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Salmon Says: An Examination of Salmon Farms and Sustainability

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Abstract

Through increased commercialization and consumption, our style of living has become destructive to the planet. Every part of our lives will have to adapt to these new issues that will arise in our future, a future shaped by climate change, including our food systems. This paper explores salmon farms and discusses them from a historical, economic, and ethical point of view. Chapter 1 provides an overview of the salmon industry, some introductory information, and statistics regarding salmon farming. Chapter 2 dives into the historical significance of salmon and the development of farms. Chapter 3 discusses the economics of the salmon industry, analyzing our need for and consumption of the fish, as well as exploring how we can reduce and repurpose waste. In this chapter, I use what I have learned through my internship in salmon industry sustainability. Chapter 4 examines the ethical implications of keeping salmon in farms, utilizing the philosophical ideas of various scholars. It also touches on the current regulations in place regarding the fishing industry. The final chapter draws on information from the previous chapters and concludes with policy recommendations that could hopefully make sustainable changes throughout the industry.

Keywords: salmon industry, overfishing, climate change, sustainability, environmental history, fish farms, wild-caught, environmental economics, waste reduction

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Introduction

How do you think climate change is going to affect the aquaculture industry? That is one of the questions I recently asked my former boss Rob Snyder, Chief People and Sustainability Officer at Acme Smoked Fish Corp. He has a Ph.D. in cultural anthropology focused on the intersection of community economies, seafood, and ocean policy, and had been with the company a little over a year when I was hired as an intern. I worked at Acme for 6 months starting in July of 2022, and my work experience there inspired me to choose this topic for my thesis. During an initial conversation with Snyder, he mentioned that Acme gets their salmon mostly from farms and asked me what I thought. I said that farms can be a valuable resource so that we don't deplete wild populations, and he agreed. In response to the question of climate change that I asked a few weeks ago, he said: "The aquaculture industry relies on inputs from all over the globe to grow fish. For those fish grown in the ocean, climate change is causing farmers to move their pens toward the north and south pole, where water is warmer, and therefore disease doesn't spread as well. Places in southern Norway are no longer optimal for fish growing, whereas areas in the arctic circle are becoming more desirable. The same thing is happening in South America. A country like Chile which is the largest exporter of salmon to the global market, is now prioritizing growing salmon farther south in favor of colder water" (Snyder, 2023). In terms of supplemental aspects of the industry, he stated: "Feed ingredients are also impacted. A pellet of fish feed may have wild caught fish in it, along with agricultural products like soy and wheat. The areas where these inputs grow are changing as a result of climate change" (Snyder, 2023). I also asked Snyder to identify any recent changes he has witnessed in the industry in regards to sustainability, and he responded saying: "I think that overall, the industry is aware that climate change is playing a role in the overall location of farming and the availability of other inputs. As a result, more investment is flowing to creating stains of fish that can grow healthier in warmer water, without the need for more inoculations or other disease fighting measures. The other tactic that can be found in the industry is that the technology for growing fish is moving farther offshore, and deep under water – where the water temperatures are more stable. This is called off-shore aquaculture. It generally takes places between 3-200 miles offshore and deep in the water column. There are experimental sights for this technology in Norway today" (Snyder). He feels that the industry is acknowledging the warming oceans and is adapting accordingly.

Not only will aquaculture have to make adjustments as we move into a future ruled by climate change, but businesses will have to adjust as well. Acme as a company is one of those businesses that is preparing for the future. While I worked there, we had many conversations about how climate change would affect us, and how important it is to be sustainable, have backup plans, and minimize environmental harm. Acme makes sure that the majority of the salmon they use are either ASC or MSC certified. This year, the company joined ClimateSmart, a service that tracks greenhouse gas emissions. Additionally, Acme keeps consumption consistent, avoiding buying more fish than they need and attempting to be minimally wasteful.

Finally, I asked Rob how he thought aquaculture could be made more sustainable in order to move into the future, and he responded with "Aquaculture can be made more sustainable through tracing the environmental and social impacts of every input that helps grow a fish. So, transparency is a must. In addition, we need to find alternatives to wild caught fish to add to fish feed so that we are not impacting wild caught species when we grow fish. In addition, we need to look creatively at how to lower the carbon footprint of the aquaculture industry. As land based aquaculture comes into the mainstream, we will be able to grow fish closer to the urban centers where they are consumed. This will dramatically lower the carbon footprint of the industry" (Snyder, 2023). Increasing transparency can be done through the release of sustainability reports, which Acme does annually. Land based aquaculture and alternative feeds are being researched further in aquaculture spaces, and Acme facilitates research and innovation through a yearly grant. Companies can be important drivers of sustainability if they make it a main focus, and this will become increasingly important in coming years.

In this thesis, I focus on analyzing aquaculture from a few different perspectives, and discussing the benefits and drawbacks of industry practices. In chapter 1 I will discuss some basic information about the fish farming industry, and I explain how farms work. In chapters 2-4 I will examine fish farms through historical, economic, ethical, and political framworks. In chapter 5, I discuss policy recommendations to make the industry more sustainable, including the implementation and encouragement of integrated multi-trophic aquaculture (IMTA) and aquaponics, increasing adherence to sustainability certifications, escapement goals, and a focus on fish welfare.

Chapter 1: An Overview of the US Salmon Industry

The vast majority of salmon in the world do not live in rivers as shown through glamorized nature documentaries, but instead live in farms controlled by humans, and are grown in pens according to our specifications before they are brought to our grocery stores. The fish that is broadly referred to as "salmon" can be split into two major groups: Atlantic and Pacific salmon. While they are all technically the same species, they can vary wildly in size and appearance. Pacific salmon can have a few different subcategories, including coho, sockeye, chinook, etc. However, the fish that most commonly ends up on our plate is the Atlantic salmon, and while Pacific salmon can still be caught in the wild, the vast majority of Atlantic salmon are products of aquaculture: “In fact, every appearance of the species Salmo salar, or “Atlantic salmon,” in supermarkets today, be they labeled Canadian, Irish, Scotch, Chilean, or Norwegian, is farmed. Except for isolated pockets in far northern latitudes, there is no longer a popular memory of “wild Atlantic salmon” as food.” (Greenberg 2010, 15). Coho and chinook salmon are also farmed, but not nearly to the extent of their Atlantic counterparts. Additionally, because of increased demand for this specific fish within our capitalist system, “the aquaculture companies operating in the frigid fjords of southern Chile now produce almost as much salmon per year as all the world’s wild salmon rivers combined.” (Greenberg 2010, 15).

Salmon are an important part of both freshwater and saltwater ecosystems. In fact, they are considered a keystone species, an important part of the food web that keeps ecosystems intact, as without them, other species could not survive. They are an important predator as they eat a variety of smaller fish, and an integral part of the diets of larger predators such as bears. Since nature is so interconnected, seemingly small interactions can also play large roles in the maintenance of ecosystems. For example, “When wild salmon enter the rivers to spawn, bears, eagles, wolves and other predators catch them and carry them into the forest to feed on. As these fish remains decompose, nutrients are released into the soil. Nitrogen-15 is found almost exclusively in the ocean and so when it is detected in trees along the rivers where salmon spawn, we know it came from salmon” (Morton 2021, 34). Trees can be an indicator of the health of the environment, because they act as carbon sinks, soaking up excess carbon dioxide and managing the levels of it in the atmosphere, and the nutrients deposited in the soil from salmon help these trees grow. Therefore, the more salmon there are in a year, the more trees grow, the more carbon is absorbed and this leads to a less intense greenhouse effect. Therefore, wild salmon are an environmentally integral resource.

Industrial salmon farming. The way in which we have domesticated fish is similar to that of cows and chickens, although in a much quicker span of time. We have found a way to control every aspect of their life cycle and optimize the salmon so that they are sufficiently fatty and profitable. In fact, “Aquaculture is distinguished from other aquatic production by the degree of human intervention and control that is possible. It is closer in principle to forestry and animal husbandry than to traditional capture fisheries. In other words, aquaculture is stock raising rather than hunting” (Asche and Bjorndal 2011, 7). It has become far removed from nature in order to feed the demands of industrial capitalist society. The process is highly controlled and efficient, from breeding to “harvesting” in a way that it does not need to rely on nature anymore: “In intensive aquaculture, such as salmon farming, the production system is closed. Fish are reared in confined areas and the farmer controls production factors such as farm size, stocking and feeding of fish. For salmon the confined area is a sea pen, while for other species, instead of pens, land-based tanks (turbot), ponds (tilapia) or raceways (halibut) are used” (Asche and Bjorndal 2011, 7-8). At its most basic level, aquaculture is the domestication and raising of fish for human consumption. It can happen in a variety of places as long as there is water, from race tracks to fenced off areas in the ocean. Because salmon is a fish that spawns in fresh water then moves to salt water, the farming operations are split into distinct parts according to the life cycle of the fish. The first step, or the hatchery, deals with the eggs and juveniles, and while many of these young fish go directly to larger pens where they spend the rest of their time, some of them go to natural freshwater streams to supplement the wild population. Those in the farms live in close quarters with one another, and a farm can have over 10 pens, each with a few hundred fish in them. They are fed on a computerized timer, although sometimes they are fed by hand, especially when they have just been transferred. Some of them die on their own in the pens, and they are removed through a chute. The rest are collected and killed systematically, then transferred to other facilities where they end up at their final destination.

Salmon farming has become very successful, very fast. In fact, “One of the most striking features of contemporary salmon farming is its unprecedented scale: salmon aquaculture has quite simply been a huge success, from a business point of view, with a potential for expansion far beyond what anyone could predict. By the late 1990s it was estimated that more than 95 percent of all Atlantic salmon living in the world had been raised at a fish farm (Gross 1998). Since then, the global production has more than doubled and the percentage is likely to have increased” (Lien 2015, 4). In a next step to the domestication of pigs, cattle, and sheep, we have moved to salmon in order to control the production of one of our favorite fish. On a basic level, “Domestication is seen as the process whereby a population of animals or plants is changed at the genetic level, accentuating traits that benefit the humans” (Lien 2015, 9). It has also been defined as “the way in which humans bring about “the social incorporation or appropriation of successive generations of animals”” (Lien 2015, 12). The domestication of salmon is another way we have utilized the environment and made changes to it for our benefit. Wild salmon are not consistent throughout the year, but farming techniques have allowed us to have access to the fish whenever we want.

In terms of the numbers, salmon is a dominating force in the world market, especially recently: “The global salmon supply consists of both wild and farmed salmon… supply has increased substantially during the last 25 years, from about 570,000 tonnes in 1981 to 2.65 million tonnes in 2008” (Asche and Bjorndal 2011, 17). However, much of this increase is due to the expansion of the farming industry. Wild salmon has indeed also shown an increase, but aquaculture, in which we can manipulate every variable and breed fish in a seemingly endless stream, is the cause for most of the increase: "In 1981, the supply was essentially wild salmon, 560,000 tonnes, while farmed production was just over 10,000 tonnes. Since then, the supply of wild salmon has grown substantially, reaching historically high levels. In the last 10 years landings have varied between 700,000 and 1 million tonnes. However, what has driven most of the growth in world salmon supply has been a tremendous increase in the farmed salmon supply that has grown to over 1.9 million tonnes in 2008" (Asche and Bjorndal 2011, 17). This growth is due to a variety of factors, including increased mechanization and more efficient technology, which has decreased the cost of operations on farms. Many aspects of farming are now computerized, such as feeding, which was previously exclusively done by hand, but is now increasingly controlled by computer systems that analyze pens and determine when to distribute feed, and do so very efficiently.

