Surviving The Salmongeddon

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Abstract

In Dillingham, and around the world, oceans are changing; due to these changes oceanic habitats are being affected. The changes could result in what we call the “salmongeddon”- the functional extinction of Alaska’s salmon. Sockeye salmon are an important staple food of Dillingham’s residents and the loss would be devastating. The Dillingham Tsunami Bowl team decided to look at the feasibility of creating an aquaponics system to provide food for Dillingham’s residents. Although aquaponics is currently frowned upon in Alaska, it would be a better route than losing the subsistence, cultural, and economic values forever. To explain the pros and cons of creating an aquaponics system, we have used a SWOT analysis. This will allow us to explore the Strengths, Weaknesses, Opportunities and Threats of the plan in an effort to develop practical recommendations. These recommendations include monitoring of water quality and subsistence numbers, use of genetically modified local salmon, and further analysis of cost.

Introduction

Since the 20th century, carbon emissions have been rising (See Figure 1). This rise in carbon emissions is affecting the oceans and causing changes. Changes include acidification, increasing sea levels, reduction in density, rising ocean temperatures, and the introduction of foreign species (EPA, 2013). The question presented is how environmental change affects aquatic species, with particular interest on the interactions of Bristol Bay salmon.

A change being observed is ocean acidification. Ocean acidification occurs when CO_2 levels in the ocean become higher than normal and the pH level of the water drops. The CO_2 combines with the water (H_2O) and forms HCO_3, also known as carbonic acid. As the carbonic acid or HCO_3 forms from the combination, the increase in acidity of the ocean causes the pH to decrease. Calcareous phytoplankton, mussels, snails, sea urchins and other marine organisms use calcium and carbonate to construct their calcium carbonate shells or skeletons (Hood et al., n.d.). For these creatures, having a shell is what keeps them alive; without it they would die. If these creatures were to die, the food supply for salmon would shrink or disappear altogether leading to starvation and therefore shrinking the population of the salmon or losing the salmon entirely. Finally, accumulation of CO_2 in the ocean could also lead to the build up of carbonic acid in the body fluids of the non-shelled organisms. This buildup of carbonic acid could lead to problems in the organisms such as lower immune response, metabolic depression, and behavioral depression. These affect physical activity, reproduction and could cause asphyxiation. The acidity is not shown to rise enough for asphyxiation so although it is the most dangerous it is one of the smallest problems (Hood et al., n.d.).

The next issue related to ocean change needing to be addressed is sea level rise, or the increase of the global mean sea level (See Figure 2). Increases in global temperatures, due to carbon emissions, are causing the melting of glaciers and thermal expansion of oceans (NOAA, 2013a). This change can cause harm to ecosystems, both marine and terrestrial, and can force many coastline communities to relocate due to receding coastlines. The rising of sea levels will most likely devastate salmon habitats and disrupt their natural migration patterns

Salmon born in fresh water migrate to the open sea once mature enough. After reaching full maturity, they travel back to their spawning point to reproduce. Shorty after securing the next generation of salmon, they die. This is because the mature salmon’s sole focus is to get to its spawning location. The returning journey is arduous and they never stop to feed, only to rest (Washington State Recreation and Conservation Office, 2012). The rising sea levels can disrupt this migration pattern by changing the habitats they live in. Estuaries may move higher upstream and terrain near water may be submerged creating new obstacles for the salmon.

The next change being observed is a reduction in ocean density. The global temperature is rising, thus causing ocean temperatures to rise. As the temperature of the ocean rises, the volume increases, thus lowering its density. These changes can affect ocean currents (NOAA, 2013b).

Density currents flow by salty (more dense) cold water descending below the warm, less salty (less dense) water. As the cold water’s salinity falls and temperatures rise, the density decreases, thus changing the currents. These currents hit the sea floor and create upwellings that send cold, nutrient rich water upwards (NOAA, 2013c). A change in density will therefore change where upwellings occur and could potentially change locations of feeding grounds for the salmon.

