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The Interdisciplinary Study of Genetically Modified Salmon and Their Effects on the Environment and Indigenous Communities

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Abstract

This project is an interdisciplinary view of Genetically Modified Organisms (GMOs), specifically GMO salmon, through a biological, anthropological, and economic lens. The interconnection of these disciplines is shown through looking at GMO salmon and aquaculture effects on the Lummi Nation and the environment, while taking a close look at the first company to be approved for GMO salmon for human consumption that occurred in 2015 and the processes that are involved for approval of GMOs. The essay, through a biological lens, will explore the importance of salmon and their role in the ecosystem. Through an anthropological lens a discussion of the Lummi Nation, the importance of salmon in their culture and the Cooke Aquaculture Spill that took place in 2017. Economically there will be the discussion of the Food and Drug Administration approval process and the economic impacts of introducing GMO salmon onto the market. To tackle complex issues, it requires the collaboration of multiple disciplines, otherwise a cohesive solution will never be reached.

Interdisciplinary Studies:

One of the most important facets in the world of research is the collaboration between fields of study. However, it is not often implemented in the academic world. Considering that most real-world experiences concern diverse fields and interests, there should be more of a push for interdisciplinary collaboration by researchers. Interdisciplinary work allows experts in their respective fields to create a comprehensive view of a particular topic, which is essential to address modern complex issues which cannot begin to be resolved by a sole discipline. When disciplines do not collaborate, there is a gap in research and ideas where many resolutions may lie. Specifically relating to Genetically Modified Organisms (GMO's), there is a need for more collaborative research as many studies focus on only one side of the topic or the other, there is little crossover between ecological, anthropological and economic focuses when it comes to the introduction of genetically modified (GM) salmon into the marketplace. This paper will explore this concept of intersectionality of these topics by viewing the effects of GM salmon not only on the native population of salmon, but also the Native Lummi Nation Culture, and the potential economic issues that may occur due to the introduction of GM salmon into the market.

An Introduction to GMOs:

GMO's have been a widely discussed and controversial topic in public spaces, despite having been around for hundreds of years in the form of selective breeding, where humans began to pick what traits they found most valuable in an organism and bred them to be that way. An example of this is the current wheat that industries produce. Early humans selected optimal traits that made farming wheat easier or more efficient and continued to breed until undesirable traits were no longer present. This created a more ideal strain of wheat for agricultural farming and human

society. Currently, GMOs are thought of as plants with genes from other plants, but for the premise of this project the discussion will focus on salmon that have been genetically modified, mostly with other fish genes. The way that this process works is most often through microinjection, where embryos are collected after in vitro fertilization, and the chorion is penetrated with a thin glass needle that injects exogenous DNA (Wang et al, 2021). Genome editing reagents, such as CRISPR/cas9, can introduce nucleic acids into embryos by this method. This is one method of genome editing and implementation into embryos, although many other variations exist.

One of the most frequent modifications for commercial GM salmon is the introduction of a growth hormone (GH) from another fish, which broadens the range of tissues that express that GH gene (Satimehin and Olufeagba, 2015). This growth hormone allows the fish to grow faster and to reach a larger maximum size. Fish with the genetic modification affecting their growth hormones can grow up to 2-3 times larger than that of the unmodified fish, meaning that they can reach 2500 grams in 2 years instead of the normal 4 years (Sunstrom et al, 2014). The unmodified fish may reach the same size as the modified fish depending on the resources available to it, but it would take a longer time, and this has significant impacts on early development and predation, as well as consumption of nutrients in the environment. There are other modifications that can be made to GM salmon, such as the introduction of an antifreeze protein to help them adapt to different climates, or triploidy, where fish contain three sets of chromosomes as opposed to two, to make the fish genetically sterile (Satimehin and Olufeagba, 2015).