In creating artificial environments for these fish, we have significantly altered their life cycles and geographic areas: "Before the Norwegians came along, there were no salmon living in the world south of the equator—the equator acts as a thermal barrier that the cold-water-requiring wild salmon could not cross in nature. Today there are hundreds of millions of salmon in Chile, which is now the second-largest salmon-producing nation in the world…Every year more than 3 billion pounds of farmed salmon are produced, around three times the amount of wild fish harvested" (Greenberg 2010, 23). Chile is an important country in the world of salmon farming, and it has been the preferred site of aquaculture for the past few decades. Salmon are not naturally at home in Chile, but the coastal conditions are similar to those in which the fish naturally thrive, especially in the southern region of the country. In this area, the water can reach ideal temperatures, with lower variation than in Europe or North America (Asche and Bjorndal 2011, 23). However, Norway is the birthplace of salmon farming, and has consistently been a leader in the salmon farming industry, with it being a central part of their economy: “Norway is the world’s leading producer of farmed salmon, with an estimated output of about 827,000 tonnes round weight in 2008 [...]This comprised 741,000 tonnes of Atlantic salmon and 86,000 tonnes of salmon trout. From 1990 to 2008 the industry nearly quadrupled its production, with an average annual growth rate of 9.6%. Atlantic salmon production was at its highest level ever in 2008 and is still on the rise” (Asche and Bjorndal 2011, 19). Salmon are farmed in other areas of the world too, such as Scotland, Ireland, and Canada, but not to the same extent. Aquaculture began elsewhere in Europe in the 1970s after Norway had gotten the idea off the ground. Scotland is where all of the UK farms are located because of the ideal conditions, and it has expanded greatly since the 1980s (Asche and Bjorndal 2011, 26). Canada came on to the scene around the same time, starting in British Columbia and later making its way to other parts of the country. “Initially it focused on chinook (Canada was the largest chinook producer, with about 15,000 tonnes in 2005 but only 1400 in 2008). However, as in other larger producing countries, Atlantic salmon eventually became the most important species. Production of Atlantic salmon was about 120,000 tonnes in 2008” (Asche and Bjorndal 2011, 29). Both Chile and Canada entered the industry by farming Pacific salmon, but consumers’ taste for Atlantic salmon urged both countries to switch.

Environmental issues. Our increasing impact on the planet through the release of excess carbon into the atmosphere is drastically changing all aspects of the climate. This could prove to be disastrous for salmon, because “The colder the water, the higher the oxygen content, and salmon, with their hard-swimming, predatory metabolism, need a lot of oxygen.” (Greenberg 2010, 14). While farms can pump oxygen into pens and keep those levels stable, the warming of oceans could be dire for wild salmon. According to the IPCC, “increased water temperature and reduced mixing cause a decrease in dissolved oxygen. In 400 lakes, dissolved oxygen in surface and deep waters declined by 4.1 and 16.8%, respectively, between 1980 and 2017 (Jane et al., 2021). The deepest water layers are expected to experience an increase in hypoxic conditions by >25% due to fewer complete mixing events, with strong repercussions for nutrient dynamics and the loss of thermal habitat" (IPCC, 210). This is not only dangerous for salmon, but for all freshwater organisms. Life on this planet has evolved under a certain set of ecological conditions, and while it can adapt, these adaptations occur over hundreds of years. As it stands now, we are changing the conditions of the planet faster than species can evolve to adapt to them. One biologist says, "One of the complexities of being a biologist today is that we don't know how much time an ecosystem under siege has left before it collapses. I did not imagine that it was actually possible for the abundance of the Broughton salmon and herring to drain away. [...] This was shocking to me—the idea that the powerfully abundant salmon could disappear." (Morton 2021, 31). The act of domesticating and farming salmon comes with its own environmental damages, which can be worse for wild salmon and the species as a whole in the long run. Global warming and our human activity have drastically changed the natural world. "What makes the contemporary man-made salmon crisis unique and alarming is the effect humanity is having on the genome of all salmon species, simultaneously, throughout their global ranges. Pacific salmon are now extinct in 40 percent of the rivers where they were known to exist in California, Oregon, Washington, and Idaho and highly diminished in the runs that remain." (Greenberg 2010, 18). This leads to a decrease in those benefits for the forests, as well as a decrease in the food sources for wild animals as well.

Farmed salmon have been known to have their share of problems and negative impacts on wild species, such as increasing competition in breeding, and increasing disease levels. First, there is a longstanding issue with escapees from salmon farms, and their breeding with wild salmon. Through farming, we have created a fish with a different set of genes and traits, and when these fish escape, we risk replacing wild salmon with a breed that cannot sustain itself without the help of human intervention: "Salmo domesticus has been bred to eat a lot and grow fast in a controlled environment, but it has lost many of the fierce, determined traits that make a wild salmon able to swim against powerful currents, withstand fluctuations in temperature, and spawn in a river besieged by predators. Critics argue that escaped farmed salmon may outcompete wild salmon in some phases in their life cycle only to be unable to reproduce later on down the line" (Greenberg 2010, 23). This could have an impact on the biodiversity of wild salmon stocks and the long term lifespan of wild populations. This is a threat because when breeding, a species always wants to bring the strongest genes and most favorable genes to the next generation. This is why during mating rituals throughout nature, females often choose the male with the best dance or loudest call or other factors, because these signify fertility, strength, and health. So when farmed salmon outcompete wild salmon for food, there are fewer wild salmon to breed with, and the farmed fish may not be able to reproduce, or if they are they pass down the weaker genes that are more fit for the fenced-in pens than the raging rivers.

Another commonly cited issue with farmed salmon is disease transmission. As we have seen with the COVID-19 pandemic, being in close, crowded spaces increases infectious disease transmission through super spreader events. The same rules apply for other animals kept in crowded conditions. This issue has been brought up with poultry farming, and so the widespread and controversial use of antibiotics emerged to inoculate the chickens and prevent the spread of disease. The same has been done with salmon, and they are now systematically vaccinated against diseases. However, some diseases can get past this routine vaccination, and because of the crowded conditions of farms, they can spread like wildfire: “When the first outbreak of furunculosis occurred early in 1991 in the farms, it spread rapidly farm to farm. Furunculosis is a bacterial disease that ruptures into open sores that broadcast bacteria into the water where they drift until they infect another fish” (Morton 2021, 42). This spread can affect escapees, which are very common from farms, and further infect wild populations: “continued large-scale introduction of Atlantic salmon to British Columbia would eventually result in the introduction of exotic disease agents that could damage wild salmon and “devastate” the economy of those who depended on wild salmon. Chamut went on to say, “Unlike terrestrial animals, where complete containment and isolation is possible, fish are difficult to contain as well as isolate. Once an infectious agent becomes established in a wild population of fish, it is impossible to eradicate” (Morton 2021, 37). Fish cannot be quarantined nearly as easily as cows or chickens, and even so, the diseases that infect fish have evolved to utilize the water. For example, sea lice are a major problem among farms. For wild salmon, the trials of nature keep lice from grabbing hold and devastating a population. Additionally, salmon in the wild make a fair amount of mucus, which can be helpful to protect them from the diseases transmitted by the lice. However, “The problem caused by the salmon farms is the million or so salmon going around in circles that never migrate out to sea. Thus the lice keep breeding in the bays along the coast all winter, and in the spring their reproduction accelerates as water temperatures increase. Instead of entering an archipelago swept clean by the tides of winter, young wild salmon were migrating through clouds of lice at every operating farm” (Morton 2021, 60).

Because of increased demand for salmon as a protein source, it is no longer necessarily consumed by those in geographic proximity to areas where salmon live in high concentrations. Through increased globalization and therefore a new ease of access, there is now a higher demand for salmon. Add onto that our 21st century health obsession, and that creates a perfect storm for an ever-growing, insatiable salmon market. The seas cannot support our growing population, increased development, and appetite on top of the pre-existing issue of climate change. Fisheries are not what they used to be. We have overfished to a concerning point, only leaving a small percentage left for the oceans to bounce back. Our current consumption of fish is unsustainable. While we make various other changes to our ways of life (such as addressing CO2 emissions, reducing our energy and resource consumption, etc.), we can utilize salmon farms as a way to sustain the industry as fisheries try to recover from our actions. Salmon is an important source of protein, and has a lower carbon footprint than terrestrial animal protein. Additionally, it contains healthy fats and oils that are beneficial to the human diet. That being said, mainstream salmon farming as it currently operates is not very sustainable, and can be made more sustainable with a few important changes. The future of salmon farming could be a less intensive process, and could actually protect wild salmon populations.

Chapter 2: This History of Fishing and Salmon Farms

Humans have been fishing for thousands of years, and have relied on salmon as a food source wherever they could find it. According to the book Four Fish, “The Spanish salmon were in fact the first salmon, the strain that birthed the entire Atlantic salmon genome, which millions of years earlier had radiated out across the Atlantic” (Greenberg 2010, 14). A major species for many ecosystems, we have evolved virtually alongside salmon, and because they were abundant in the wild, catching them for subsistence created no problems: “dozens of salmon rivers throughout New England and Atlantic Canada that made salmon an abundant wild staple for natives and early colonists alike” (Greenberg 2010, 14). The abundance of salmon has made it a staple in many diets and cultures. We have developed a taste and preference for the fatty fish, large and rich with necessary oils for our health. However, it is difficult to trace its roots, because "even archeologists struggle when it comes to fish, whose traces are rarely visible. While domesticated goats and sheep reveal glimpses of our shared evolution as pieces of bone in the ground, fish leave few such remains. Ancient middens can tell us about human marine diets but very little about the shape of the fish and how we might have evolved together" (Lien 2015, 2). Therefore, the origins of salmon and how they got to where they are today have had to be determined through other methods. According to Becoming Salmon, our relationship with salmon can be traced back to Norway during the last ice age. When glaciers moved, they created crevasses that salmon used to migrate from the oceans up the rivers to spawn: "As the ice retreated, the coastal area near the edge of the glacier emerged as a habitable zone for humans as well as for mammals, fish, and shellfish. Archeological evidence indicates that there were human populations along this coastline as early as eleven thousand years ago" (Lien 2015, 33). While it is difficult to physically study our relationship with salmon throughout history, plenty of cultural evidence exists to show our reliance on the fish throughout the years. Salmon and other fish have even become part of some cultural identities. For example, salmon, tuna, sardines, and other fatty fish are integral to Mediterranean cuisine so much so that the famed "Mediterranean diet" (dubbed one of the healthiest diets in the world) revolves around the inclusion of fish. Another example of this is lox (smoked salmon) in Jewish culture. When I worked for a large smoked salmon company, I toured the warehouse and saw a large section of whole-smoked salmon of a specific trim reserved just for the Jewish delis in NYC who like to slice their salmon in a more traditional manner. The Jewish community is a crucial consumer for smoked salmon businesses. These are two ways in which salmon can be considered a cultural food staple.

