Climate Change and the Effects on the Bering Sea Pollock Fishery

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Abstract

Climate change is a crucial yet irreversible issue. With possible species range shifts occurring because of this change, a comprehensive ecosystem wide plan will need to be implemented in order to adequately adjust to these shifts. This paper investigates the impact of a decreasing pollock population due to climate change, and the effects that this will have on the Bering Sea ecosystem. Although there is a current management plan for the pollock fisheries within the Bering Sea and Aleutian Islands area, it is a year-by-year plan, species specific, and only looks at pollock fishery catch data, observer data, and survey data. In order to keep fisheries at the landing levels they are currently at, and continue to have the pollock industry as sustainable as it has been in previous years, a more sustainable plan needs to be instituted. An ecosystem-based plan would take into account many additional factors. Implementing ecosystem based fisheries management for the pollock fishery would be more effective in managing the pollock fisheries in conjunction with other fisheries in the Bering Sea, and would take into account various factors as well. Being able to take into account a changing climate will be crucial for the years to come, as a reduction in the pollock industry in Alaska would be a huge cut in revenues. Maintaining these fisheries in a changing environment should be one of the state's priorities, and implementing an ecosystem-based plan would be an effective way to do so. Due to the large changes and effects on various species due to climate change, this management plan is more sustainable for the long run in this changing, delicate environment.

BACKGROUND

Climate Change

Many things have been attributed to the increased warming of our planet in the past years. However, climate change has been largely attributed to the overuse and overproduction of machinery and goods, and the subsequent emission of fossil fuels (MacMillan, 2016). The effects of climate change have proven detrimental for many ecosystems. From melting ice caps, to rising sea levels, to ocean acidification, many effects of climate change are causing changes in environments. The negative effects that have been manifested by climate change in recent years are becoming more prevalent, causing harm to many environments, including the marine ecosystem.

One of the particular effects of climate change that is harmful to the marine ecosystem is ocean acidification. Ocean acidification is the result of the absorption of approximately 30% of the carbon dioxide from the atmosphere into the ocean (Fujita, 2013). Though this process removes some of the waste anthropogenic gas from the atmosphere, it is extremely detrimental to the majority of marine organisms. For example, organisms that form calcium carbonate shells are severely and negatively affected by ocean acidification due to the fact that the formation of their calcium carbonate shells is disrupted by the increased acidity in the ocean. However, ocean acidification is not the only result of climate change that is putting ecosystems at risk. The melting of the polar ice caps and the subsequent rising of sea levels is another detrimental effect of climate change that will change the structure of ecosystems. A switch from a benthic-dominated to a pelagic-dominated ecosystem in the Chukchi Sea and other northern seas is predicted to occur in the upcoming years. This switch will be inimical towards many benthic organisms, and will change the entire ecosystem of our arctic seas. This is one of many examples of the changes that a warmer arctic will bring, and these changes are quickly occurring.

Due to the plethora of negative effects that are manifested by climate change, the welfare of the marine environment wholly depends on what mankind does in the near future to both help resolve the issues that are causing climate change and prepare solutions to the issues resulting from climate change in our ecosystems.

<u>Pacific Ocean</u>

The Pacific Ocean, stretching from Japan to California, covers roughly 160 million square kilometers. Because it spans over numerous latitudes, it has many different average sea surface temperatures. Even so, studies have shown that the average sea surface temperature throughout all latitudes is rising. Figure 1 shows the difference between the 1971-2000 average sea surface temperature and current sea surface temperatures. Due to the significant increase in temperature, many marine organisms that are accustomed to living in colder water will likely migrate further north in reaction to these warming temperatures (Climate Change Indicators, 2016).

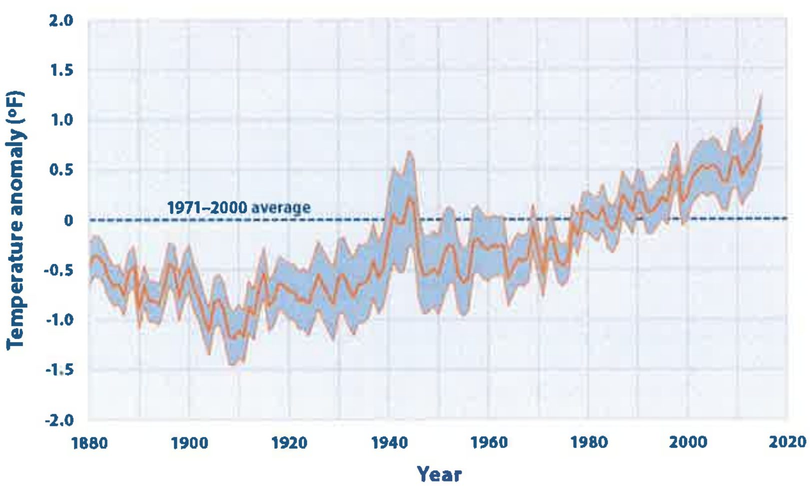

Figure 1:
Climate Change Indicators: Sea Surface Temperature. (2016, September 13). Retrieved November 19, 2016, from https://www.epa.gov/climate-indicators/climate-change-indicators-sea-surface-temperature