FDA approval guidelines:

The U.S. Food and Drug Administration (FDA) has historically put a lot of trust into the agricultural industry in terms of approving Genetically Engineered (GE) plants. In 1992, the FDA presumed that GE plants would be generally recognized as safe, which meant that FDA approval was not required extensively, and implicit trust was placed on these producers. When it comes to animals, the FDA has slightly different guidelines. The FDA defines an animal drug as "any drug intended for use in animals other than man" with a drug being "articles (other than food) intended to affect the structure or any function of the body of man or other animals"(FDA, 2021). By these definitions, altering the genetic material of an animal, regardless of the intended use, qualifies it as an animal drug. Animal drugs require an approved New Animal Drug Application (NADA) by the FDA, which does not consider environmental risks unless the risk is to man (Van Slyck, 2017). Despite AquaBounty being one of the first of its kind, they were not given special guidelines for the approval of GE salmon and instead were held to the standard of animal drugs. Ultimately, this leaves a lot of room for misunderstanding and error in approval. The environmental assessment (EA) for Aquadvantage was approved with the FDA finding a "no effect" impact, although it's still unclear on how this decision was ultimately reached; this ended the FDAs commitment to NEPA (Van Slyck, 2017). This rather controversial approval by the FDA sparked a lawsuit by the Center for Food Safety. In 2020, the Center for Food Safety sued the FDA for not assessing environmental risks associated with salmon escaping, where a judge ruled in favor of the Center for Food Safety and determined that the FDA is required to do an environmental impact assessment for the GM salmon escaping into wild salmon populations (*Federal court declares genetically engineered Salmon Unlawful*, 2020).

Salmon and their ecosystems:

Salmon live in both freshwater and saltwater ecosystems, starting from hatching in freshwater rivers, to migrating to oceans, to returning upriver to spawn (Fisheries, 2022). They are a keystone species, which is a species that has a drastic impact on their environment and their ecosystems food web. Without the keystone species the ecosystem would function dramatically differently or collapse entirely (National Geographic Society, 2019). While salmon are not the largest predator, or the most abundant in their ecosystems, they have a large influence over their ecosystem's food web. Salmon have been found to influence not only large predator's populations, such as bears and wolves, but also a wide variety of bird species, where salmon biomass often acts as a predictor for other species success (Field and Reynolds, 2012). With salmon playing such an important role in their ecosystems, their populations should be monitored and protected, for the overall health and stability of the ecosystem as a whole.

Salmon populations have been declining for years, with Salish Sea Chinook salmon populations having decreased by 60% since 1984 (Environmental Protection Agency, 2021). One of the initiatives to assist with this pressing issue is the implementation of salmon hatcheries, in which salmon are raised until they are not at severe risk of mortality and then released into rivers in mass amounts. However, this creates another issue for salmon populations. It creates a false sense of productivity in an ecosystem where salmon are critical, the different selective pressures being exhibited to these hatchery salmon who are protected in their early years (Stephens, 2012). Salmon raised in hatcheries, being less fit for their environment, but dominating it, is a growing problem; there's a possibility of these salmon not fulfilling the native species roles as keystone species. Humans affect wild fish stocks, which ripples into other levels of the ecosystem. When considering the raw fish counts, or the number of fish that return to spawn, the populations

appear to be doing well, but they aren't reproducing at high enough rates to replace the population that's dying off (Stephens, 2012). Releasing hatchery fish isn't a solution if they are different from native populations and aren't reproducing.

The mere presence of GM salmon does not constitute harm, but it's the interactions between the GM fish and the native species or native environment that can do harm. The largest environmental risk is GM species displacing native species. One method of aquaculture utilizes ocean pens for containment, which are not secure as the only barrier between the fish and the outside environment is a net; this allows for ocean water to flow through the open-net farms, meaning that there is a chance of escape and interactions with not only local fish population, but also other aspects of the ecosystem (Salmon Aquaculture, 2019). If GM fish were to breed with local populations, it would change the genetics of those populations, which has the potential to alter the fitness of these populations and change their behaviors that are reliant on their genes (Satimehin and Olufeagba, 2015). Alternatively, to breeding, the GM population could displace the native population entirely, resulting in the potential extinction of some salmon species (Satimehin and Olufeagba, 2015). Many have argued that the introduction of GM fish is comparable to invasive species being introduced into the wild habitats and causing harm to native populations (Devin et al., 2015). With GM salmon there is an increase in growth due to their manipulated growth hormones. An increase in growth corresponds with an increased consumption of food (Devlin et al., 2015) with this in mind we also see an increased ability to compete for food and a likely change in the balance of the food systems within the established ecosystem. During a controlled study, it was modeled that in a natural environment, we see a balance of cases where GH salmon are more advantageous or are at a disadvantage compared to the wild-type salmon, which is largely dependent on predator presence. When predators are