The development of industrial aquaculture. We started "fishing" by collecting shellfish, because they were easily collected by hand, and we did not have tools for larger scale fishing yet. We expanded past shellfish, then began catching fish in larger quantities: "In earliest times most foodstuffs were used at once and not stored, but as expanding populations increased food needs, techniques were developed for preserving fish by drying, smoking, salting, and fermentation. It became desirable to catch large quantities, and specialized equipment was devised. Individual fishing was replaced by collective efforts involving larger, more effective gear" (Purrington et al. 2022). We built bigger boats for the express purpose of catching more fish, and created better tools for the job. Small, basic lines were replaced by longlines that could catch thousands more fish. Fishermen combined small traps into systems, and made larger nets with the help of newly created mechanical net-making machines. These machines also facilitated the replacement of net making materials, switching from linen to the more durable cotton among others. We remained this way for a while, then in the 20th century, every aspect of life increased in scale. Post WWII, "the annual world fishing catch quadrupled. By the early 1970s, though, it had become apparent that such development was not limitless. Several of the largest resources of pelagic fish harvested by purse seiners suffered collapses generally blamed on overfishing" (Purrington et al. 2022). Fishing got too big too fast, and began harming ecosystems because we were consuming fish faster than they could naturally replenish. The effects of overfishing are still a major problem today: "In the early 21st century it was estimated that a third of the world's fisheries were overexploited and that stocks of large fish had dwindled by 90 percent. In 2017 the World Bank noted that nearly 90 percent of the planet's marine fish stocks were fully exploited or overfished" (Purrington et al. 2022). The World Bank attributed this problem to a lack of oversight of fisheries, an abundance of ocean pollution, and increased ocean acidification, all three factors working to heavily disturb marine ecosystems and threaten biodiversity and species habitat. Overfishing has put pressure on the marine ecosystems, and is forcing us to come up with a sustainable alternative. If we over consume each species, we will have to constantly change our target fish until there is not much left at all. Overconsumption of larger fish would lead to us constantly having to find smaller and more abundant substitutions, “Or, if they can still be obtained, fish from overseas replace big fish from home waters.”... “Some call it ‘fishing down the food chain’. I prefer webs, as they have more connections than a chain. In Pauly’s view, all we will eventually be left with is jellyfish and plankton. And if you think we will then stop fishing Pauly has news for you. He reports that one Georgia fisherman is already making a living by sending 22,500 kg (50,000 lb) of jellyfish a week to Japan, where the sting is removed and it is turned into a kind of wafer.” (Clover 2008). Without aquaculture, this is what fishing would have looked like. As we fish species to near irreplaceable levels, we would have had to keep working down the food chain in order to satisfy our demand, relying on fish that have less and less nutritional value and are smaller or harder to prepare.

Our relationship with fishing became more unsustainable the larger and more wasteful our equipment and operations became. We often have this idea of fishing as a small endeavor, as it is done recreationally with classic fishing poles, or if we do imagine something more industrial, it is a few boats with semi-large nets. I had no idea how massive some of the nets on industrial fishing vessels could be and how much they could hold. However, upon learning more about industrial fishing, how big the nets are, how many boats go out, and how often, it is understandable that overfishing has occurred. Additionally, major concerns with the main types of commercial fishing are bycatch and habitat destruction. Trawling and purse seining are two major forms of commercial fishing; in the first method, a large net is dragged behind a moving boat at either a mid-level in the body of water or along the bottom, while the second method involves a large net that is opened, then closed with a mechanism similar to a drawstring, hence the name "purse" seining. The problems with these large moving nets are that they often catch unwanted creatures, such as sea turtles or sharks for example. However, by the time they reach the boat, many of them are already dead, and therefore these methods are causing unnecessary deaths among non-target species. Bottom trawl fishing does not have as much of a bycatch issue, but is the target of criticism for its role in habitat destruction, snagging and destroying coral reefs and plants along the ocean floor (MSC International).

For hundreds of years, we hunted and gathered, then we transitioned to farming. This is known as one of the most integral transitions in human history, and allowed us to create large-scale civilizations. However, with increasing modernization, nothing stays the same forever. So, throughout the course of the 20th century, smaller farms got bigger, we began to raise more crops and livestock and distribute them to the larger population at a rate never seen before: "This trend toward a smaller number of much larger operations is the direct result of the industrialization of agriculture. In 1926, the US Secretary of Agriculture encouraged the transformation of farms into factories, stating: "The United States has become great industrially largely through mass production which facilitates elimination of waste and lowering of overhead costs . . . tremendous economies both in production and distribution has [sic] enabled manufacturers to supply consumers with what they want when they want it. It seems to me that in this matter agriculture must follow the example of industry" (Gruen 2021, 78-79). Farms began to evolve in the same way factories did, and soon enough they were almost identical in production method, becoming known as "factory farms." Their success and productivity has made them the primary force for food production in the U.S.: "The ability to grow larger animals, in less time and for less direct cost, could only have occurred when companies were large enough to exert control over all aspects of the industry – from production through marketing – so as to make profits more predictable, which, in turn, allowed for more investment in research" (Gruen 2021, 80). Once we had complete control over terrestrial food production, we began to look towards optimizing the seas.

Since the industrial revolution, we have been trying to control salmon populations for our benefit: "Norwegian state authorities funded the first trial hatchery experiments in 1853 in a river near Drammen, with good results. This is an early example of state-funded salmon aquaculture research." (Lien 2015, 34). However, the formal history of salmon farms did not kick off until a bit later: "Beginning in the early 1960s, around the same time as wild Atlantic salmon were being fished into oblivion off the coast of Greenland, two brothers in the Norwegian town of Hitra named Sivert and Ove Grøntvedt began collecting salmon juveniles and raising them in nets suspended in the clear waters of the local fjord. Of all fish, salmon proved particularly adaptable to this process. Generally speaking, most of the fish we like to eat hatch out of microscopic eggs and require microscopic food to get through the first phases of life—something very hard to replicate in an artificial environment." (Greenberg 2010, 22). Salmon are in a unique position due to their large eggs and build in yolk-sac food supplies. They are also able to eat other fish that are more easily accessible for us to give them earlier in their lives than other species. Their adaptability and biology have made them ideal for domestication. We have also been able to breed them efficiently, with modern scientific knowledge, to be exactly what we need. We modified cattle thousands of years ago, before we knew much about genes and breeding, so we might not have bred the most 'efficient' or the best cattle for our needs, and over the years many genes have been bred out, so we will never know. However, since our relationship breeding salmon started much more recently, we were able to use our scientific knowledge to create the ideal fish for farm conditions (Greenberg 2010, 22). We had our pick of the genes that we wanted to selectively breed. If we wanted them to be fatter, larger, have less of one thing or more of something else, we could create a population tailored to our desires. Additionally, this change could happen very quickly and efficiently, “because salmon, unlike cattle and sheep, can produce many thousands of offspring in the course of their lives, once favorable individuals were found, just a few matriarchs and patriarchs could form the basis of a whole new race of highly productive fish. A domestic population could be created quickly that would be quite different from the initial wild forebears” (Greenberg 2010, 22). This quick generational turnover has led to humanity tailoring farmed salmon to be fatty, efficient money-making creatures in a fraction of the time it would have taken to do the same for cattle or sheep if we were to start from scratch. We have managed to create a virtually different fish, “a fish that while still technically the same species as its forebears [is] markedly different in its internal metabolism. Some scientists refer to this separate line of salmon as Salmo domesticus. By the standard of sheer numbers, Salmo domesticus is now the most successful salmon in the world” (Greenberg 2010, 23).

A lot of this change has come from demand for the fish. For example, an innovation from Chile changed the ways we consume salmon as a whole: “There is little doubt that Chile has been more market oriented than other producers. For instance, in the early 1990s, they invented the pin-bone-out fillet. Until then, the US farmed salmon market had primarily been a market along the eastern seaboard where whole salmon was presented in seafood counters. With the pin-bone-out fillets, the Chileans opened a completely new market in the Midwest, and led people who until then barely ate fish at all to consume substantial quantities” (Asche and

Bjorndal 2011, 25). This innovation made salmon more accessible, especially for those who may not have been familiar with seafood and did not have the knowledge of salmon anatomy to remove the pin-bone themselves. The new accessibility of salmon along with its mostly positive reputation as a health food in an increasingly health conscious society means that consumption is reaching heights never before seen.

Tour of the farm. It is important to note that every farm has a slightly different setup and operation, thus there may be slight changes to the process from farm to farm. However, as a general overview, as was explained to me when I worked in the field, farmed salmon begin their lives in a hatchery. The hatchery is where the eggs grow into smolts/juveniles, which are then either transferred to either freshwater rivers, larger tanks (in the case of land-based aquaculture), or sea pens. Some rivers supplement their populations with hatchery grown smolts for a variety of reasons, including to increase population especially if there have been conditions over the season that have led to a less than average population around breeding time. On the farms, every aspect of the salmon's growth cycle is monitored: size, weight, amount of food, and physical health are all meticulously measured to ensure ideal conditions and determine if anything needs to be changed to produce an optimal fish. It takes around 2 years for a salmon to reach the ideal size, and so it is nurtured over multiple "seasons." In order to have a more consistent harvest, and therefore profit, some farms will tend to multiple populations each at different stages of their life. Therefore, some of these farms can be truly massive operations; but sometimes owning the hatcheries as well. It is important to note the language used around the farm such as "harvest" and "growing season," The language is interesting here because it refers to the fish in a way that is more similar to a crop rather than an animal: one would harvest salmon, like corn, rather than slaughter like livestock. This contributes to the way both the industry and the consumer distance themselves from the act and ethics of aquaculture. However, it is also important to note that even though the salmon are not swimming freely, they are generally kept in comfortable conditions. Since physical health is heavily monitored, it is not hard to note when stress is not good for the fish's environmental and nutritional quality. Physical health is a major determinant of the fish's quality, necessitating this emphasis. Overcrowding - which would be unethical - is generally avoided. After the fully-grown fish are systematically harvested, they are put on ice, or completely frozen, and transported to their secondary, or sometimes final, destination. A fully frozen fish is preferred for longer journeys. A drawback is that, between freezing and thawing, the fish can lose a degree of its mass, but at times sacrifices must be made for food safety purposes. Sometimes these fish are sent straight to fish markets, and others are sent to facilities for further processing. Through my work at a smoked salmon company, I watched how those smoked salmon products are processed firsthand. The facility first receives the fish, then thaws them. The fish are then trimmed to a particular level according to what their final product will be. There are five levels of this trimming process. The product's leanness increases as one goes up in level. This process can end up being quite wasteful; but some companies, such as the one I worked for, either utilize the materials that are trimmed or send them to other facilities to be turned into fish oils. Once the fish is trimmed, it is dried, then smoked (if it is meant to be a particular flavor, the seasoning is added before it is smoked in the oven). It is smoked for a few hours, packaged, and sent to its final grocery store shelf. Plastic packaging is a point of contention for sustainability-minded salmon producers. This is because the plastic packaging cannot be recycled due to the salmon oils that contaminate it. However, they can also not eliminate the plastic packaging entirely because of food safety concerns and regulations. This is one area in which technological innovation could really make a difference in order to find alternative, food-safe packaging for this raw product.

