From the Writer

I was inspired to write about aquaculture after I watched a program called *Eco Trip*, a show that investigates the environmental impact of everyday things in our lives. I was surprised to learn that salmon farming had so many negative consequences because I had been under the impression that environmentalists praised aquaculture for taking pressure off of wild populations. In reality, practices like salmon farming often put more pressure on wild stocks. As I did my research, I found that there are ways to make aquaculture more sustainable with operations like closed containment aquaculture. I stayed interested in this topic throughout the writing process because as a student of environmental analysis and policy, such a topic is highly intriguing to me.

The greatest challenge I faced when writing the paper was deciding where I stood on the issue. At first this was very difficult because environmentalists are so split on whether to support or criticize aquaculture. As I did my research, I finally was able to draw my own conclusions. I decided that aquaculture can be a part of society but only if more sustainable practices are adopted, and more thorough investigations of its impacts are completed. If I was asked to write another draft, I would probably develop it a little further where I begin to make conclusions about our relationship to nature. Overall though, I'm highly satisfied with the way my final paper turned out, and I believe it greatly improved my writing skills.

— Courtney Carroll

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Fish Farming and the Boundary of Sustainability: How Aquaculture Tests Nature's Resources

The advent of aquaculture has extended the industry of factory farming to earth's marine and freshwater systems. It has greatly benefited the seafood business and has allowed consumers to have traditionally seasonal fish at any time of the year; however as the aquaculture industry rapidly grows from small scale to large scale, many question its sustainability. While the industry insists that fish farming takes the burden off wild fish stocks, other experts have suggested that the farms actually do more harm than help by increasing the spread of diseases, parasites such as sea lice, and astronomically increasing the level of pollution and waste in the wild ecosystems. In particular, the large scale production of carnivorous fish such as salmon has concerned many environmental groups because it requires much larger amounts of resources than producing other types of fish. Escaped salmon from farms can also adversely affect the genetic variability of wild populations, reducing their ecological resilience. The debate over the sustainability of aquaculture represents the conflict between America's need to conserve and America's need to control nature's resources. Rising evidence suggests that fish farming may end up taxing the environment beyond its capacity if it does not become more ecologically mindful. The ultimate question of the debate remains how far society can push the boundary of sustainability and how far technology can extend the capacity of nature's resources.

Technology optimists believe new innovations can resolve any possible hurdles that may come about with the development of aquaculture. Since 1970, seafood production in the aquaculture industry has increased at an annual rate of 8.8% (Morris et al. 2). As the world population

approaches 8 billion, seafood producers have harnessed aquaculture in an effort to fill the gap between population growth and natural seafood production (Molyneaux 28–29). Farmed salmon production amounted to 817,000 tons in 2006 and increased 171 fold since 1980 (Morris et al. 2). While shrimp and oyster farms mainly grew out of developing countries, salmon farming grew out of countries with access to more sophisticated technology including the U.S., Canada, and Europe (Molyneaux 45). Initial assessments of fish farming concluded that all economies had an interest in developing aquaculture. For example, on June 2, 1976 in Kyoto, Japan, an FAO Technical Conference on Aquaculture examined and discussed types of aquaculture, the possible problems such as the risk of disease, and ultimately recommended the expansion of aquaculture, leading to huge investment in the rising industry (Molyneaux 30–31). To technology optimists, the potential rewards of aquaculture seemed infinite, but few stopped to consider possible repercussions to the ecosystem.

Some environmental concerns about aquaculture did surface as it began to develop, but any initial fears of ecological impacts did little to inhibit growth of the industry. In 1967 the United States Congress established the Commission on Marine Science, and in 1969 the commission released a report that called for more research on aquaculture. Despite the lack of research, the promise of jobs and food security outweighed any concerns about its effects on the environment, and development continued unabated (Molyneaux 45). In addition, the passage of the U.S. Aquaculture Act in 1980 also helped nurture the development of the aquaculture industry (Molyneaux 46). Fish farming has obvious benefits such as food security and jobs, but these obvious benefits obscure many of the potential problems that could arise in the future.

An industry such as aquaculture that does not make efforts to promote sustainability will inevitably run into problems, despite any short term benefits it may give to investors. Salmon farms especially merit concern because to produce predatory fish, companies need to "reduce fish" to produce fish, which essentially turns fish lower on the food chain, such as sardines or anchovies, into feed for farmed salmon (Halweil 5). This process requires a huge amount of resources compared to herbivorous fish, making the salmon industry more vulnerable if supplies become scarce and much more energy intensive. In addition, though the aquaculture business

claims that its farms provide necessary food production for society's growing populations, many estimates show that modern fish farming consumes more fish than it produces (Halweil 18). The question of whether aquaculture provides a sufficient food source for future generations means many companies will lead themselves to failure if they do not manage their resources responsibly.