present, we often see the GH salmon being at a disadvantage, specifically in the early stages of their life where they hatch sooner than the wild-type. Due to this earlier hatching time, their life-style and feeding strategies encourage them to be higher up in the water column, where predators are more likely located. This concludes that there will be more direct contact with predators and the chance of a higher mortality rate (Devlin et al., 2015). Ultimately, it seems that GH salmon do the most harm when they are allowed to grow under hatchery conditions first, since there are no predators present at that stage, then in the wild, they will be larger than their native counterparts, allowing them to dominate resources.

An Introduction to the Lummi Nation

The Lummi people are the original inhibitors of Washington's northernmost coast and southern British Columbia (Lummi Nation, 2016). They are the third largest tribe in the state of Washington. The people are known as a fishing nation and even self-identify as such (Lummi Nation, 2016). The tribe was considered to be a nomadic tribe (Emtman, 2018) and salmon has always been a staple of the Lummi nation's culture and is considered sacred.

In Emtman's (2018) article Morris says, "It was our food, just like many other animals and things. They were placed here for our use." The Lummi Nation has the story of the "Salmon Woman and her Children" which is about a man who notices that his tribe is running out of food and begins to cry out in grief. As he and his people starve, he cries out while he hears a woman call out in the distance. He places the woman in a canoe and offers her his last food and water. Due to his generosity and his unwavering love for his people, the woman reveals herself as the Salmon Woman along with her children: Chinook, Coho, Sockeye, Pink, Chum and Steelhead. Together, they want to help the man and promise to help provide food for his people year-round.

This help comes as a reward for the man's selflessness and the man takes the Salmon Woman as his wife. When the man is away, his people begin to tire of the Salmon Woman and her children. Because of this, she plunges herself into the sea with her children. The people once again began to starve, but the man returned and was able to form an agreement that the people who had no respect for her would only be provided food during the fall season to teach people that she would be respected. This story is the story of the Lummi Nation and the Salmon People. (Spino, 2018)

The Lummi Nation has a celebration for the first Salmon every year. The tribe has collaborated with the Washington Department of Fish and Wildlife to try and increase the number of chinook salmon runs that were netted during the 2012 net season through the Skookum Creek Fish Hatchery (Neumeyer, 2012). The First Salmon ceremony is in honor of the first group of salmon that begin their spawning up the Nooksack River, and Juanitia Jefferson of the tribe says, "We begin anew. Sometimes it's good, sometimes it's bad, sometimes it's easy, sometimes it's hard, but we begin anew."(Neumeyer, 2012) The First Salmon ceremony is a sign of new beginnings for the Lummi Nation and the hope for a healthy salmon season to be able to sell and have funds for the future. With the presence of fewer and fewer native salmon spawning upriver there is a worry for the future of the tribe.

The Atlantic Salmon Spill and the Lummi Nation's Response

The Atlantic Salmon spill occurred in late August of 2017, which occurred in a netted enclosure near Washington's Cypress Island and released tens of thousands of non-native Atlantic Salmon into Puget Sound (SouthCoaster, 2018). The coastal tribes and the Washington state officials were not informed of the Cooke Aquaculture spill when it first occurred. Once the coastal tribes were alerted, the Lummi Nation declared a state of emergency along with many

other coastal tribes (SouthCoaster, 2018). The Lummi Nation were the most responsive and caught 43,500 of the estimated 160,000 Atlantic Salmon that had escaped from the oceanic net pens (SouthCoaster, 2018).

