the environment (Verlasso 2011). Once again this seems debatable as the escaped salmon will still interact with other species and will likely disrupt the ecosystem. There seems to be little possibility of finding an environmentally safe way to farm salmon in the ocean.

Therefore more companies must start following Aquaseed’s lead. By moving their pens inland, there leaves little way for salmon to escape and mingle with the surrounding environment. By simply installing grates along any place where water runs off into the environment (waste water that has already been pumped through the farm), Aquaseed can prevent salmon from leaving the farm. Given that the pens themselves are well separated from water supplies, there is little chance of the fish surviving a jump over the walls into the surroundings.

A last issue that salmon farms must address to become truly sustainable is the issue of water movement, or lack thereof that is leading to unhealthy conditions. By moving to more remote areas, it is quite possible that water quality will improve and help to lessen the impacts of stale water. That being said, it will take much more to improve these conditions. A water pump
or some sort of machine to force water through will help improve water conditions, spreading out the waste that collects in the pens and leads to unhealthy conditions for the fish themselves. By farming their fish in pens away from the ocean, Aquaseed must pump water through; ensuring that none of the waste from the fish will stay in the pen and it can be collected elsewhere. Such an alternative is quite viable and will improve conditions (Gilbert 2009).

It is clear that conventional salmon farms will never fully contain their fish. There will be times that fish escape and waste will continue to build up in and around the pens. There is no way to alter their structure slightly to achieve a more sustainable outcome. Though they may move to more remote places where escapes may have less of an impact or the waste may be pumped away, these problems will not be eradicated, and, as such, salmon farmed the way they currently are will not be environmentally friendly. It will take a drastic change, such as moving the pens inland and creating an artificial ecosystem for the fish, to improve the viability of all aspects of the containment system. Such a change will eliminate pollution and improve the health of the fish involved. Waste can be collected separately and fish escapes will have no impact on surrounding populations. This change will not be easy to accomplish, but for those looking to improve farmed salmon quality, this change is necessary.

Synthesis

It is surprising that salmon farmers are not more desperate to effect change in their industry. Currently, more and more studies have found that farmed salmon is less healthy and is in fact dangerous to eat too much. The environmental defense fund claims that most people should eat less than two meals of farmed salmon every month due to high levels of PCB’s in the fish (EDF 2011). Hites et al claim that we should eat even fewer servings of salmon from almost every major country where salmon is farmed (Hites 2004). As such information becomes known by the public, it will put more pressure on the industry to change.

If such high contaminant levels are truly a health risk, the U.S. government should take some sort of action. Perhaps they could publish their own health warning or require that most farmed salmon contain a label warning consumers of its health risks, thereby encouraging farmers to farm healthy fish through new farming techniques. It also would do so with a rather limited monetary commitment for the government, which, in such tough economic times, is important.

With a larger monetary commitment, the government could certainly encourage change from the industry as well. They could provide subsidies for more sustainable salmon feeds, encouraging farmers to feed their fish food that relies less on over-fished stocks of feeder fish. They could also encourage farmers to create more inland farms, perhaps through lower interest rates on loans used to purchase new land and equipment for these farms or through tax incentives for companies that choose to farm in this new, more sustainable manner. These actions would require that the government determines that this is in fact a problem that they must address. If this does not happen, then farms will continue to farm using their current methods, and they will continue to produce fish that are unhealthy.

As markets continue to dictate salmon farming, farmers will not change their farming techniques. There is currently no economic incentive to farm fish sustainably without harming
the environment. The changes discussed earlier require significant capital, and, as such, will not occur on their own. As much as many people wish, environmental concerns are not enough to trump economic concerns. Most salmon farmers will choose their own well being over that of the environment. While it easy to write a paper about changing salmon feed or containment systems, it is much more difficult to make that happen. The government can take the lead in several ways, some requiring more money and some requiring less, which will have a major impact in improving salmon farming. Until that happens however, there will be little change and farmers will continue to hurt the environment until it can no longer support salmon farming.
Sources