Does aquaculture pose a risk to wild salmon? Supporters of the industry would argue that aquaculture takes excess burden off the wild stocks that might otherwise become dangerously depleted. Many agree that commercial fishing practices have severely reduced the populations of wild fish in North America's oceans and freshwater habitats. Wild salmon have particularly felt the impact of commercial fishing in the Atlantic and Pacific waters. Aquaculture came about as a possible solution to the problem and would give wild salmon an opportunity to rebound from endangerment due to overfishing. It has been proven successful with other types of seafood such as catfish and tilapia; however, some have contested that serious problems associated with fish farming have put potentially much greater pressures on the wild populations of salmon (Claiborne 1).

According to a report which observed the recurrence of escaped farmed salmon in rivers in eastern North America, "A critical first step to assessing the risk that escaped farmed salmon might pose to wild salmon populations is to quantify the frequency with which farmed salmon enter wild salmon rivers and the frequency with which such escapes recur" (Morris et al. 2). This report provided a preliminary look into the effects of farmed salmon on wild salmon and demonstrated that farmed salmon have a significant prevalence in wild habitats. For example, their observations of rivers in the eastern United States and Canada showed that, "escaped salmon were reported in 54 rivers and bays in the region" (Morris et al. 14). Such escape events call for greater monitoring of farmed salmon production. Some areas have made more efforts to do this than others. For instance, "In Maine growers have implemented a Hazard Critical Control Point process to address the issue for sea cage sites and freshwater hatcheries" (Morris et al. 15). Keeping track of escape events and how many salmon find their way into wild habitats helps identify the risks posed by aquaculture and to what extent they affect the ecosystem.

As production in aquaculture exploded, disease became the defining issue that could impede or even kill its expansion. Infectious salmon anemia (ISA), which began to affect farmed salmon in Maine, became a serious problem and resulted in the destruction of 1.5 million fish (Jenkins 857). The aquaculture industry has not yet come up with a standard method to approach the problem of disease. "The apparent solution is to destroy all infected or potentially infected fish and let the pen sites lie fallow for a season or more, so that the virus, denied its host, will be flushed out by normal tides and dissipate" (Jenkins 857). The epidemic of ISA cost the aquaculture industry as much as $25 million in lost fish and left the fish growers struggling for control (Molyneaux 102). ISA spread through many pathways such as sea lice, gulls, and sloppy disposal practices (Molyneaux 104). Industry supporters spoke of the ISA outbreak as a natural disaster, but temporary workers hired to dispose of the infected fish placed blame on management practices, as one worker stated, "They knew this was coming but they still overstocked their pens" (Molyneaux 103). The negligence of the aquaculture industry to use more caution in managing its supplies could have led to its abrupt failure and should serve as a warning to fish growers that ignorance of proper resource management has high ecological and economical consequences.

Outbreaks of viruses such as ISA led to the rapid establishment of programs to eradicate them. As one technology optimist stated, "We're looking at improving the immune systems of the fish. And labs are working on vaccines" (Molyneaux 107). Vaccines did help the industry gain control over many diseases that had hindered its development in the 1980s; however, vaccines can create other undesirable consequences (Molyneaux 104, 108). As one expert stated, "One thing people don't talk about is how much protection the vaccine gives the transfer of disease" (Molyneaux 108). In the case of salmon farming, vaccines prevent the fish from showing symptoms but do not protect them from infection, which effectively hides the problem instead of curing it (Molyneaux 108). As stated in Paul Molyneaux's book, "You could have salmon swimming and shedding the virus" (Molyneaux 108). This makes it extremely difficult to monitor how extensively disease impacts the populations of wild salmon and could slow down efforts to make aquaculture more sustainable.

Parasites known as sea lice have risen as another problem, but one that has had a greater impact on the wild salmon than the farmed salmon. Normally, the presence of sea lice does not present much of a threat to wild salmon, but each industrial salmon farm produces large numbers of sea lice which usually end up right in the middle of the migration routes of wild juveniles ("Salmon"). Each female lays hundreds of eggs, meaning billions of lice invade wild salmon habitat and infect the fish, making them vulnerable to disease. In addition, the lice that become attached to the fish can ultimately cause the host to starve to death because they become so large and take up too much nutrition from the host fish ("Salmon"). Aquaculture farms have managed this problem by using a drug known as SLICE, which acts as a nerve poison that kills the sea lice ("Salmon"). This effectively rids the farmed fish of the lice problem, but its benefits to the farmed salmon have not translated to the wild salmon ("Salmon"). Drugs such as SLICE represent the struggle of farmers to control nature's variability and demonstrate the belief that we can use technology to control nature's ecological processes.

