**Atlantic Salmon Farming in Puget Sound and the Salish Sea:**

An Analysis of the Environmental Risks

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On August 19, 2017, an aquafarming operation containing over 300,000 Atlantic salmon near the San Juan Islands in Washington State suffered a catastrophic failure. The company running the farm, Cooke Aquaculture, had failed to adequately maintain the net pens housing the fish, and a combination of weak moorings and more than 110 tons of biofouling (muscles, kelp, etc.) had left them susceptible to increased tidal currents. Initial reports in the weeks following the collapse estimated that around 160,000 non-native salmon had escaped into Puget Sound, however an investigation conducted by the WA Departments of Natural Resources, Ecology, and Fish and Wildlife has since shown that the figure is in fact closer to roughly 250,000 fish[[1]](#footnote-1). Since the incident, DFW has opened more fisheries to recover as many fish as possible, but thus far only ~57,000 fish have been caught, leaving close to 200,000 still unaccounted for. The potential long term impacts on the local ecosystem are still unclear.

Events like this give fresh life to the debate surrounding how much restriction is put on large scale aquaculture, and more particularly finfish mariculture systems, where there are minimal barriers between farmed populations and the natural environment. The subject as a whole is one that merits further research and dialogue, but this paper will examine the policy allowing of Atlantic salmon farming in Puget Sound and the Salish Sea in particular, and weight the benefits against the potential risks.

**The Need for Increased Food Production**

According to the 2017 revision to the World Population Prospects from the UN, the world’s population is expected to reach roughly 9.8 billion people by 2050, and over 11 billion by 2100[[2]](#footnote-2). This drastic increase will necessitate the production of more food than has ever been produced in history, and in a way that does not destroy the planet’s biosphere in the process. In fact, a comprehensive outlook published by the Food and Agriculture Organization of the UN in 2012, using a figure of only 9.15 billion by 2050, estimated that global food production will need to grow by 60% to support the population[[3]](#footnote-3). The report also cited trends in developing countries away from grain and towards livestock based diets, and while fish consumption in particular was not singled out, meat consumption in general is expected to rise by more than 75% over the same time period.

Compounding on this demand pressure is the fact that the global limit for capture fishery production has apparently already been reached. According to the FAO, capture production has been relatively stagnant since the late 1980s, and as of 2013, roughly 89.5% of world fisheries were being fished at or above biologically sustainable levels (58.1% and 31.4% respectively)[[4]](#footnote-4). In light of these revelations, it is critical that every potential method of food production is examined and weighed against all others for its productivity and sustainability.

**Farmed Atlantic Salmon as Part of the Solution**

Proponents of raising Atlantic salmon in Puget Sound and the Salish Sea argue that marifarming can provide an abundant and stable supply of healthy protein, at low prices to consumers and with minimal environmental impact. A 2013 nationwide investigation conducted by Oceana found that wholesale prices for wild caught Chinook salmon were 66% higher on average than that of farmed Atlantic salmon, which resulted in corresponding retail prices that were 88% higher to consumers[[5]](#footnote-5), supporting at least part of that claim.

An initial review of the regulatory reports summarizing environmental impacts from these mariculture farms actually appears to support the assertion that they pose little risk to the local ecosystem as well. A pair of reports released by the National Oceanic and Atmospheric Administration in 2001 and 2002 examined a comprehensive list of potential vectors for ecological damage, and surprisingly found an overall lack of historical research data supporting the level of concern surrounding them. The first report focused on the environmental risks attributable directly to the operation of the mariculture farms. The issues raised were: i) the buildup of bio-deposits from excess feed and fish fecal matter, and the effects these have on the volatile solid and sulfur chemistry of the sediment, ii) increases in benthic biota feeding on the aforementioned deposits, and the potential for reduced dissolved oxygen levels in sediment resulting, iii) the accumulation of heavy metals in the sediment due to their use in anti-fouling paints and fish feed, and iv) a number of other less likely consequences including enhanced algae blooms, and low dissolved oxygen levels in the water column, among others. In each case, their findings supported the position that environmental impacts were within reasonable limits in areas with sufficient tidal flushing, and could be virtually eliminated with careful regulatory oversight and by cycling pens and allowing fallow periods in between rearing cycles[[6]](#footnote-6).

The second report focused on the more pernicious concerns regarding how the introduction of Atlantic salmon in Puget Sound could adversely affect the endangered native Pacific salmon species of the region. In particular, the potential risks that were investigated were: i) the transmission of exotic or treatment resistant pathogens to wild stock, and ii) whether escaped Atlantic salmon could negatively impact wild salmon populations through hybridization, competition for food or habitat, or direct predation. Again, NOAA studied the historical research and found that these risks posed little or no threat to native Pacific salmon[[7]](#footnote-7). The same report cited that between 1988 and 2000, at least 900,000 farmed Atlantic salmon escaped from their pens in Washington and British Columbia, and did not result in any self-sustaining populations. In fact, between 1951 and 1991, WDFW coordinated 27 dedicated, albeit misguided, attempts to establish self-sustaining Atlantic salmon populations for commercial fishing via the release of smolts, and in each instance failed to do so[[8]](#footnote-8).

Taken at face value, these reports would suggest that farming Atlantic salmon, when properly regulated and monitored, can be a perfectly safe and environmentally sustainable option for producing healthy protein in the Pacific Northwest. However, in situations such as these it is important to remember that the absence of a negative historical result does not prove the nonexistence of risk.