<u>Bering Sea</u>

The Bering Sea, located in the northernmost part of the Pacific Ocean, separates North America from Asia. It is bordered by the Kamchatka Peninsula in the west, Alaska's mainland in the east, and the Aleutian Island chain--which covers a total area of over 2 million square kilometers--in the south.

The Bering Sea has already seen numerous examples of organisms being affected by warmer waters. For example, the Total Allowable Catch, or TAC, for snow crab in the Bering Sea has decreased by 40% in the past year. Snow crab prefer colder temperatures and are known to migrate long distances to remain within the cold pools of the Bering Sea. The 2016 Eastern Bering Sea fisheries trawl survey showed low densities of crab in the southern and central ranges of the survey and high densities of snow crab in the northernmost region of the survey, further north than they are generally found. It is most likely that the snow crab population has not decreased by such a significant amount as recently decreased TACs would suggest. The location of the majority of the population in the northernmost area instead suggests that snow crab have migrated out of the range of the survey. This could possibly have led to an inaccurate population estimate, which caused commercial fisheries to suffer (Good, 2016).

The Bering Sea has supported some of the largest and most valuable commercial fisheries in the United States, as well as global fisheries, for hundreds of years. The thriving ecosystem of the Bering Sea has produced numerous successful fisheries, including everything from Pacific cod, to fur seals, to whales, to salmon, to crab, to walleye pollock. Out of all of these fisheries, the walleye pollock fishery has quickly become the most predominant. For the purposes of this paper, we will refer to this species simply as pollock. Pollock has grown to be the largest single species fishery in the world, and the commercial fishery for pollock in the Bering Sea is the most successful of any of the global pollock fisheries. However, climate change threatens the success of all of the Bering Sea's fisheries. The snow crab fishery is only one of the numerous examples that have occurred in recent years that demonstrate the deleterious effects of climate change. Ecosystems throughout the world will continue to change, and it is vital that the effects that climate change will have on various organisms are studied in order to manage our global ecosystems and resources.

Pollock

Pollock are a member of the cod family and one of the most commercially important species in the Bering Sea. Pollock mature quickly and have an average lifespan of approximately 15 years. Because of their short life span and quick development, pollock are generally more biologically productive than other fish species that have longer life spans and a slower maturation period. Most pollock begin to reproduce when they reach the age of three or four, and, since they are extremely fertile, each new generation replaces the aging or harvested population in just a few years. Pollock feed on a variety of different species throughout their life, including euphausiids, copepods, and smaller fish, all primarily within the shallow waters of the outer continental shelf. They face predation from larger fish, marine mammals, seabirds, and humans. Because of this, if the population of pollock decreases, it will largely affect both the ecosystem and the economy.

Since 1988, the pollock harvest has averaged 1.3 million tons per year, making it the largest fishery in the United States by volume and accounting for more than a third of the total U.S. fisheries landings. It is valued at more than 500 million dollars annually. Currently, there are fishery regulations in place in order to conserve the pollock spawning population. Conservation of the pollock spawning population assures that reproduction will remain successful and that the population size will remain at a healthy level. Within the Eastern Bering Sea and the Gulf of Alaska, the most recently surveyed spawning biomass of pollock is significantly above the level needed to warrant commercial fishing (Picture, 2016).

THE EFFECTS OF CLIMATE CHANGE

Impact on Pollock

The waters of Alaska provide over half of the seafood landings within the United States. Hypothetically speaking, if Alaska were a country, its rank would be ninth in terms of seafood production compared to other countries. The most remarkable aspect is its presence in global groundfish fisheries, where Alaska has one of the largest in the world. Alaska's groundfish species landings include pollock, haddock, hake, and cod, and accounted for 20% of the global groundfish harvest as of 2006 (The Seafood Industry in Alaska's Economy, 2009).