Along with changing densities, ocean temperatures cause a change in currents and habitats (See Figure 3). Ocean currents carry thermal energy on the global conveyor belt, a worldwide deep-ocean thermohaline current that never ends (See Figure 4). The heat carried on the belt regulates global temperatures and climates. As temperatures rise, it is possible the range of species may shift farther away from the equator towards their preferred range of ocean temperatures (Schiele, 2009).

These ocean changes can lead to the increased occurrence of invasive species. An invasive species is defined as a species alien to an environment whose presence has the potential to cause harm to the ecosystem, or to human health. Invasive organisms may be animals, plants, fungi, and even microbes. In most instances, human activity is responsible for the introduction of these alien species to new areas (Alaska Department of Fish and Game, 2013).

For example, the sea squirt *Styela clava,* a toxin-excreting benthic invertebrate, has the potential to cause harm to the salmon species of Bristol Bay (Noble & McCann, 2012).

As salmon are often found in a variety of habitats, including ones where sea squirts may flourish, the toxins produced by these squirts may affect salmon. As the ocean continues to change, additional niches may open up for invasive species. New invasive species may outcompete native organisms or destroy the habitat.

In a century, these ocean changes may create an environment under which salmon, and their food sources, can no longer survive. A lower pH dissolves shells of food sources (Hood et al., n.d.), while temperature change can cause harm because if it gets too high the salmon and their food may not be able to handle it. Finally, rise in sea levels can cause problems by shifting the salmon's fresh water habitat, possibly causing them to swim further up stream. All of these examples prove potentially deadly to salmon populations. This event has been labeled the "salmongeddon."

In addressing ocean changes, the geographic area of focus is the Nushagak Bay in the Bristol Bay region of Alaska (See Figure 5). The Nushagak Bay is an estuary and pelagic zone located on the southwest coast of Alaska. Nushagak Bay is surrounded by mountains, which decline into tundra and drainage plains closer to the ocean. Bristol Bay supports one of the largest wild salmon populations on the planet, which includes sockeye, chinook, coho, pink, and dog salmon. Nushagak Bay also supports populations of marine mammals, such as beluga, seals, and orca, as well as small benthic organisms, including starry flounder, isopods, and rainbow smelt (Radenbaugh, pers. comm.). The Bristol Bay region has an average yearly high temperature of 4.8°C and average yearly minimum temperature is -2.8°C. The region receives an average of 64.7 cm of total precipitation and 210.6 cm of snow (Western Regional Climate Center, 2013). The water of the bay tested at pH 6.9 in Sept. 2012 (Ito, et al., 2012).

Annually, Alaska produces 42% of the world's wild sockeye salmon (Trout Unlimited, 2013). Of the many regions that contribute to Alaska's salmon harvest, one of its top contributors is the Bristol Bay. In the Bristol Bay region is Dillingham, a small community consisting of about 2,300 people (U.S. Census Bureau, 2010). Many of its residents depend upon the annual income of salmon to support their financial needs; the salmon caught in the bay are a very important part of the local economy and Alaska Native traditions.

During the fishing season over 12,000 jobs are available in the area harvesting and processing Red Gold (aka sockeye salmon) (Waldrop, 2013). Dillingham, our hometown, is a major part of the industry and has depended upon salmon for hundreds of years. However, traditionally, the Native Alaskan tribes of the southwest depended on the annual salmon runs to sustain them through the winters, and to this day, residents of the region still utilize salmon as a subsistence resource. The act of gathering food through fishing is a bonding experience for families.

Plan

Our objective is not focused on solving all of the inevitable issues relating to “salmongeddon,” but rather the most important one for our town. The objective is to produce food in a sustainable way to replace subsistence fishing in the event salmon are no longer available as a main food source. Salmon are a major part of our diet; therefore the continuation of their existence as a part our culture and subsistence, is one of the main concerns.

The plan is to create a sustainable aquaponic system that contains four major parts: the fish, fish feces/waste, vegetation, and insects/food source (See Figure 6). By implementing this system, a cycle is created that can sustain salmon, Dillingham residents, and our culture.