Future of consumption culture. The future of salmon consumption looks very different from the past. Aquaculture is only predicted to expand and evolve, and provide a larger percentage of the total fish consumption more efficiently. For example, "At the global level, since 2016, aquaculture has been the main source of fish available for human consumption. In 2020, this share was 54 percent, a figure that can be expected to continue to increase in the long term" (MOWI 2021, 12). We have just about hit the limit on what wild seafood stocks can provide as our population and appetites increase: "By 2029, per capita fish consumption is estimated to be 21.4 kg (vs. 9.9kg in the 1960s and 20.6kg in 2020). This is equivalent to another 20 million tonnes of seafood supply, which aquaculture is estimated to provide" (MOWI 2021, 13). Additionally, meat in general is in higher demand than it used to be: "Global per capita supply has more than doubled since 1960, and the seafood segment is a big contributor to this increase" (MOWI 2021, 9). This increase in meat consumption can be attributed to a steadily increasing middle class, and an increasing quality of life among that population. Now that more people around theworld have the purchasing power to afford meat, more people are consuming it. This is happening more rapidly in developing countries, where fish consumption per person is estimated to grow in the coming years: "The middle class is growing in large emerging markets, allowing more people to eat different, and more nutritious, protein rich foods, such as fish, meat and eggs. Consumption of high-quality proteins is expected to increase" (MOWI 2021, 19). We are seeing a shift towards animal based proteins, and since developed countries do not seem to be radically reducing their consumption of these proteins, overall consumption will rise. However, not all proteins are created equally, and focusing on fish rather than terrestrial protein is more resource efficient and less water intensive (especially farmed fish) than terrestrial agriculture. According to the MOWI industry handbook, if we increase our consumption of fish, that could lead us to reduce greenhouse gas emissions as well as be good for the health of our populations (MOWI 2021, 19). This is because of the lower carbon footprint of fish farms than terrestrial farms, and the ability of fish to more efficiently convert their feed to meat for consumption, as well as their noted health benefits for humans.

Chapter 3: Salmon Economics

Capitalism and the fish industry. Many countries around the world operate in market economies. A market economy is one that is controlled by the supply and demand of goods and services, and this is generally in the hands of producers of these goods and services and their consumers. The history of capitalism is relatively short, as it emerged from the Reformation, because of the societal values of hard work that came out of that era, as well as the industrial revolution that succeeded it and created the machinery to foster capitalism's domination. "Unlike earlier systems, capitalism used the excess of production over consumption to enlarge productive capacity rather than investing it in economically unproductive enterprises such as palaces or cathedrals" (Boettke and Heilbroner 2022). Since the industrial revolution, it has only grown and expanded, making its way to more countries. It is difficult to operate in a perfect market system, so most countries have some sort of government regulation, but for the most part, supply and demand play a more important role in these economic systems.

This is important to note, because salmon production has exploded since the 1970s: "Aquaculture has been the world's fastest growing food production technology in recent decades. In 2016, global production from aquaculture was 80.1 million metric tons (MMT), up from 603,000 metric tons (MT) in 1950 and 2.5 MMT in 1970 (FAO 2018). In 2013, aquaculture surpassed fisheries as a source of food for human consumption (FAO 2016) and is projected to surpass total fisheries production sometime in the 2020s (OECD/FAO 2018).1 The growth in aquaculture production is, in many ways, a global success story of new production technologies and food systems that contribute to income, food security, and public health" (Anderson et al. 2019, 20.2). In fact, the late 1960s and early 1970 are sometimes referred to as the 'Blue Revolution' due to advances in technology and production processes for aquaculture farms. Salmon specifically led the charge in the industrialization of fish farms, and farmers of other species took note and followed suit with shrimp and other species of fish (Anderson et al. 2019, 20.4). Aquaculture has gotten the point that it has because of the forces of supply and demand. There was demand for the fish during the peak seasons before farms, and when farms were introduced, there was enough demand for salmon throughout the year to keep them going. If consumers had not wanted the fish, the farms would have failed: "As farming practices improved and production increased, the season length increased and an Easter season was created… it was primarily satisfying latent demand that could not be satisfied by the seasonally available wild salmon" (Asche and Bjorndal 2011, 125). The uniformity and consistency of farmed salmon has also kept demand relatively steady, as "producers found that the main competitive advantage for farmed salmon was the ability to supply the fresh product with a high degree of reliability. This might be expected since for most fish species, fresh is the most sought-after product form and therefore provides the highest price to the producer" (Asche and Bjorndal 2011, 127).

Additionally, fish farms can create a large number of jobs, and even support economies, especially in Scotland, where it has become an incredibly important industry for jobs and an incredibly high earning business for the country : "The combined number of jobs in aquaculture and fishing is estimated at around 5000, of which about 1300 are in trout and salmon production.

The number of jobs in fish processing is estimated at 14,000. In addition, there are a number of jobs in services, supplies and processing" (Asche and Bjorndal 2011, 27). Scotland is just one example of this economic benefit. Salmon farming is a vital industry in Norway, and it is sometimes referred to as "Norway's Ikea" because of its prominence and value. The United States is an example of where "It was the third largest aquaculture-producing country in the world as late as 1975, but production has only grown moderately since then, and it is now no longer among the top ten producers. The United States now imports more than 90% of the seafood it consumes, with a large part coming from aquaculture production in developing countries" (Anderson et al. 2019, 20.2). Due to increased regulations on the industry, countries such as the United States and Canada have seen the growth of aquaculture slow over time, whereas in many parts of Asia and South America, Chile especially, have seen explosive growth in the industry. Farmed salmon is now a major export of Chile and a major facet of its economy.

However, a few major criticisms of capitalism also greatly affect the salmon farming industry. First, capitalism relies on constant growth, but growth cannot occur indefinitely. This idea of perceived infinite growth has contributed to a host of environmental problems, such as overfishing: "Fish were once seen as renewable resources, creatures that would replenish their stocks forever for our benefit. But around the world there is evidence that numerous types of fish, such as the northern cod, North Sea mackerel, the marbled rock cod of Antarctica and, to a great extent, the west Atlantic bluefin tuna, have been fished out, like the great whales before them, and are not recovering" (Clover 2008, 7). Capitalism relies on the exploitation of resources for production, none of which are infinite and they cannot sustain constant growth especially when we use them faster than they can naturally replenish: "Many critics have alleged that capitalism suffers from an inherent instability that has characterized and plagued the system since the advent of industrialization" (Boettke and Heilbroner 2022). Additionally, along with constant growth, the system relies on constant consumption, which is also unsustainable. We consume more than we need, which leads to issues such as overfull landfills and food waste. However, if we did not constantly demand, there would be too much supply, and that would create economic instability.

Economics and Environmental issues/externalities. Major issues with salmon farming include a potential increase in demand for fish meal (and therefore putting pressure on and potentially depleting the stocks of smaller fish that fish meal is made of), escapees and their potential to contaminate wild fish stocks, and concern for the amount of chemicals/antibiotics/vaccines that are used in aquaculture. Firstly, whether or not there is an increase in demand for smaller fish used in feed depends on the way that those fisheries are managed. There are a few potential management styles for the fisheries that provide the fish used for salmon feed, consisting of open access, restricted open access, or privately managed by some kind of sole owner. In the case of open access, there is a higher probability of overexploitation due to its lack of regulatory oversight. These fish are often used for feed because they are often bony and oily, and therefore ideal to make fish meals and fish oils. Because of the fisheries' status as essentially communal, these fish will remain profitable even when they are overharvested, and overharvesting would lead to higher demand, which would not give them the chance to replenish naturally. That scenario would be an issue for both the environment and the farming industry. However, "fisheries management has improved over the last decade, with increasingly stricter regulations of inputs. The most important regulatory instruments used in Chile and Peru are total allowable catch (TAC) quotas, limited access, input factor regulations, and fishery closures that are imposed for certain periods and in certain areas" (Asche and

Bjørndal 2011, 68). In addition to this, fish meal has protein substitutes, such as soya, which could ease the pressure on wild fish as the prime food source for farmed salmon.

Another concerning environmental issue for farmed salmon is the previously mentioned escaped salmon competing with and/or breeding with wild salmon stocks. However, “The main reasons for accidental release of farmed salmon are winter storms, propeller damage, and wear and tear on equipment. In recent years, better management of these problems has ensured that the number of salmon escapees is relatively stable, which contrasts with the increased number of salmon produced each year” (Asche and Bjørndal 2011, 78). As aquaculture expands and technology evolves,the industry will be more able to handle the escapee issue. It is important to note that aquaculture is still an incredibly new field, and we have not had as much time to iron out the mechanics and address potential issues as we have had in terrestrial farming. While it is integral now more than ever to address environmental issues, it is also important to understand how fast aquaculture is moving and has yet to move to handle these concerns. An important step in this is to consider environmental issues in initial proposals and economic predictions, and price things accordingly rather than looking towards the environment after the fact. “Detrimental environmental effects of aquaculture not accounted for in market prices are by definition negative externalities” (Asche and Bjørndal 2011, 73). True cost pricing has been proposed to combat this issue and keep environmental effects at the forefront of economic decisions. Additionally, if industry is not motivated to increase sustainability, governments can step in, because “if there is no negative feedback on profitability, it is unlikely that the industry will internalise detrimental environmental effects. In this case the government has to regulate the industry if the effects are to be avoided… it is desirable that regulations are efficient in addressing the externalities but, conversely, also allow the aquaculture industry to be economically sustainable if that is possible" (Asche and Bjørndal 2011, 74). Moreover, addressing and including these externalities in pricing could motivate producers and consumers to broaden their scope to the environmental effect.

As touched on in chapter 1, sea lice is another concern regarding salmon farms. Farms (like other industrial agriculture) also garner a negative reputation for the amount of chemicals that are used on their fish, including antibiotics. Antibiotics are used to treat bacterial diseases, but overuse can lead to harm to positive bacteria and in extreme (and now more frequently occuring) cases, they can create antibiotic resistant super bacteria. However, according to economic scholars Asche and Bjørndal, "Chemicals are mainly used for cleansing cages and for treating salmon lice. Wrasses have been introduced as a more environmentally friendly method of treating sea lice because they feed on the lice that live on salmon… [and while] salmon farmers must still rely on chemicals to treat infected fish, but they use considerably less now than they did in the mid 1980s" (Asche and Bjørndal 2011, 77- 78). Additionally, instead of relying on antibiotics, farms have switched to vaccinations instead. One of the ways farmed salmon can actually be identified is by the vaccination injection marks on their bodies. The growth of salmon farms has made finding pharmaceutical solutions to biological problems a worthy endeavor. As explored by Asche and Bjorndal, industry growth in regards to the oil-based vaccine in the pharmaceutical realm came about once aquaculture was seen as a profitable market. Because of the aquaculture boom, the vaccine was made available at a much quicker rate than it would have been in other circumstances. This expansion of the increasing vaccinations has led to a reduction of antibiotic usage which is a positive step forward for the industry (Asche and Bjørndal 2011, 77). The demand for farmed salmon in the market economy created an incentive for a vaccine that could replace a reliance on antibiotics and slow the development of antibiotic resistance.