Some of the tribal fishermen estimated that they caught 7,000 pounds per day on their boats which included the non-native species (SouthCoaster, 2018). With the accidental release of the Atlantic Salmon the native salmon populations at risk not only due to competition, but also to diseases carried by Atlantic Salmon (SouthCoaster, 2018). This accidental release concerned much of the Lummi Nation worried because most of their income comes from the annual harvest of salmon, clams, halibut, crab and shrimp (Rosenbaum, 2018). The Lummi Nation even refused an offer by Cooke for an increase in pay per fish in agreement that the Lummi Nation would not advocate for a net-pen aquaculture ban (Rosenbaum, 2018). Ballew, a member of the Lummi Nation, said that the offer was "insulting" and the tribe called for "the ban of non-native saltwater finfish aquaculture." (Rosenbaum, 2018) This net-spill of Atlantic salmon brings into question what ecological damages have occurred and are occurring to the native population of salmon but also the ultimate damage that could occur to the Lummi Nation. All Atlantic salmon are genetically modified, which means that these salmon that are possible out in the water with native salmon populations could have a great effect not only on the culture of the Lummi Nation, but also the native salmon population itself. Not only will it have an impact on the income made by the Lummi Nation makes on the salmon that they harvest, but also on the ceremonies that are performed in honor of the salmon.

The Lummi Nation has worked tirelessly to protect the native population of salmon and have tried to protect the spawning of salmon with their hatchery (Spino, 2018). All of this work may be put into danger with the Atlantic Salmon spill, but this may not be known until those

salmon that were unable to be caught become of mature spawning age. Salmon is greatly important to the people of the Lummi Nation, as Morris puts it, “We’ve been known as ‘The Salmon People.’ That’s our livelihood. That’s our survival. That helps us survive. So our needs now–we do need the revenue that we get from fish, to buy these things for our survival.” (Emtman, 2018)

For the Lummi Nation the original use of salmon was for food especially before colonialism took over Washington State originally the Salish Sea peoples’ land. However, now salmon is used in the colonial form to exchange the salmon for the American dollar to be able to pay for food and clothing that in the past they would have made themselves or traded.

AquaAdvatage:

The demand for salmon has increased by more than 20% in the last decade. The only way to keep up with this increasing demand for salmon is aquaculture, which provides 70% of the global salmon market, or around 2.4 million metric tons of salmon (Howard, 2014). There is always research being done to see how production can grow further. One of the leading companies in fish aquaculture is AquaBounty and their Atlantic Salmon AquAdvantage, which was the first to be approved for GM salmon marketed for human consumption. The AquAdvantage salmon was found to be nutritionally the same as other non-GM salmon that were viable for human consumption, meaning that GM salmon is safe for humans (FDA, 2020). This salmon on average grew to a weight of 6,000 grams heavier than wild Atlantic Salmon (Van Slyck, 2017). The FDA was criticized extensively for their approval of this GM salmon, as Americans feel the process by which they did environmental assessments was not sufficient. AquaBounty grows these GM salmon in three facilities, one located in Ohio and two in Canada,

with another planned for Indiana (*About us*, n.d) . Notably, all of these facilities use inland pens containing female, effectively sterile fish, instead of the ocean nets; this minimizes the risk of escape into the environment (FDA, 2018). The facilities are also required to have multiple levels of physical barriers.

With the approval of AquaAdvantage genetically modified salmon, this could create a market for fish that the native Lummi Nation may not be able to compete in. Not only with a possible influx of genetically modified salmon in the market, there is the chance for net spills like the one that occurred in 2017. With the approval of AquaAdvantage genetically modified salmon, this could create a market for fish that the native Lummi Nation may not be able to compete in. Not only with a possible influx of genetically modified salmon in the market, there is the chance for net spills like the one that occurred in 2017. AquaAdvantage GM salmon are generally only sold to distributors for commercial consumption, but that doesn't mean that there never will be a case in the future where AquaAdvantage sells live salmon, in which the potential for environmental damages increases. . This then raises the ethical question of allowing genetically modified salmon into the market especially since the native populations who make most of their profit on salmon may have even more financial struggles with the lack of native salmon spawning that has been occurring. When the government does not stand up for the local people then the local people must stand up for themselves. With all of the concepts brought up in this paper, there needs to be the contemplation of the pros and cons of having genetically modified salmon or any other genetically modified organism on the market and how this can affect the local market and the people that contribute to it.