It is proposed the salmon hatchery use genetically modified salmon since they are able to grow at faster rates than non-modified salmon and can also grow to larger sizes. An example of a genetically modified salmon would be Aqua Advantage salmon, also known as “Frankenfish,” developed by Aqua Bounty Technologies (AquaBounty, 2013). The salmon are held in a well-contained tank based on land to prevent environmental hazards, such as the possibility of an invasive species and spread of disease into the environment. The fish are managed and cared for by qualified local residents–providing jobs.

The fish produce waste, which may be discarded, or may be utilized as a resource. Instead of disposing the waste, it will be used in an aquaponic system. Aquaponic systems work in a cycle. Fish are fed, and thus produce waste. This waste is rich in ammonia. Within the system, there are microorganisms, which feed upon this waste, breaking the ammonia into nitrate. This water is then circulated to plants, where the nitrate nourishes them, and causes a higher growth rate. (Sawyer, n.d.) The plants chosen to grow are cold-weather vegetables. These vegetables could be sold to the local population and the rotten ones could be used to feed the insects, which will feed the fish. Some of the easier vegetables to grow in colder environments would be cabbage, rhubarb, chives, and broccoli. These plants remove the nitrate, as well as carbon dioxide from the system, and replace them with oxygen. The water then cycles back to the fish. Ideally, this is a perfect system, producing no waste from fish, microorganisms, or plants (Sawyer, n.d.).

Housefly maggots (*Musca domestica)* are a viable replacement for fish feed. Housefly maggots are known to have the ability to consume a very large range of organic material and convert it to protein and fat. They consist of about 50% protein and 25% fat and this makes them suitable for incorporating into fish food (Heuzé & Tran, 2013).

The production process begins by introducing adult flies to a compost area filled with organic waste. The adult flies will lay an estimate of 9,000 eggs. After hatching, the maggots will begin consuming the compost and will convert the organic waste into protein and fat. Leaving mature flies behind in the compost to lay eggs will continue this cycle. Based on multiple research produced in Nigerian catfish farms, the best ratio of housefly maggots to fish feed should be 4:1. This provides enough nutrition for the fish and is cost efficient. Feeding fish entirely housefly maggots is possible, however, it could reduce their size and their growth rate (Heuzé & Tran, 2013).

For location it was decided one of the quarries in Dillingham could be used for the holding of the salmon hatchery. It is assumed that in 100 years the quarry will be cleaned of its gravel so the hatchery could be built in that location. The quarry chosen is located about 4 miles down Aleknagik Lake Road. As of right now there is plenty of room to hold the entire operation, and the quarry is sure to grow by the time this plan would be implemented. It was decided to choose a quarry instead of where the current processing plants are located because the current plants would be submerged due to the rise in sea level.

To compare the negatives and positives of the plan, the Dillingham Tsunami Bowl team decided to use a process called SWOT analysis (See Figure 7). It allows us to weigh the pros and cons of the plan to determine the feasibility, without knowing all of the specific futuristic details. SWOT is an acronym for Strengths, Weakness, Opportunity, and Threat, organized into a simple yet efficient matrix (Manktelow and Carlson, 1996). We are using this form of analysis because it is an effective project management system with which can easily deduce the feasibility of the aquaponic system to be a sustainable food source.

Strengths

There are several potential strengths to this proposed system. This plan would provide food for the individuals within the community, as a means to replace the food currently procured through subsistence. This would reduce the need to import supplementary food supplies from external sources, potentially providing food security to the people. Food security is when individuals have the methods and ability to procure safe and nutritious food (World Health Organization, 2013). So, by growing salmon as a reliable food source, the community would no longer suffer from food insecurity, thus removing themselves from the global problem.

Another strength is that aquaponics is an environmentally neutral system, as the plants absorb the waste produced by the fish, and the plants are in turn used to supplement food for the fish. This environmentally neutral system is beneficial to the ecosystem, as it does not discharge harmful by-products into the inter-land. In addition, this is advantageous to the users of the aquaponics system, as it eliminates the need for a waste processing facility.