And this is important to note, because while antibiotic resistance is becoming a more common and concerning reality, vaccination resistance is much rarer. Therefore, it is a much more efficient method that will not lead to super bacteria wiping out an entire population of salmon any time soon.

Land-based aquaculture and sustainable fishing. It is predicted that in the coming years, aquaculture production will continue to expand at a rapid rate: "The Fish to 2030 project conducted by the International Food Policy Research Institute (IFPRI) and the World Bank (Kobayashi et al. 2015) projected that aquaculture production will be 93.6 MMT in 2030, or a 50% increase from 2011. While this growth rate is slower than in previous decades, it is likely to maintain aquaculture's position as the fastest growing food production technology" (Anderson et al. 2019, 20.4). Because of this, it is important to be careful how we proceed due to unstable climate conditions and not much political action in that field. Therefore, more research and technological advancements have been put towards alternative methods of salmon aquaculture, specifically land based recirculating aquaculture systems (RAS), which consume less water and energy (Bjørndal and Tusvik 2019, 6).

Land-based aquaculture shows great promise in solving some of the environmental issues associated with sea pen aquaculture, such as lice and escapees. Because they are situated on land, they can be anywhere and do not have to be close to large bodies of water. This greatly reduces if not eliminates the chance of salmon escaping and infiltrating wild salmon stocks, competing with them for resources and eventually breeding with them and affecting the genetic makeup of wild populations. Additionally, certain pathogens rely on currents to expedite their infectiousness, including lice: "salmon lice originating from sea pens are currently assessed as the main threat to the wild salmon population, since salmon in aquaculture facilities contribute to the dispersion of the parasite, which in turn may lead to mortality and a decline in the wild salmon population. Biological sustainability has become the major framing condition for the industry, and it now acts as a significant constraint on increased production" (Bjørndal and Tusvik 2019, 3-4). Without currents and connection to open water, the possibility of lice originating from salmon farms infecting wild salmon populations would no longer be a concern.

However, RAS land-based systems are estimated to be more expensive than sea-based farms: "In most scenarios cost of production will be higher than in sea-based salmon farming. For this reason, land-based facilities are likely to be located in or near the large consumer markets so as to provide savings on transportation costs which for several markets are fairly substantial" (Bjørndal and Tusvik 2019, 22). Cost can also be added based on the setup of RAS systems. One large tank would cost less than 5 smaller tanks, but 5 smaller parallel systems would greatly reduce risk. Disease still does exist in land-based systems, and in the event of an outbreak, "the losses in one large RAS facility will be five times the losses with five modules of 1,200 tonnes each. [(A critical assumption is that the incidence in one module is contained in this module)]" (Bjørndal and Tusvik 2019, 19). In this case, separating the fish would be a higher cost, but lower risk activity. In the article "Economic analysis of land based farming of salmon" by Trond Bjørndal & Amalie Tusvik, they examined various methods of determining pricing, and "Using statistical simulations (Monte Carlo simulations), they estimated that around 90% of the simulated RAS growout would have a superior cost of production compared to Tasmanian south-east inshore sea pen production" (Bjørndal and Tusvik 2019, 17). Even so, it is not clear if these estimates take into account the environmental externalities discussed. Because with less of an impact on wild salmon stocks, RAS looks like a more environmentally promising option. Furthermore, "as one gains experience with the production technology, the scale is increased and specialized suppliers appear, production cost will decline and competitiveness increases as has already been demonstrated in sea-based salmon farming and juvenile production" (Bjørndal and Tusvik 2019, 22). While the technology and methods of production are new, there will still be some kinks to work out and of course it will be a substantial initial investment, but as evident by the growth of other forms of aquaculture, cost will probably go down relatively soon. Adding onto that, profit can be made back due to the fact that in a land-based system, every aspect of the farm is highly controlled. Therefore, harvest times are not dependent on the seasons and temperatures like they are in sea-based systems, and that would allow RAS systems to provide salmon to the market during non-peak times (Bjørndal and Tusvik 2019, 22).

Looking towards the future: The expansion of aquaculture could actually prove to be positive for wild fish populations: "overfished fish stocks encourage aquaculture development. As aquaculture adopts lower-cost production technologies and supply increases, fishing effort will tend to decline, and the fishery's sustainable supply will tend to increase along the backward bending supply schedule as stocks recover" (Anderson et al. 2019, 20.8). It has also been shown in certain locations to reduce wild fishing in general. According to an article by James L. Anderson, Frank Asche, and Taryn Garloc, "increased farmed salmon production has contributed to reduced rents and participation in the Bristol Bay fishery. This creates an incentive to improve efficiency of salmon fishery management through well-designed, rights-based systems and also to reduce the number of fishers" (Anderson et al. 2019, 20.8). Future increases in regulation will also be integral to reducing the environmental impact of salmon farms. Regulations have already been introduced in much of North America (as previously mentioned, and this is the reason for the increase in salmon importation), but regulations may start to increase in places where aquaculture is growing faster. This would impact emissions, because "emissions initially increase with the production. However, in part because the private cost becomes too large due to reduced productivity at specific locations and in part because regulations are implemented, emissions go down even as production continues to grow" (Anderson et al. 2019, 20.10). Consumer preferences will also change the landscape of the industry. As explained earlier, industry relies on demand, so an increase in consumer demand for sustainable products will increase production of sustainable products. In one study, it was found that people preferred wild caught salmon over farm raised. However, "Bronnmann & Asche (2017) nuanced this picture somewhat when introducing different ecolabels for wild [Marine Stewardship Council (MSC)] and farmed [Aquaculture Stewardship Council (ASC)] salmon. They showed that, while the preference for wild fish is maintained for unlabeled fish, there is a preference for sustainably harvested fish as signaled by the MSC label, and the preference for wild fish seemed to primarily be a preference for sustainability, as MSC and ASC labeled salmon have the same preference" (Anderson et al. 2019, 20.15). Finally, unsustainable consumption of fish can be slowed through the utilization of all parts of the fish. Decreasing fish waste is an expanding field of research, and there are many ways that anmore of the salmon can be used rather than discarded. When salmon is being prepared, there are different levels of "trim," which is identified by what parts are removed based on preferences for the final product. The parts that are trimmed off can be utilized in other food products such as salmon meatballs, jerky, or as flavoring. If the pieces are too small, they can be utilized in the extraction of fish oil. Utilization of more of the fish would force us to rethink our consumption habits and the levels of waste we produce, and even possibly lead to reduced consumption overall through satisfaction with products made with parts we were not previously using. The reduction of waste, more research into RAS systems, and true cost pricing can all increase the economic sustainability of the aquaculture industry and reduce overfishing habits and our dependence on wild caught fish.

Chapter 4: The Ethics of Our Salmon

What is animal ethics? Animal ethics is essentially the idea that we should treat animals as beings worthy of respect and moral consideration. Animal ethics can be considered in a variety of philosophical frameworks, such as utilitarianism, ecofeminism, deontology, etc. However, historically, animal ethics and animal rights have never been deliberately associated with fish. Animal ethics, and by extension, ideas of animal welfare and animal cruelty, have traditionally tended to focus almost exclusively on mammals. The further removed an animal is from us, the less we seem to care about it. Think about the influx of ASPCA ads about the welfare of dogs and cats, common pets, or the world wildlife fund ads about tigers or polar bears or elephants. They are all terrestrial creatures, and on top of that, they are animals we find "cute" and lovable. Therefore, these ads play on our desire to protect them. If asked, "what is your favorite animal," the above answers may come to mind. It is doubtful that anyone's favorite animal is the Atlantic salmon.

A well-documented issue in conservation movements is the desire to protect animals that we favor, and feel a connection to. Because of this, we may want to protect the environment to save the polar bears or koalas, but in focusing on them, thousands of other species are left by the wayside. Every day we lose biodiversity in the form of fungi, bacteria, and bugs. However, nobody seems to be getting up in arms about saving the ants. In fact, most people will not hesitate to squash a spider that has trespassed into their home. Even bees have to be marketed as lovable, fuzzy, harmless, and ecologically important creatures for people to care about them.

This limited focus does not only apply to ads, but to philosophical literature as well. In Lori Gruen's *Ethics and Animals*, she discusses a variety of issues related to animal welfare and the ethics of the ways we treat animals. However, she never focuses on fish. In the book, there are chapters about animal testing, zoos (not aquariums!), and industrial agriculture, and all of which focus on terrestrial species. She discusses the ethics of eating animals, then discusses the suffering of chickens, cows, and pigs specifically. And while Gruen's book can be seen as a starting point, and some can argue that seafood is implied, many other sources regarding animal rights also exclude fish.

The Animal Welfare Act is the United States' leading piece of animal rights legislation. Passed in 1966, it has seen many amendments, including additions for the welfare standards of lab animals. However, fish are notably absent in this legislation, as the animals that are specifically protected under the act are "any live or dead dog, cat, monkey (nonhuman primate mammal), guinea pig, hamster, rabbit, or such other warm-blooded animal, as the Secretary may determine is being used, or is intended for use, for research, testing, experimentation, or exhibition purposes, or as a pet; but such term excludes (1) birds, rats of the genus Rattus, and mice of the genus Mus, bred for use in research, (2) horses not used for research purposes, and (3) other farm animals, such as, but not limited to livestock or poultry, used or intended for use as food or fiber, or livestock or poultry used or intended for use for improving animal nutrition, breeding, management, or production efficiency, or for improving the quality of food or fiber. With respect to a dog, the term means all dogs including those used for hunting, security, or breeding purposes" ("Animal Welfare Act"). There have been various social movements for the protection of farm animals, because the expansion of industrial agriculture has greatly increased their suffering. But as seen here, fish, especially those in industrial aquaculture, are a footnote in the animal rights movement, if they are thought of at all.

Fish are indeed very different from us, so their exclusion from animal welfare movements is understandable. They do not breathe air. Even the sea creatures that are commonly cared for, such as dolphins, whales, and orcas, still breathe air. Movements to protect sharks seem to be the exception in animal welfare circles, not the rule. So, since fish tend to be left out of animal rights discussions, do they have rights? Can we eat them?