Public Impact:

One environmental impact, unrelated to GM salmon escaping into the wild, is concerns of local pollution and increased pressure on wild fish stocks that provide food sources for salmon (Smith et al. 2010). If producers have to draw from wild fish stocks to feed the GH salmon within aquaculture, then native populations of fish will be decreased at high rates given the projected output of AquAdvanatge salmon. This struggle with the FDA has not helped with public opinion. GM salmon are often nicknamed “fraken-fish” and distrusted for one reason or another by the general public. In some cases, it has to deal with the ecological impact to the environment and/or cultural impacts to indigenous communities who rely on native fish populations, in other cases people are afraid to be eating something that they are unsure of. The process of genetic modification is known by word, but not by process. The term “bioengineered” is now required on GE foods; it was determined that labeling as GMO carries too much negative connotation to be the standard (Hernandez, 2022). Information on how AquaBounty produced AquaAdvantage Salmon is unavailable to the general public and therefore are not included in their study reports, even those that are older. There was a long-time frame between the time AquaBounty started development and from when the AquaAdvantage Salmon was approved for production. More current studies are potentially unavailable at this time due to the timeframe of this type of research as well as the current COVID-19 pandemic.

Concluding Thoughts:

GMOs are not inherently harmful in their concept and are important for the continuation of scientific progression. When considering the approval of GMOs, there are some impacts that need to be considered not only ecologically or economically but also as cultural impacts. The complex issues that arise when discussing integrated topics, such as GMOs, need to be approached from multiple disciplines to create a cohesive solution. Without an interdisciplinary approach there is a very high possibility that a connection will be missed, and a group will suffer because of it. These cohesive solutions not only need to address each group's concern, but also be transparent when they occur, so that everyone is able to fully understand the potential impacts of these decisions.

Cited Work

About Us. AquaBounty. (n.d.). Retrieved March 2, 2022, from https://aquabounty.com/about-us

Amin, L., Azad, M. A., Gausmian, M. H., & Zulkifli, F. (2014). Determinants of public attitudes to genetically modified Salmon. *PLoS ONE*, *9*(1). https://doi.org/10.1371/journal.pone.0086174

Casey, C. (1993). World Vision: The Lummi Nation Thinks-And Acts-Globally. *Tribal College: Journal of American Indian Higher Education*, *5*(2). Retrieved February 9, 2022, from https://www.proquest.com/docview/231753987?accountid=15006&parentSessionId=Htf6zu2K440BhCu6WncJq2t%2FDvdI%2FWZEYR6Y%2B9%2F9Zbw%3D&pq-origsite=primo.

Devlin, R. H., Sundström, L. F., & Leggatt, R. A. (2015). Assessing ecological and evolutionary consequences of growth-accelerated genetically engineered fishes. *BioScience*, *65*(7), 685–700. https://doi.org/10.1093/biosci/biv068

Emtman, J. (2018, September 17). *Sacred Catch*. KUOW. Retrieved February 9, 2022, from https://www.kuow.org/stories/sacred-catch

Environmental Protection Agency. (2021). *Chinook Salmon*. EPA. Retrieved March 14, 2022, from https://www.epa.gov/salish-sea/chinook-salmon

FDA. (2018, September 14). *Response to public comments on the Environmental Assessment*. U.S. Food and Drug Administration. Retrieved February 9, 2022, from https://www.fda.gov/animal-veterinary/animals-intentional-genomic-alterations/aquadvantage-salmon-response-public-comments-environmental-assessment

FDA. (2020, April 15). *Aquadvantage Salmon fact sheet*. U.S. Food and Drug Administration. Retrieved February 9, 2022, from https://www.fda.gov/animal-veterinary/animals-intentional-genomic-alterations/aquadvantage-salmon-fact-sheet