In addition, the preservation of salmon as a food source would help maintain the local culture. While the traditional methods of obtaining the fish would be altered, the same techniques for processing and utilizing the salmon could remain unchanged.

Because of these factors, this plan is potentially sustainable for an indefinite period of time, as long as new, fertilized salmon eggs are provided. The people of the region would be free from food insecurity, as the farmed salmon would be a reliable food source. In addition, the system poses minimal ecological threats, and allows for the preservation of Native traditions.

Weaknesses

Despite the strengths of the plan, it also has weaknesses that must be addressed. The plan will be economically challenging and difficult to start. Dillingham is a cold place, so the tanks and the greenhouse will have to be heated, becoming energy intensive.

Another weakness is the possible economic infeasibility of the project. If inflation rises too high, current estimates may no longer be applicable. Changes in prices of fish, both farmed and natural, may rise or fall and profits, if any, will be unpredictable. Initial costs will also be incredibly high. Massive tanks, water heaters, building construction, and energy costs will need to be paid for. In addition, future technology may be more expensive and make anything currently needed obsolete. These factors will play major roles if the plan is to be economical.

Not only may the plan be economically infeasible, it has never been executed before. There will be no previous information on how to fulfill the plan, or any mistakes to learn from. There may also be reasons this has never occurred, such as it may be implausible to make efficient.

Besides these other factors, the public's reaction to the farmed salmon must be considered. People here may not like the genetically altered Atlantic salmon. People will also want to consider their cultural ties to the natural salmon run every year. This may cause the plan to not have the favor of the public.

Opportunities

Based on predictions gathered from annual censuses, the human population is predicted to be somewhere between nine and eleven billion people by the next century (Ghose, 2013). As the population of the world rises, the demand for food will also rise. This is likely to raise the cost of food. If the plan to create an efficient and sustainable fish farm succeeds, it is likely it will be implemented in other places to provide cheap and reliable food. Also by creating a sustainable food source in Dillingham, residents will be more likely to stay.

Another opportunity that may arise in the future is possible improvements in renewable energy technology. Of these, tidal and hydro energy may be introduced to Dillingham creating cheaper energy cost for local residents. Using renewable energy sources will help reduce the costs running the fish farm making it a more viable source of a sustainable food production.

Aside from advancing technology, the changing environment may also prove beneficial to creating a sustainable food source. As the climate warms, certain species may migrate to Alaska possibly opening a door for new source of food for the salmon. The warm weather will provide a suitable environment to grow agriculture, providing another source of commerce.

Threats

One global threat to the plan is an increasing population in the area of Dillingham. If Dillingham were to increase in population, then it would require more resources then what are available to make the project work. Another problem with increasing population is it would become harder to supply the town with similar amounts of fish as compared to current Dillingham levels. Also, the increase in population would cause problems in the hatchery location in relation to housing developments and the potential new zoning requirements.

A second threat would be any advances in technology, which would make the salmon not as vital as they are now. For example, if in 100 years it becomes cheaper to send supplies to Dillingham, it would become much easier to buy and send the supplies then create the fish farm and farm the fish. Likewise if the barges and shipping became too expensive to send things to Dillingham, whether it is a small amount or not, the salmon hatchery would be needed as a viable food producer. However, the operating cost would increase dramatically because of the increase in the cost to ship supplies to Dillingham. Another threat with the advances in technology might be the ability to create foods that are cheap and compact- to where they do not take up much room until you hydrate them or warm them up and they have a good taste.

Finally, a large change in climate could make it difficult for this to be a feasible project. For example, if the climate were to warm up enough to where it would make it easier to plant and grow fruits and vegetables, there would be less need for large scale fish growing. Although it would still be needed because the salmon provide nutrition plants cannot give. Salmon provides Vitamin B12 and Omega 3 fatty acids, both of which are needed to be healthy. Along with its' nutritional value, is its cultural relevance. Salmon are a cultural staple food that would be missed in meals if they were no longer available.