Can we eat fish? An argument against eating animals in general is that by consuming them, "we don't respect them in the right way, as "fellow creatures," who, like us, do not belong in the category of the edible. Another way of illustrating this point is to say that in turning other animals from living subjects with lives of their own into commodities or consumable objects we have erased their subjectivity and reduced them to things" (Gruen 2021, 103). However, one would not criticize the cheetah, who consumes the gazelle, of disrespect. And while an argument can be made about the roles of necessity and industrial agricultural scale in that comparison, on a basic level, we are animals, who are eating other animals. Additionally, Gruen mentions that utilitarianism, especially Peter Singer's version of utilitarianism, generally has little problem with eating animals: "For those concerned about promoting happiness and minimizing pain – the hedonistic utilitarians…, for example – eating animals who are raised humanely and killed painlessly would not be ethically wrong. For preference utilitarians, like Peter Singer, who judge actions based on the total amount of preferences satisfied over those thwarted, killing is objectionable only if that killing thwarts a preference or desire about the future, and, Singer argues, only persons can have preferences about the future." (Gruen 2021, 98). Eating meat can also be a cultural practice or a necessity, either biologically or socioeconomically (as not everyone lives in an environment where it is feasible to be vegetarian).

While eating meat is usually up to personal philosophical preference, industrial farming is generally considered to increase animal suffering. Aquaculture is a much newer phenomenon than terrestrial animal agriculture, so we have not had as much time to reckon with it and determine what the best course of action is. We have spent hundreds of years alongside cattle, raising and killing them, but salmon farms only really picked up steam in the 1960s. However, we can start by including fish in animal welfare legislation. It cannot be comfortable to swim in small circles in a pen with hundreds of other fish, cramped and susceptible to disease. So we can start treating fish the way we have started to treat terrestrial farm animals, by providing them some space and attempting to improve their quality of life.

Ethics on the farm. These concepts of animal ethics are applied to aquaculture in an article by Kriton Grigorakis, in which he analyzes the ethical impacts of each stage of production. The article emphasizes that aquaculture is a necessary form of production to meet human protein demands. However, even though it is necessary, aquaculture can still be ethically analyzed and made better. Ethics is a form of social sustainability, and as we move towards the future, the more that ethical practices are implemented and executed, the less harm we will have to contend with as we learn more about salmon wellbeing or as aquaculture expands. Grigorakis lays out a matrix that he uses to analyze the ethics of aquaculture according to three principles: “The principle of autonomy (i.e., our duty to respect everyone/everything) philosophically derives from the deontological theory of Immanuel Kant.[...] The principles of beneficence (i.e., doing good) and nonmaleficence (i.e., avoid producing harm) have been combined for simplicity in the principle of wellbeing.[...] Justice (i.e., something ethical implies that no favoritism will be shown), can be interpreted as the common sense of fairness" (Grigorakis 2009, 347-348). These three principles of autonomy, wellbeing, and justice are mapped onto the environment, producers, consumers, and treated organisms in order to produce an ethical matrix, which serves as the lens with which he views certain actions involved in the aquaculture process. In applying ethics to the treated organism, which are the fish, we must discuss the killing method. The method of choice for killing products of aquaculture is electro-stunning, and this is deemed humane and less stressful for the fish, as it is quite instantaneous. A potential reason that the ethics of killing fish and the ethics of aquaculture as a whole has been under-analyzed is that it is still unclear whether fish feel pain, or at least feel pain, fear, or stress in ways that we as humans can conceptualize. It has been "concluded that fish lack the essential brain regions or any functional equivalent in cerebral cortex, responsible for experiencing pain or fear. Huningford et al. (2006), on the other side, in their recent review on fish welfare provided evidence that fish have the ability of learning (both associated and more complex)," (Grigorakis 2009, 358). This is why the question "is it ethical to raise and consume fish" is a difficult one to answer, and may not even have one concrete answer. Additionally, "Based on the evidence the former authors concluded that fish have the sense equipment required to perceive harmful stimuli and probably the central nervous system to perceive harmful stimuli that is associated with pain in mammals. One ethical question raised within these, and already pointed out by Lund et al. (2007), is what degree of evidence is necessary in order to admit safe indication of fish sentience" (Grigorakis 2009, 358). This brings up questions outside of the scope of this paper, but that are important to consider in a society so dependent on animal agriculture: how do we define sentience for different animals? Do our needs outweigh the needs of animals? Is it ethical to 'produce' animals and have so much control over every aspect of the process?

Another ethical issue that Grigorakis points out is aquaculture's effect on the treated organism's autonomy. Through our intensive management of aquaculture systems, we remove any choice from the organism's existence. We completely control their birth, growth, movements, and death. Grigorakis brings up the idea of feed, saying "Since the aquacultured organism has no alternative other than eating the feed, and this not always at the time and quantity of its choice, its autonomy is violated" (Grigorakis 2009, 355). The hyper control of farms treats the fish more like an object than an organism, and is so removed from what the salmon would experience in the wild. Additionally, farms have an ethical impact on the environment as well: "In the stage of breeding, the major ethical issues lie within the ethical principle of the autonomy of environment and of fish. In environmental aspects, the biodiversity maintenance is questioned when selective breeding occurs for the organisms." (Grigorakis 2009, 349). Through breeding, we select for the traits that will give us the fish that grows the fastest or the fish that grows the largest and just breed a lot of those, and that interferes with the idea of biodiversity and a variety of traits, which then removes environmental autonomy.

Moving from the impact on the treated organism (the salmon) to the impact on the producers and consumers, it is also important to consider the human variables in the aquaculture equation. The employees of fish farms may be exposed to a variety of substances and chemicals on a regular basis, such as "antibacterials, disinfectants, antifouling agents, and in many cases are unaware of potential health risks associated with these exposures. Sapkota et al. (2008) have recently reviewed the potential risks associated with antibiotics exposure in aquaculture, and concluded that further research is required to determine the adverse health effects associated with chronic exposures of low-level antibiotic residues. Among these potential health impacts, the balance of microbial communities in the gut and the development of resistance are what seem to be the more profound ones" (Grigorakis 2009, 352). As mentioned in the previous chapter, antibiotic resistance is a serious concern for the future of illness and medicine, so activities that can speed up antibiotic resistance such as the overuse of antibiotics should be reduced or avoided. Additionally, according to the principles outlined in this article, exposing the employees to these types of hazards interferes with the principle of wellbeing for the producer. There are also the factors of the wellbeing, autonomy, and justice of the consumers. Many people have a skepticism towards farmed/treated fish for health reasons, as skepticism in general towards science and medicine has become much more widespread in recent years. The effects of DNA vaccination that the fish receive are concerns for consumers in their own health, but there seems to be no data to suggest any effect on the consumer, let alone a negative effect (Grigorakis 2009, 358). For the consumer, farmed fish seem to be positive in the fields of wellbeing and justice: "In aspects of justice, the adequacy and affordability of food seems generally to be positively affected by the aquaculture production. This is due to the increasing quantities of produced fish and to the lower prices than the respective wild caught fish" (Grigorakis 2009, 359). This has an impact on justice, as it allows people to have greater access to fresh, nutritious food that is more affordable. It also has an impact on autonomy by allowing people to have more of a choice about what protein sources they would prefer because of the now widespread accessibility of fish. Grigorakis concludes his article by discussing aquaculture through the lens of utilitarianism, since it is such an important and widespread ethical theory, and so applicable to everyday life. Does the harm outweigh the good? Grigorakis states: "The major benefits from aquaculture (Frankic and Hershner 2003) for household economies, human nutrition, employment, country economies, preservation of biodiversity (in cases of restocking and recovering of species), fishery resources (in case of aquaculture sustainability), respective research and development, and education and environmental awareness should always be weighed against generated ethical objections." (Grigorakis 2009, 362). In these cases, aquaculture seems to do more good than harm, and while the potential negative impacts should be taken seriously, they are not enough to deny that aquaculture is a net positive and should be expanded.

The important question to pose is: Is some suffering on the account of the salmon worth it for the positive benefits of meeting humanity's protein demands and potentially shifting away from animal agriculture (which would have a positive effect on the environment)? In Gruen's book, she mentions the negative environmental impacts of concentrated animal feeding operations (CAFOs), which is a phrase used to refer to modern industrial animal agriculture. She points out the amount of waste, air, and water pollution that these operations produce, writing that animal agriculture emits around forty times as much waste as humans do, and that when the chemicals in that waste break down, they can release noxious gasses into the atmosphere (Gruen 2021, 87). CAFOs have an impact on greenhouse gases as well, as according to "The UN Food and Agriculture report, Livestock's Long Shadow, claims that between 14 percent and 22 percent of the 36 billion tons of "CO2-equivalent" greenhouse gases produced in the world every year is the result of animal production. Globally, "the livestock sector" emits more greenhouse gases than all forms of transportation combined" (Gruen 2021, 88). Animal agriculture is also one of the main sources of methane emissions, which majorly contribute to the greenhouse effect. If we can expand aquaculture, which has a much smaller carbon footprint than terrestrial agriculture and a much smaller comparative effect on the environment, then why not do it. Reducing terrestrial animal agriculture will probably not happen on its own, so providing a more sustainable alternative is a good way to shift consumption.

Environmental legislation around salmon. Our views on ethics tend to directly influence the policies we put into place. So, with a need to preserve wild salmon but also a need to feed the population, how do we balance the two? One idea that has been implemented is that of fishing limits, and this is seen in action in Alaska in Greenberg's book: "Everyone was waiting for the handful of white men and women at the Department of Fish and Game at the far end of town to determine if enough salmon had escaped into the upper river to allow for a commercial "opening" of the fishery. Every year in every major river system in Alaska, Fish and Game sets what they call "escapement goals,"—that is, a total quantity of salmon that must escape capture so that a sufficiently large number of adults make it to their spawning beds to lay enough eggs to ensure a viable next generation." (Greenberg 2010, 17). In theory, this is a great idea because it protects the amount of wild salmon in that area. However, for the people who rely on fishing those wild salmon as a source of income, restrictions on the fishery, especially by an outside regulatory industry, can do them more harm than good. This also highlights a justice issue, with an outside regulatory body coming in with less local knowledge about the community and taking legislative measures to govern people's livelihoods. It is difficult to balance the good of the environment with the welfare of those who depend on its resources in a capitalist economy.

Governments have not always put environmental interests at the forefront of policy decisions, and this is criticized in Morton's book, where she chronicles her battle with the Canadian government over fish farms. One of the legal loopholes that caused trouble for Morton was the categorization of what fish farms actually were. There are regulations in Canada that do not allow anyone to claim ownership over ocean fish. Since the farms themselves consist of fences in the ocean and the salmon within them, it should mean that the ownership of farms is not allowed, because it would be claiming ownership to what is technically a fishery. However, "The federal government realized that it had no clear right to issue licences to the industry, so it gave this fishery to the provinces to regulate as "farms." But they aren't actually farms" (Morton 2021, 30). Additionally, there has historically been a lack of government accountability and follow through, especially when it comes to environmental legislation. As Morton explains, "these were farms, and the provinces knew what to do with farms. This was why my requests to government to reduce the impact of these farms drifted in circles, never landing fully on anyone's desk. The provinces oversaw the farms, even though the farms were in the oceans, a federal jurisdiction." (Morton 2021, 36). While the farms were very commonly known to be farms, the label of "fishery" let them get away with a lot and allowed the complaints of the author to go ignored for years.