Federal Court declares genetically engineered Salmon Unlawful. Center for Food Safety. (2020, November 5). Retrieved February 9, 2022, from https://www.centerforfoodsafety.org/press-releases/6186/federal-court-declares-genetically-engineered-salmon-unlawful

Field, R. D., & Reynolds, J. D. (2012). Ecological links between salmon, large carnivore predation, and scavenging birds. *Journal of Avian Biology*, *44*(1), 009–016.

https://doi.org/10.1111/j.1600-048x.2012.05601.x

Fisheries, N.O.A.A. (2022, February 25). *Atlantic salmon (protected)*. NOAA. Retrieved March 14, 2022, from https://www.fisheries.noaa.gov/species/atlantic-salmon-protected

Guernsey, P. J., Keeler, K., & Julius, J. 'J. (2021). How the Lummi Nation revealed the limits of species and habitats as conservation values in the Endangered Species Act: Healing as Indigenous Conservation. *Ethics, Policy & Environment*, *24*(3), 266–282. https://doi.org/10.1080/21550085.2021.1955605

Hernandez, J. (2022, January 5). *GMO is out, 'bioengineered' is in, as new U.S. food labeling rules take effect*. NPR. Retrieved March 13, 2022, from https://www.npr.org/2022/01/05/1070212871/usda-bioengineered-food-label-gmo

Hiruko, A. (2017, August 31). *Lummi Nation responds to Salmon Spill*. Lynden Tribune. Retrieved February 9, 2022, from https://www.lyndentribune.com/news/lummi-nation-responds-to-salmon-spill/article_944ca93e-8d89-11e7-850b-5b95b4747623.html

Howard, B. C. (2014, March 19). *Salmon farming gets leaner and Greener*. History. Retrieved March 10, 2022, from https://www.nationalgeographic.com/history/article/140319-salmon-

farming-sustainable-aquaculture

Kempe, Y. (2021, October 15). *Why did thousands of chinook salmon die this month in the Nooksack River's South Fork?*Spokesman.com. Retrieved February 9, 2022, from https://www.spokesman.com/stories/2021/oct/15/why-did-thousands-of-chinook-salmon-die-this-month/

Ladd, A. E. (2011, November 1). *Feedlots of the Sea: Movement Frames and Activist Claims in the Protest over Salmon Farming in the Pacific Northwest*. Humanity & Society. Retrieved February 9, 2022, from https://journals.sagepub.com/doi/abs/10.1177/03043754211073463

Lummi Nation. (2016). *Lummi Nation*. Retrieved February 17, 2022, from https://www.lummi-nsn.gov/userfiles/63_2016LummiAtlas.pdf

Lummi Nation fishermen catch an estimated 20,000 Atlantic salmon following fish farm collapse. (2017, August 29). *The Canadian Broadcasting Corporation*. https://link.gale.com/apps/doc/A502106819/CPI?u=wwu_wilson&sid=bookmark-CPI&xid=cf48af40

Lummi Nation Natural Resources. (2010). *Salmon enhancement*. Natural Resources | Salmon Enhancement. Retrieved February 9, 2022, from https://www.lummi-nsn.gov/Website.php?PageID=43

Mapes, L. V. (2018, May 17). *State honors Lummi Nation for its emergency response to escaped Atlantic Salmon*. The Seattle Times. Retrieved February 9, 2022, from https://www.seattletimes.com/news/state-honors-lummi-nation-for-its-emergency-response-to-escaped-atlantic-salmon/

Mesec, D. (2017, August 28). *Lummi Battle Atlantic Salmon spill*. Indian Country Today. Retrieved February 9, 2022, from https://indiancountrytoday.com/archive/lummi-battle-atlantic-salmon-spill

National Geographic Society. (2019, September 5). *Role of keystone species in an ecosystem*. National Geographic Society. Retrieved March 10, 2022, from https://www.nationalgeographic.org/article/role-keystone-species-ecosystem/12th-grade/

Neumeyer, K.Northwest Treaty Tribes. (2009, May 15). Lummi Nation Celebrates First Salmon. *The Bellingham Herald*. Retrieved February 9, 2022, from https://nwtreatytribes.org/lummi-nation-celebrates-first-salmon/.