In conclusion these ocean changes may affect Bristol Bay negatively, devastating our salmon population. This will harm our subsistence lifestyle and impact our economy greatly. In response to this a plan was created to use an aquaponic system as a replacement for local salmon. A SWOT analysis was used to determine the feasibility of the plan. SWOT analysis resulted in three main recommendations.

The first recommendation is to begin monitoring the water quality of Bristol Bay along with the yearly salmon subsistence numbers. This will be used to ensure the number of salmon caught for subsistence is not decreasing. If subsistence numbers were to drop it would be increasingly necessary to implement the plan.

The next recommendation from the SWOT analysis is to use local salmon stocks to engineer genetically altered salmon. It would marry the benefits of fast growing “Frankenfish” with the cultural traditions associated with local salmon. Genetically altered local salmon may be less controversial than imported “Frankenfish.” This would also relieve the need to procure genetically altered eggs from out of state sources.

The last recommendation resulting from the SWOT is further research into the economic feasibility of construction and operation of the aquaponic system. Due to an ever-changing economy, future costs are unpredictable. However, it is known that the plan will be expensive. Investigation into outside support and cheaper methods of building and maintaining could begin. Future technologies may also lend themselves to ease the economic burden. If these recommendations are implemented the plan may become more feasible.

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Figure 1

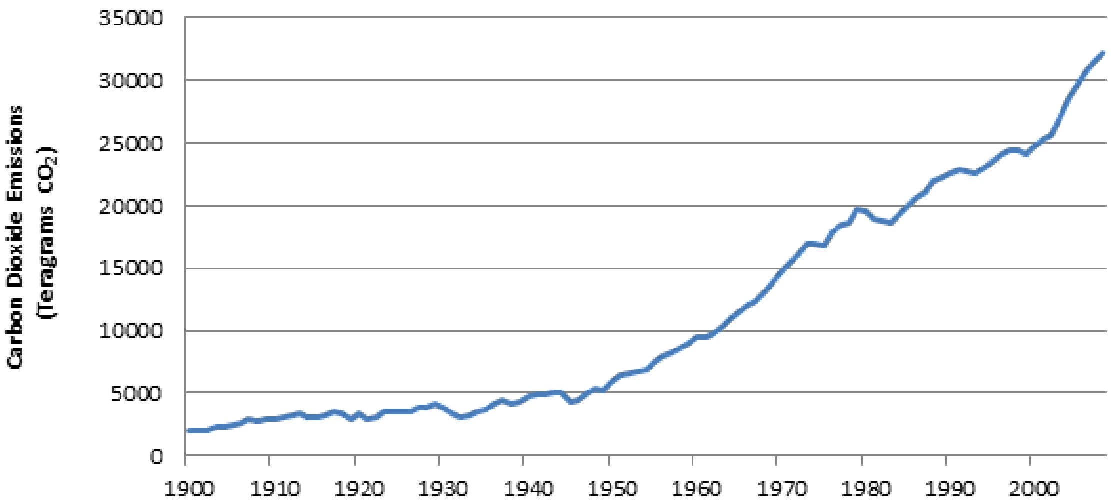

Figure 1. Rise in global CO_2 emissions in teragrams since 1900.
http://www.epa.gov/climatechange/ghgemissions/global.html