Ownership regulations and the development of large, privatized farms. A major issue with the salmon industry, especially as it is practiced outside of Norway, is the privatization and corporatization of it. It is more loosely regulated because of its lucrative economic benefits to big businesses. This came about because of regulations in Norway that dictated how the profits from salmon farms would be handled: "So, who should benefit from commercial salmon cultivation, and how should the emergent industry be organized and regulated? These were among the questions posed to the so-called Lysø committee in Norway in 1972, and the committee's proposed regulations[…] left an imprint on Norwegian salmon aquaculture for many years to come. The objectives of these regulations were to first and foremost to regulate growth and to strengthen local economic livelihoods in remote coastal villages (Osland 1990, 14). These aims were further formalized in the Aquaculture Act of 1981, which reflects the policy objective to "maintain an industrial structure based on small enterprises, an ownership structure based on local ownership, and a widely distributed industry" (Lien 2015, 35). These ideas are admirable, if a bit idealistic, and as Lien explains, not all of them lasted: “In 1985, another Aquaculture Act was passed; it abandoned the owner-farmer principle, but the restrictions on growth were otherwise maintained. As a consequence, potential aquaculture investors looked elsewhere for expansion opportunities. This is the background for the growth of salmon aquaculture in Tasmania and also in Chile” (Lien 2015, 36). The expansion of salmon farming to other countries came about because Norway maintained its goal of local ownership and curbing the interests of large corporations. Aquaculture was originally meant to support the economies of smaller coastal communities. However, the interests of large investors would not be ignored, and they would search elsewhere for conditions in which aquaculture could succeed (Lien 2015, 39). Because of this expansion to other countries and an increase in business management and foreign investors, farming has grown past its humble beginnings as a way to supplement coastal income into a massive industrial project: “Ownership regulations limited firms’ potential for investment in Norway. Consequently, from the early 1980s onwards, many Norwegian firms invested in fish farming abroad, particularly in Canada and the USA, but also in Chile” (Asche and Bjorndal 2011, 35). Other countries ran with Norway's idea of farms, without the added weight of local ownership, but with Norwegian company investment. For example, Scotland’s aquaculture industry does not have the same ownership restrictions, and instead is much more lax in terms of oversight. This has led to a greater variation in the development of their aquaculture industry as opposed to Norway, with the emergence and advancement of both large and small Scottish farms (Asche and Bjorndal 2011, 38). The lack of regulation expands beyond Europe, with governments seeing aquaculture as an economic positive: “Salmon farming has been actively promoted by the government of Chile, to some degree as part of its plans to develop the southern regions of the country. As a consequence, Chile imposes no regulations on ownership” (Asche and Bjorndal 2011, 38). Additionally, some multinational corporations have entered into the salmon farming industry. For instance, "Marine Harvest is the largest salmon producer operating in all the four largest salmon-producing countries, Canada, Chile, Norway and Scotland. In 2008, Marine Harvest's share of salmon production was about 23%" (Asche and Bjorndal 2011, 40). The entrance of multinational corporations changes the face of salmon farming, and they can easily establish dominance in the market because of their scale and the requirements of supermarkets. The company I worked for, Acme Smoked Fish Corp., is one of the largest smoked fish companies in the world, and has to abide by the regulations for sustainability and traceability from their supermarket customers, which are becoming increasingly strict. It would be very difficult for a smaller company to keep up with those interests, so larger corporations have a strong hold on the industry (Asche and Bjorndal 2011).

Chapter 5: Policy Recommendations for the Salmon Industry

With our current habits of consumption, we cannot rely entirely on wild salmon, that much is true. Because of the changing environment as well as salmon's migratory patterns, "wild salmon is a resource that is ultimately so limited and variable that any attempt to maintain it in a world market is a risky endeavor" (Greenberg 2010, 31). Additionally, wild salmon have never had to sustain a large population before. Pre-globalization, the only ones who had access to salmon were coastal or river communities, people who were geographically close to salmon and fished them for subsistence. However, because of the rise of globalism and large-scale markets, now landlocked communities who never would have had access to salmon can find them in the fish section of their grocery stores. According to Greenberg, "It would be wonderful if all the salmon we eat could be wild. But as one marine ecologist said to me recently, to continue to eat large wild fish at the rate we've been eating them we would need "four or five oceans" to support the current human population." (Greenberg 2010, 31). Our rivers simply do not have the stock for us to abandon farms altogether. While it would be ideal, it is not realistic. It would also be ideal for those who do not live where salmon occur naturally to stop consuming salmon, and for us to reduce our consumption of all meats in total. That would be the most environmentally sustainable solution, along with an overhaul of our capitalist system and transforming it into something less wasteful and more closed-loop, that encourages more mindful and limited consumption. But that does not look like it will happen any time soon. So, more tangible solutions can include incentives and subsidies for IMTA and sustainability certifications, increased research into aquaponics, increased escapement goals and compensation for local people who rely on the fishing industry, and the integration of fish into animal welfare laws and regulations.

Fishery management and legislation. Even though many governments have had their missteps, there is legislation in place to protect and manage fisheries. The Marine Mammal Protection Act was put into law in 1972 in the US, and was one of the first pieces of US legislation to look after the health of the oceans ("Marine Mammal Protection Act Policies, Guidance, and Regulations."). While it still only focuses on mammals and not fish, it opened the door for other legislation. The Marine Protection, Research, and Sanctuaries Act puts limits on ocean dumping for the welfare of marine life (EPA, 2023). There are also international and regional fisheries management organizations that are focused on more specific marine issues. For example, the North Atlantic Salmon Conservation Organization, or NASCO, "is an international organization whose objective is to conserve, restore, enhance, and rationally manage Atlantic salmon through international cooperation, taking into account the best available scientific information. The United States participates as a member of this organization" ("International and

Regional Fisheries Management Organizations.”). The management of fisheries connects to Grigorakis’ definitions of environmental autonomy and human justice by protecting biodiversity and limiting human intervention, and allowing those who economically rely on fisheries to do so sustainably. Fisheries management is a delicate balance between human and fish wellbeing, and it becomes more important as climate change and environmental changes intensify. Fisheries management also relates to Gruen’s ideas of respect for animals, because allowing fish to replenish and live more naturally would lead to us treating animals less like commodities and more like living subjects, allowing more of them to go about their existences independently from our intervention. Finally, there are systems of certification that can promote sustainable fisheries and aquaculture management. Two of the major certifications are the ASC and MSC certifications, standing for Aquaculture Stewardship Council and Marine Stewardship Council respectively. These certifications can inform consumers on the type of fish they are getting and are attempting to help make the industry more sustainable through strict guidelines for certification.

IMTA. In order to minimize the effects of aquaculture on the surrounding environment as well as making farms more sustainable as a whole, we can implement policies to incentivize closed system aquaculture and integrated multi-trophic aquaculture, or IMTA. Closed system aquaculture is the practice of raising salmon “in tanks away from natural systems, [and] is the only way to guarantee that wild and domesticated forms of salmon stay separate” (Greenberg 2010, 31). This prevents the issue of escaped fish and the ecological damage that comes with them. Additionally, IMTA is a “method of farming combines species that require feed (such as salmon) with other species (such as seaweeds) that extract dissolved inorganic nutrients and species (such as mussels and sea urchins) that extract organic particulate matter, to provide a balanced ecosystem-management approach to aquaculture." (Greenberg 2010, 31). In principle, this idea makes a lot of sense. Nature has evolved to work together and has created a web of connections and relationships. Our method of agriculture and domestication has removed certain species from their relationships, raising them as individual units. However, farming salmon alongside other species, creating small self-contained ecosystems more closely mimics relationships in nature. The mussels grown with IMTA have high nutritional value and can actually be more meaty than those harvested by traditional methods. Moreover, " Mussels turn out to do another interesting thing on a salmon farm. Evidence suggests that they may absorb some of the infectious salmon anemia virus; adding mussels to the aquaculture equation could serve to break the disease cycle that is rife in some of these salmon-farming operations." (Greenberg 2010, 32). The species can work with each other and be mutually beneficial, creating webs that help each species grow and thrive. Additionally, this method of agriculture could prove to be profitable: "Seaweed, it turns out, is an integral part of the food, cosmetics, and textiles industries and constitutes a $6.2 billion market. Chopin had been working on the production of carrageenans, the thickening or emulsifying agents extracted from red algae that are particularly useful to industry. In an "aha" moment Chopin saw that the inorganic waste from salmon farms could be used to grow those very valuable algae" (Greenberg 2010, 32). Seaweed could prove to be a valuable byproduct from IMTA as well as a contributor to the health of the system itself.

Aquaponics. Another method that we could look into to farm more sustainably is aquaponics. Aquaponics is the combination of aquaculture and hydroponics. Hydroponics in itself is a farming technique that is being heavily researched as an alternative to traditional agriculture, as it does not require farmland. Hydroponics is the growing of crops in a facility utilizing just water and minerals. A substrate is used, such as sand, woodchips, coconut fiber, etc., but it does not require soil. The term aquaponics was coined in the 1970s, when the two farming practices were combined. Seeing as aquaculture and hydroponics are both practices that rely primarily on water, it made sense to put them together and circulate that water through one system that would produce both crops and fish. According to one textbook, “Aquaponics is defined as an integrated multi-trophic, aquatic food production approach comprising at least a recirculating aquaculture system (RAS) and a connected hydroponic unit, whereby the water for culture is shared in some configuration between the two units. Not less than 50% of the nutrients provided to the plants should be fish waste derived” (Goddek et al. 2019, 118). In this type of system, waste from the fish provides nutrients for the plants, cutting down on the amount of pesticides and fertilizers needed for the plants. In a traditional hydroponics system, minerals are added to the water to supplement the growth of the plants (since they need more than just water), but with aquaponics, the fish provide a lot of the necessary nutrients for the plants, so if they do need to be supplemented then it is much less than a traditional system if at all. Adding onto that, the minerals needed for plant fertilizers often need to be mined, such as phosphorus, which is “an essential but exhaustible fossil resource that is mined for fertilizer, but world supplies are currently being depleted at an alarming rate. Using digesters in decoupled aquaponics systems allows microbes to convert the phosphorus in fish waste into orthophosphates that can be utilized by plants, with high recovery rates” (Goddek et al. 2019, 7-8). The plants also essentially clean the water, and reduce the accumulation of waste that could be seen in a standard aquaculture setup (Goddek et al. 2019, 122). Aquaponics increases the productivity of both hydroponics and aquaculture by making them more efficient and producing multiple outputs.