Okamura, K. (2019). Interdisciplinarity revisited: Evidence for research impact and dynamism. *Palgrave Communications*, *5*(1). https://doi.org/10.1057/s41599-019-0352-4

Press releases: | FDA lifts import ban on genetically engineered Salmon. Center for Food Safety. (2019, March 11). Retrieved February 9, 2022, from https://www.centerforfoodsafety.org/press-releases/5536/fda-lifts-import-ban-on-genetically-engineered-salmon

Pittman, T., & Caulfield, K. (2017, August 25). *Lummi nation declares state of emergency after Salmon Spill*. king5.com. Retrieved February 9, 2022, from https://www.king5.com/article/tech/science/environment/lummi-nation-declares-state-of-emergency-after-salmon-spill/281-466942662

Rosenbaum, C. (2018, February 23). *Who cleaned up the Atlantic salmon spill? northwest tribes*. Crosscut. Retrieved February 9, 2022, from https://crosscut.com/2018/01/who-cleaned-up-the-atlantic-salmon-spill-northwest-tribes

Satimehin, F. P. D., & Olufeagba, S. O. (2015). Environmental Impact of Genetically Modified Fish – A Review. *Octa Journal of Biosciences*, *3*(1), 34–36.

Salmon Aquaculture . Georgia Strait Alliance. (2019, December 10). Retrieved March 10, 2022, from https://georgiastrait.org/issues/other-issues/salmon-aquaculture

Scigliano, E. (2020). *Washington Sea Grant Teaches the Practical Skills Needed to Preserve Sustainable Fisheries, Tribal Employment, and Coastal Communities*. Washington Sea Grant. Retrieved February 9, 2022, from https://wsg.washington.edu/better-bleeding-and-savvier-selling/

Smith, A. (2021, October 19). *Lummi Nation says 2500 Nooksack Salmon died in recent weeks*. 790 KGMI. Retrieved February 9, 2022, from https://kgmi.com/news/007700-lummi-nation-says-2500-nooksack-salmon-died-in-recent-weeks/

Smith, M. D., Asche, F., Guttormsen, A. G., & Wiener, J. B. (2010). Genetically modified salmon and full impact assessment. *Science*, *330*(6007), 1052–1053. https://doi.org/10.1126/science.1197769

Southcoaster. (2018, January 22). *Native tribes left to clean up after Cooke Aquaculture Salmon Escape in the Pacific*. Responsible Aquaculture DIGEST. Retrieved February 9, 2022, from https://responsibleaquaculture.wordpress.com/2018/01/22/native-tribes-left-to-clean-up-after-cooke-aquaculture-salmon-escape-in-the-pacific/

Spino, A. (2018, December 17). *The Salmon People*. Medium. Retrieved February 9, 2022, from https://theplanetmagazine.net/the-salmon-people-dc1839ef0157

Stephens, T. (2012, February 2). *Hatchery fish mask the decline of wild salmon populations*. UC Santa Cruz News. Retrieved March 10, 2022, from https://news.ucsc.edu/2012/02/hatchery-salmon.html

Sundström, L. F., Vandersteen, W. E., Lõhmus, M., & Devlin, R. H. (2014). Growth-enhanced coho salmon invading other salmon species populations: Effects on early survival

and growth. *Journal of Applied Ecology*, *51*(1), 82–89. https://doi.org/10.1111/1365-2664.12185

Van Slyck, K. M. (2017). Salmon with Side of Genetic Modification: The FDA's Approval of AquAdvantage Salmon and Why the Precautionary Principle Is Essential for Biotechnology Regulation. Seattle University Law Review, 41(1), 311-[ii].

Wang, Y., Hamid, N., Jia, P. P., & Pei, D. S. (2021). A comprehensive review on genetically modified fish: Key techniques, applications and future prospects. *Reviews in Aquaculture*, *13*(3), 1635–1660. https://doi.org/10.1111/raq.12538