Figure 2

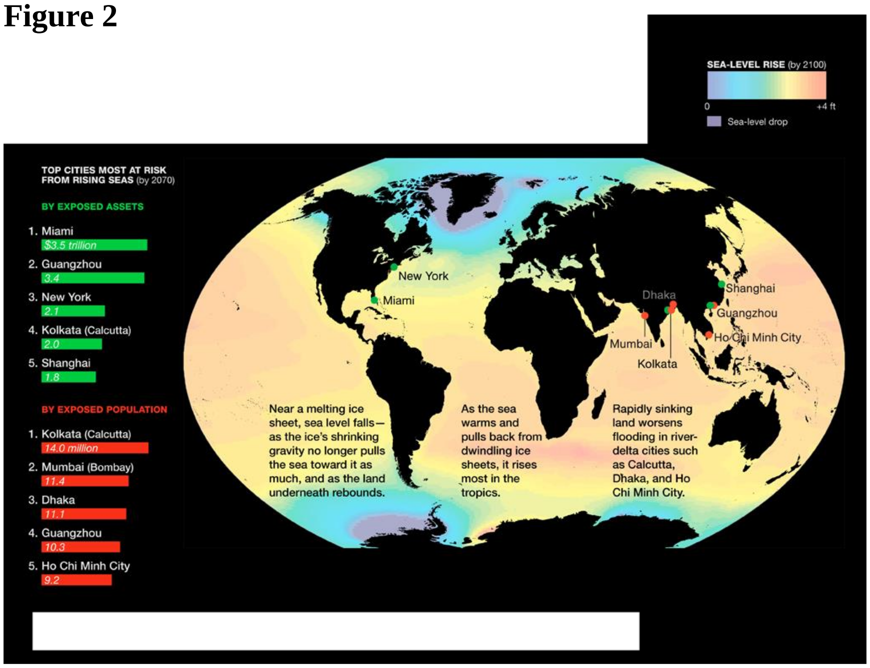

Figure 2. The global rise in sea level by the next century. Purple shading is equivalent to zero feet ranging up to red which is four or more feet.
http://www.epa.gov/climatechange/ghgemissions/global.html

Figure 3

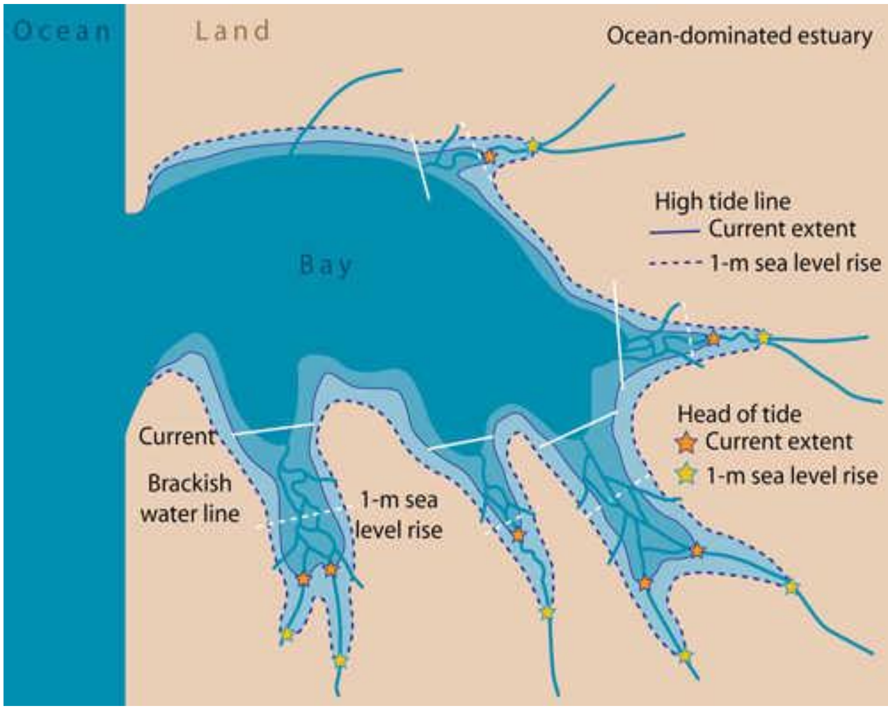

Figure 3. The ocean is rising, changing the land and river veins. The undisrupted outline of the bay is the current extent of the bay. The dotted outline of the bay is predicted 1m sea level rise. http://ngm.nationalgeographic.com/2013/09/rising-seas/uneven-impacts-map