Aquaponics can have a variety of environmental benefits. The first being the lack of soil used. “Agricultural land currently covers more than one-third of the world’s land area, yet less than a third of it is arable (approximately 10%) (World Bank 2018). Over the last three decades, the availability of agricultural land has been slowly decreasing, as evidenced by more than 50% decrease from 1970 to 2013" (Goddek et al. 2019, 6). Erosion and reduced soil health are massive problems for us to contend with in the coming years, so it would be helpful to look into methods of food production that do not rely on soil. Food production in itself is a reason to expand usage of aquaponics, as "Modern intensive agricultural practices, such as the frequency and timing of tillage or no-till, application of herbicides and pesticides, and infrequent addition of organic matter containing micronutrients can alter soil structure and its microbial biodiversity such that the addition of fertilizers no longer increases productivity per hectare" (Goddek et al. 2019, 23). As aquaponics is soil-less, the nutrients or lack thereof in the existing soil is not an issue. Additionally, a way to expand agricultural production is not only to increase productivity, but to also expand it physically, which may not be able to be done on the increasingly dwindling arable land but can be achieved through aquaponics facilities. Aquaponics also uses water more efficiently than either traditional agriculture and aquaculture. In traditional land-based aquaculture, the wastewater is usually released into waterways. This rapidly increases the amount of nutrients in that body of water, particularly nitrogen and phosphorus and can lead to eutrophication. In aquaponics however, "systems take the dissolved nutrients from uneaten fish feed and faeces, and utilizing microbes that can break down organic matter, convert the nitrogen and phosphorous into bioavailable forms for use by plants in the hydroponics unit" (Goddek et al. 2019, 23). This is undoubtedly a better outcome than contributing to the eutrophication of already scarce water. Additionally, the water is used efficiently as well, unlike in traditional agriculture which "currently accounts for roughly 70% of the freshwater use worldwide, and the withdrawal rate even exceeds 90% in most of the world's least developed countries. Water scarcity will increase in the next 25 years due to expected population growth" (Goddek et al. 2019, 25). Because of the water recycling capacity of aquaponics, it can be incredibly beneficial for arid regions of the world, as "In these regions, recirculation of water in aquaponic units can achieve remarkable water re-use efficiency of 95–99%" (Goddek et al. 2019, 27).

Aquaponics can also address some aquaculture specific concerns such as antibiotic use and disease. According to *Aquaponics Food Production Systems*, "Pathogen control, for instance, is very important, and contained RAS systems have a number of environmental advantages for fish production, and one of the advantages of decoupled aquaponics systems is the ability to circulate water between the components and to utilize independent controls wherein it is easier to detect, isolate and decontaminate individual units when there are pathogen threats" (Goddek et al. 2019, 8). This is similar to the features of multi-pen RAS that I discussed in chapter 3, with the added benefit of growing plants as well. Since RAS is utilized in aquaponic setups, it "also prevents disease transmissions between farmed stocks and wild populations, which is a pressing concern in flowthrough and open-net pen aquaculture" (Goddek et al. 2019, 25). The high level of technological control along with the separation of pens for plant-growing efficiency mean that there is less pathogen transmission and a lower use of antibiotic treatments, therefore a lower risk of antibiotic resistance.

A final concern with aquaculture, land-based or not, as well as agriculture, is location. Where can we put farms? Where can we expand agriculture? Trends towards increasing urbanization means that there are fewer people working in food production because of its usual location in rural areas. However, aquaponics can be done in urban environments, and this can be positive in environmental and economic ways. Firstly, locating aquaponics systems in urban areas can reduce greenhouse gas emissions and quality concerns associated with transportation over long distances: “When sourcing food, the transport of goods is not the only factor to take into consideration, as the freshness of products determines their nutritive value, taste and general appeal to consumers. By growing fresh food locally, many scholars agree that urban farming could help secure the supply of high-quality produce for urban populations of the future whilst also reducing food miles” (Goddek et al. 2019, 11). However, urban areas generally have high property prices and expensive land that is generally highly sought after for use for purposes other than food production. Therefore, buying up land in growing cities is unrealistic. However, “ in shrinking cities, where populations are decreasing, unused space could be used for agricultural purpose (Bontje and Latten 2005; Schilling and Logan 2008) as is the case in Detroit in the United States” (Goddek et al. 2019, 11). Using these spaces can help revitalize an urban area, as well as create jobs and boost the economy.

Aquaponics does have a few drawbacks we must contend with if we move forward with its expansion. Firstly, while it minimizes use of water and resources, aquaponics systems are generally quite energy intensive. We could power them with renewable energy, but based on the energy needs, relying on solar alone would not be enough, especially in areas with less solar radiation. If renewables were to be used as an energy source, it would only be to supplement the systems. Additionally, it is not clear through research if the crops grown through aquaculture systems are quite as high quality as those in traditional hydroponics systems, as there are conflicting results regarding this question. However, even if they are not, the crops could still be processed and utilized or frozen and do not have to be discounted altogether.

Overall, we should expand research into aquaponics and begin implementing it on a small scale to see if it works as a more sustainable alternative to traditional sea-pen aquaculture: “aquaponics has been identified as a farming approach that, through nutrient and waste recycling, can aid in addressing both planetary boundaries[…] and sustainable development goals, particularly for arid regions or areas with nonarable soils" (Goddek et al. 2019, 5). Aquaponics can be used to make nutritious food more easily accessible, reduce transportation costs and emissions, and overall lead to more sustainable transitions in our food systems. It is able to create more value than aquaculture or hydroponics on their own and is less resource intensive, which is ideal for a future where access to certain resources such as fresh water may be more limited than we have seen in the past (Goddek et al. 2019, 13). Additionally, "until recently, recirculating aquaculture systems (RAS) farms have been relatively small compared with other types of modern aquaculture production. The last two decades have seen a significant increase in the development of this technology, with increased market acceptance and scale." (Goddek et al. 2019, 35). Increased development generally means increased technological innovation and increased efficiency. This can be seen with comparisons of sea-pen aquaculture from 1970 to now. As we expand usage of aquaponics, it can be made more effective and the concerns that we have now can be addressed. However, we must avoid the trap of thinking that this one technology will fix all of our problems. The technology of aquaponics is still generally new because the field of aquaculture as a whole is very new. Because of this, it comes with a fair amount of risk: "We suggest this situation is characterised by a misplaced techno-optimism that is unconducive to the deeper shifts towards sustainability that are needed of our food system. Given this, we feel the aquaponics research community has an important role to play in the future development of this technology." (Goddek et al. 2019, 394). We tend to rely on the promise of intangible future technological innovations to fix climate issues, but in reality we have to do the work now to develop sustainable systems and technologies. It is unlikely that one magical piece of technology will be a cure-all for climate change within the next ten years. So any emerging systems such as aquaponics have to be made more sustainable as they are being implemented to avoid having to overhaul everything in the future, or worse, implementing a system that is technologically promising only for it to hasten our downfall.

Fishery management, increased escapement goals, and compensation. Helping the wild salmon populations get back to a normal state and fishing them sustainably is an important goal as climate change starts to have a major effect on wildlife and biodiversity. As I mentioned, the wild population cannot sustain humanity's appetite alone, especially not with how fisheries have been depleted in recent decades. Therefore fishery management is integral to the future of sustainable fisheries, and the continuation of aquatic life as a whole. A policy analysis of Canada's fishery could provide insight as to what to do with our own salmon populations, particularly in Alaska. In Canada, the government implemented "Restrictions on openings and allowable gear, habitat protection, and salmon enhancement [which] were generally [successful] in protecting the viability of the major stocks" (Schwindt et al. 2003, 76). Additionally, the restructuring of the fishery prioritized native peoples' access to the fish: "The Pearse Commission also proposed providing financial assistance to the Aboriginal population to further participation in licence purchases ($20 million over five years) and a prohibition on the sale of licences held by Aboriginal fishing corporations to non-Aboriginals" (Schwindt et al. 2003, 82). This emphasized native populations rights to the fishery, as before the restructuring their participation was being limited by newer fishers. "Aboriginal peoples have cultural, economic, and now constitutionally protected stakes in the use of the salmon fishery. Any policy change must, at a minimum, protect these interests and ideally should provide the flexibility to accommodate expansion of Aboriginal claims to the resource" (Schwindt et al. 2003, 82). This mentality should be used when thinking about how to improve US fisheries, prioritizing those who have been using them the longest and rely on them. As mentioned previously, fisheries in Alaska have escapement goals, which are limits on fishing windows to make sure enough fish can make it to breeding grounds and repopulate. Increasing those would improve the health and population of the fishery but that does not come without a cost. In order to increase escapement goals, we would have to compensate those who economically rely on the fishery, and that would make things more equitable. This would work toward a more well-rounded version of sustainability, one that is not just environmental, but social and economic as well, and one that puts justice at the forefront of decision making.

Animal welfare and physical wellbeing. Sustainability is not just environmental. It is well-rounded, and that includes ethics and wellbeing. As the cruelty of industrial terrestrial farming is being brought to light, we should consider what that means for aquaculture, and how to avoid backlash and increase the welfare of the fish while we continue to rely on them for food. As mentioned earlier, fish have commonly been excluded from animal welfare legislation (as have farm animals, which should also be remedied), therefore there have not been any animal rights parameters to use as guidelines for fish farms. This is because fish and other non-mammals lack certain features of the brain that create what we understand as suffering. Because of this, many believe that fish cannot suffer in the ways that we would define or recognize it. However, some argue that "complex animals with sophisticated behaviours, such as fish, probably have the capacity for suffering, though this may be different in degree and kind from the human experience of this state" (Goddek et al. 2019, 56). Implementing basic guidelines for fish welfare is a way to address this issue. To start, many define welfare through physical health. Because fish cannot speak to us, we must observe their physical conditions as a way to determine stress or suffering. Not only does promoting welfare have the ethically positive benefits for the fish, it can also be financially positive as well, especially in an ever growing market: “Grimsrud et al. (2013) provided evidence that there is a high willingness to pay, among all Norwegian households, to improve the welfare of farmed Atlantic salmon through increased resistance to diseases and salmon lice, which may imply less use of medicines and chemicals in the production process” (Goddek et al. 2019, 56). Increased animal welfare could improve consumer attitudes towards farmed salmon, which already have a perception disadvantage compared to wild caught salmon for being “less natural.” It could also be economically beneficial, especially to emerging aquaponics industries, to in their infancy advertise that they prioritize the welfare of their salmon. Finally, putting extra care on the physical health of the fish would also reduce their stress and make them potentially more resistant to disease. Including fish in animal welfare conversations is a win for all parties.

By tracing the history, economics, and ethics of the aquaculture industry, the benefits and drawbacks are evident. We do not need to do away with aquaculture, as it is less environmentally detrimental than farming cattle for instance, but we do need to modify it. Some of those modifications would come naturally with time as the industry grows and becomes more efficient, since it is still comparatively very young. However, we can incentivize businesses to be more environmentally conscious by financially supporting those that align with sustainable goals. It is important that the industry begins doing everything in its power to mitigate environmental impact, carbon footprint, disease transmission and impacts on biodiversity. Governments would ideally be making actual climate change legislation and subsidizing/encouraging research into more sustainable yet experimental forms of aquaculture. As consumers, reducing consumption as a whole would be a great place to start in our journey towards a sustainable future, as well as shifting away from animal agriculture in general. Being mindful of how we consume is important, and if we have the means then we should do so sustainably.

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