Disease not only hurts the salmon but could also develop into a human health issue because many companies will send them to market as long as they do not show excessive symptoms (Molyneaux 108). Some studies have also found that farmed salmon contain ten times the levels of cancer causing PCBs than wild salmon, another major human health issue derived from aquaculture ("Salmon"). Preventing and controlling diseases will continue to cost salmon growers thousands of dollars a year, making disease a controlling factor of how rapidly aquaculture develops or how quickly it crashes. The attempt to control the threat of disease represents an assumption that we can utilize technology to control nature and overcome any obstacle. This stems from the anthropocentric belief that humans dominate nature and gives a license to society to exploit its resources without considering the harmful effects their activities might have. By not taking more careful consideration into their practices, the aquaculture industry also assumes that nature has the capacity to adapt to whatever negative effects they produce, whereas in reality they may fail to see that nature simply displaces those effects, as in the case of sea lice afflicting wild salmon. The industry will not openly acknowledge these implications that their practices have on larger ecosystems because such an admission

would harm the industry economically. Ultimately, the complacence of society towards the environmental costs of its activities presents the biggest challenge facing conservation efforts because it prevents change from occurring.

Some other problems that wild salmon have inherited from farmed salmon include threats to biodiversity, degraded water quality, and habitat conversion. According to the aforementioned report on farmed salmon escapes, aquaculture can have a negative impact on the ecological fitness of wild salmon. "Results suggest that farmed salmon can exhibit lower genetic variability than wild salmon and that the introgression of farmed salmon genes into a wild population can be comparatively rapid" (Morris et al. 16). The escape of farmed salmon can threaten biodiversity because lower genetic variability makes a species less able to adapt to changing environmental circumstances. Furthermore, negative impacts on water could also threaten wild salmon. Industries like aquaculture demand a high amount of resources for a relatively small space, creating a situation in which the environment may degrade because of overexploitation. As one article on aquaculture stated, "Clearly, high densities of cages and high numbers of fish in cages could produce situations in which the assimilative capacity of water is exceeded by the demands of aquaculture" (Diana 6). All of these problems mean that resources have limits, and though the prospects of aquaculture seem boundless, the oceans only have so much to give. American society constantly tests these limits with the use of technological advances, signifying that control of our resources takes priority over conserving them.

Practices such as aquaculture and agriculture create a perceived certainty of food security and control of resources, but unchecked growth in industrial food production can lead to unforeseen consequences in the future that could potentially undermine that certainty. This uncertainty in the stability of nature's resources stresses the need for a line between control and total ambiguity. An approach that aims to preserve the integrity of the ecosystem through more responsible treatment of the environment would justify our use of resources because such a policy would ensure a respectful relationship with nature. In the case of aquaculture, this means adopting more sustainable methods. For example, closed containment aquaculture has a much smaller impact on the environment because waste

and effluents do not go into the ocean, and no escape events can occur, eliminating many problems associated with large scale marine aquaculture ("Salmon"). Also, an organic label has recently risen as a niche market in aquaculture and offers another option for sustainability that would reduce or eliminate the use of vaccines (Taylor 4). Polyculture, otherwise known as Integrated Multi-Trophic Aquaculture (IMTA), offers yet another example of a more sustainable seafood industry. This method effectively promotes sustainability because "nutrient losses from one species are nutritional inputs for another" (Reid 2). IMTA more closely resembles how a natural ecosystem operates; it makes environmental and economical sense because resources do not get wasted but get recycled in an endless loop.

America's need to invest in an industry that promises to protect our food security sends a message about America's attitude toward nature. It suggests a belief that we have a right to use technology to control nature and the power to control its resources at our discretion. Aquaculture shares many similarities as agriculture in this regard because both represent attempts to control nature's resources for our needs. Agriculture attempts to control nature's resources by taking charge of what type of crops grow in a certain place. The mass production of crops such as corn and wheat in the Midwest take advantage of nature's resources for high profits, because of a high demand for items that include these products. These monocultures have a keen susceptibility to disease and pests because a lack of variety in genetics makes them ecologically vulnerable. Farmers fight for control with chemicals, pesticides, and genetically modified crops. Aquaculture will experience similar dilemmas as fish growers fight for control of the oceans with new vaccines and genetic engineering. Technology will play an important role in maintaining food security; however, if society emphasizes conservation over reliance on technology, this would eliminate a lot of the uncertainty that technology only seems to complicate. Practices such as IMTA stress conservation over technology because they rely on natural processes rather than new inventions or technological advances. The move to more sustainable practices in aquaculture means that our belief of control over nature will shift to a dynamic partnership with nature, a relationship that will ensure the survival and the success of both.

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COURTNEY CARROLL is a student in the College of Arts and Sciences studying environmental analysis and policy. She hopes to build a career in public health or environmental education. This essay was written for Frederic Fitt's course, WR 150: American Environmental History.