Figure 4

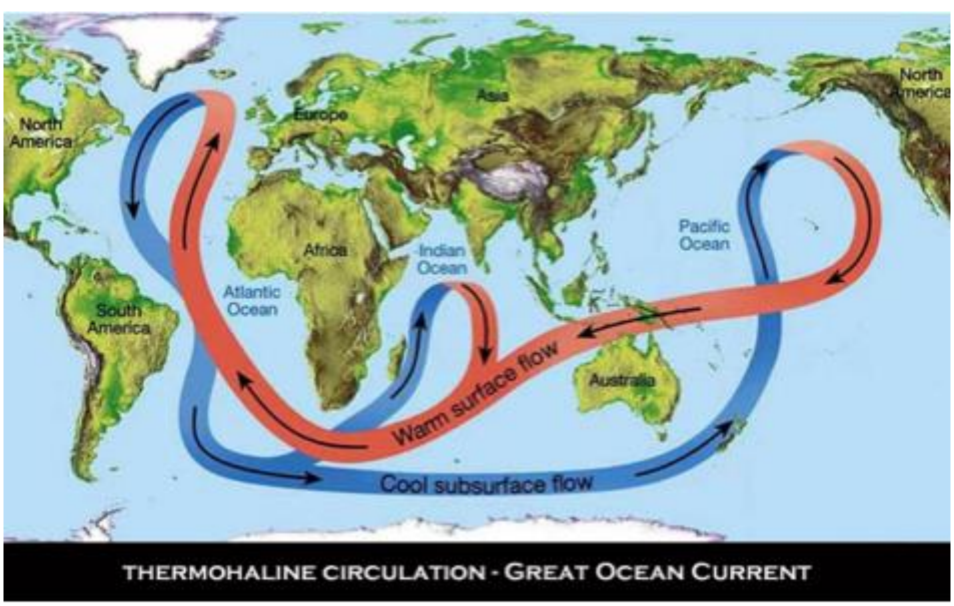

Figure 4. A map showing thermohaline circulation. Red arrows represent warm water and blue arrows represent cold water. (Schiele, 2009)

Figure 5

Figure 5. A map of the Bristol Bay Area showing Dillingham and surrounding villages. http://www.visitbristolbay.org/bbvc.

Figure 6

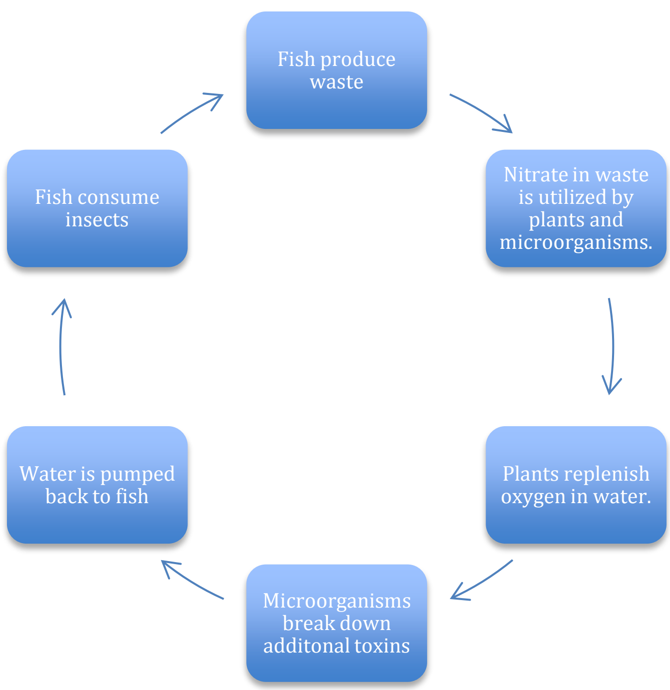

Figure 6. A flow chart showing the cycle found in an aquaponic system.

Figure 7

S (Strengths)	**W** (Weaknesses)
Sustainable Creative Progressive Environmentally safe Innovate	Costly Cooler climate Lack of experience Perception Cultural shift Unproven
O (Opportunities)	**T** (Threats)
Inventive Renewable Tech. Advancement Sustainability	Humans Supply and demand shift Economic roles change Climate change

Figure 7. A diagram illustrating the four elements of SWOT analysis