**Remaining Risks to Consider**

It is worth reexamining at least a couple of the risks written off in the NOAA reports that could still be of consequence. First, and arguably foremost in the public consciousness since the 2017 Cooke Aquaculture collapse, is the possibility for escaped Atlantic salmon to negatively impact endangered Pacific salmon stocks by outcompeting them for food and habitat. This concern was squarely dismissed by NOAA in their reports, however there has been at least one recent case that has refuted this. One study from 2000 found evidence that escaped Atlantic salmon had spawned in the Tsitika River in northeastern Vancouver Island. A total of 40 juvenile *Salmo* were observed, of which 12 were captured and shown through mitochondrial DNA testing to be farmed Atlantic salmon. Additional evidence such as scale growth rings suggested the fish had been exposed to seasonal variations in temperature, and were even of two distinct age classes. Based on this evidence, it was concluded that these juvenile salmon were likely the result of spawning feral Atlantic salmon[[9]](#footnote-9).

A follow up study conducted by the same research group attempted to discern whether Atlantic salmon could successfully compete with steelhead in laboratory conditions. The steelhead were overwhelming more successful in a variety of settings with one notable exception. When the Atlantic salmon were allowed to establish residence with a three day lead on the steelhead, they were able to outcompete them for forage. It was therefore concluded that based on this evidence, combined with the fact that Atlantic salmon typically spawn a number of months prior to steelhead in the wild, that it was entirely possible for Atlantic salmon to establish habitats in niche “high risk” river systems where native populations had dwindled[[10]](#footnote-10). One need not look very hard to find countless examples of invasive species that have been able to turn a small foothold into complete dominance of an ecosystem, and therefore this concern should be heeded carefully.

Another issue that should be reexamined is the risk of spreading infectious pathogens to native species from farmed populations. One particularly troubling case of this is the ongoing infestation of Lepeophtheirus salmonis, or sea lice, in populations of pink and chum salmon in the Discovery Islands in British Columbia, which is home to one of the largest Atlantic salmon farming industries in North America, producing almost 3.5 million fish annually[[11]](#footnote-11). Sea lice are parasites that feed on the surface tissue of salmonids, causing stress, osmotic failure, viral and bacterial infections, and death[[12]](#footnote-12). A study conducted in 2005 and 2006, based on a sample size of more than 4,600 fish, found that the prevalence of sea lice in juvenile salmon collected in waterways directly adjacent to farms in the Discovery Islands was significantly higher than in those collected in peripheral waters, but that in both cases the prevalence was significantly higher than in regions where no salmon farming was taking place at all[[13]](#footnote-13).

Furthermore, a recent study published in December of 2017 found a similarly troubling pattern in the spread of piscine orthoreovirus (PRV), which is the caustic agent in heart and skeletal muscle inflammation (HSMI). This disease causes lesions in the heart and skeletal muscles of salmonids and can impair swimming behavior - a disastrous effect to populations with arduous migration patterns - and in extreme cases lead to anorexia and death. The study found that while farmed salmon populations in British Columbia had the highest incidence of the virus (in some cases up to 95%), wild salmon populations were also infected at rates proportionate to how far from mariculture operations they were located[[14]](#footnote-14).

These are just two examples of how pathogens can be inadvertently cultivated in Atlantic salmon farms and then spread to wild salmon populations, and yet taken together they pose a real existential threat to the native Pacific salmon of British Columbia. Given this information there is simply no basis to presume similar outbreaks could not happen here in WA.

The final risk that should be reexamined is the impact excess feed and fecal matter can have on the local environment. One study published in 2015 comparing two large Atlantic salmon farms located in the Hardanger Fjorden in Norway, showed that small differences in hydrological conditions could lead to significant impacts in the abundance and diversity of benthic macrofauna. One site was located in relatively open waters with average water current rates of 3-5 cm s-1 and surges of >20 cm s-1, while the other was located in an inlet further from the coast with maximum flow rates rarely exceeding 2 cm s-1. All other factors, including the size and history of each farm as well as water depth and temperature were closely related. This study found that sedimentation up to 700 m away at both sites showed significant decreases is macrofaunal diversity and evenness (distribution of species), but impacts at the low current farm were severe, with species diversity dropping from 13-19 species down to only 1, and overall macrofaunal abundance dropping nearly 100 fold to borderline azoic levels[[15]](#footnote-15).

The conclusion drawn was that a spike in levels of deposited particulate organic carbon (POC) and nitrogen (PON) led to the increased propagation of pollution tolerant species - in this case *Vigtorniella ardabilia*, a carpet worm typically associated with whale falls - and their eventual domination of the local ecology. Studies such as this one reinforce the critical importance of thoroughly evaluating the hydrodynamics of proposed sites before approving the operation of Atlantic salmon farms.

**Conclusions and Recommendation**

The State of Washington should honor the wishes of local tribal leaders[[16]](#footnote-16) and immediately put an indefinite freeze on new permits to install and operate Atlantic salmon farms until improved standards and protocols can be established regarding the construction, maintenance and inspection of net-pen systems. The State’s own joint report released by DNR, DOE, and DFW summarizing their investigation of the 2017 Cooke incident identified that operations in WA are not up to international standards and in need of improvement[[17]](#footnote-17). Furthermore, research from the past two decades showing real risks to native wild Pacific salmon and the local ecology in the form of potential habitat competition, disease transmission, and the release of excess organic particulates compels the State to do a more thorough examination of Puget Sound, the Salish Sea (with collaboration from Canada), and the Strait of Jaun de Fuca to find sites with adequate water currents and distance from wild salmon habitats to allow farming. With these preconditions met, Atlantic salmon farming can be a productive source of food and economic growth for the State of Washington, but the protection of endangered Pacific salmon and the local environment should be considered paramount.

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