Alaska's fisheries play a very integral role within the state's economy, specifically the pollock fishery, which accounts for a large portion of Alaska's private sector economy. In addition to that, the pollock fisheries also provide thousands of jobs, including offshore and onshore processing plants. These particular jobs provide millions of dollars in tax revenue. These revenues are distributed to small villages, larger cities within Alaska, the State of Alaska, and the United States Government (The Seafood Industry in Alaska's Economy, 2009).

The effects of both climate change and ocean acidification have significant impacts for the ocean's ecosystems and the fisheries which Alaska's economy depends on, including the pollock fishery. One of these impacts is the shifting of species range, which was mentioned earlier in the example about the migration of the snow crab population. Species range shifts, often resulting in fishing ground shifts, could potentially move fish populations farther from ports, or even outside of U.S. waters. In addition, there could also be a loss of food sources and habitat for fish species that are commercially important. Warmer temperatures, which could subsequently result in a loss of food sources, will cause fish to become weak, making them more susceptible to predators and disease. Species that are adapted to colder water, like pollock, may migrate north due to warmer temperatures and a lack of food in areas that they traditionally inhabit. Although pollock may not be directly affected by ocean acidification, their food supply will. This means that the pollock population will be detrimentally affected by ocean acidification, as well an increase in sea surface temperatures (Alaska Fisheries Science Center NOAA Fisheries Service, 2010).

Impact on Food Web

Pollock play an integral role in the Bering Sea's ecosystem. They consume species like euphausiids, copepods, other types of zooplankton, and smaller fish. Many of these species prey on phytoplankton. The changing ocean temperatures directly affect phytoplankton populations, with warmer temperatures melting sea ice, resulting in increased blooms in the arctic. Currently, algae that grow on the ice drift to the sea floor, feeding benthic organisms. However, with changing arctic conditions, a reduction in sea ice will result in a reduction in ice algae and an increase in phytoplankton. As mentioned earlier, this will cause a regime shift, changing the arctic marine ecosystems from benthic dominated ecosystems, to pelagic dominated ecosystems. This shift is said to favor midwater species such as pollock, as a warmer spring favors the growth of young pollock larvae. However, a warm autumn depletes pollock's food sources, causing lower mortality rate in young pollock. This decrease in pollock will have effects throughout the food web as well. Young pollock are known to be the prime food source for young salmon (Alaska Fisheries Service, 2010). Therefore, the survival rate of salmon could decrease as well, regardless of the fact that they are also a midwater species.

Effects on Dutch Harbor

Commercial fishing within the Aleutian Islands Region generates roughly $438 million in yearly labor income for fishermen along with providing over 8,000 jobs. Due to the importance of fisheries in the Bering Sea Region, which includes the Aleutian Islands Region, the Community

Development Quota Program, or CDQ, was created. The CDQ is a program that portions ten percent of the TAC to be allocated to six non-profit corporations representing 65 communities throughout the Bering Sea Region, including Dutch Harbor (Dischner, 2013). These programs have been developed for a variety of species including pollock, crab, and halibut. Its purpose is to get villages involved in fisheries, to support the economy, to reduce poverty, and to establish maintainable jobs. Many of these jobs are located in Dutch Harbor, the main fishing and transportation hub of the Aleutian Islands. The Port of Dutch Harbor has consistently been the nation's top seafood port in terms of pounds landed, and is ranked second by value landed. In 2014 alone, Dutch Harbor landed 762 million pounds of seafood, with 87% of these landings being pollock. Because of this, Dutch Harbor plays an integral role in both Alaska's economy and the economy of the United States, and therefore greatly depends on the population of pollock. Decreases in TAC, such as those that could be caused by a decreasing pollock population, could directly affect CDQ related jobs. This means that if pollock populations decrease due to lack of survival in warmer waters, or relocate due to species range shift, then the number of jobs available in Dutch Harbor, would greatly decrease, as well as the town's economic revenue (Community Development Quota Program, 2016).

Effects on Alaska

Alaska's seafood industry is contingent on a sustainable and healthy marine ecosystem. The seafood industry within Alaska is ranked third according to importance, behind only the North Slope oil and gas industry and the federal government in terms of generating basic economic activity in Alaska (The Seafood Industry in Alaska's Economy, 2009). The seafood industry also provides employment and income opportunities for both urban and rural residents of Alaska. In 2014, Alaska's seafood industry employed approximately 60,000 workers within the state of

Alaska, with 41,200 of those being full-time equivalent, or FTE, jobs. Furthermore, as of 2006, the seafood processing in Alaska accounted for 80% out of all the manufacturing jobs in the state. The 2013/2014 average of the total economic output of Alaska's seafood industry placed this industry at $5.9 billion (Group, 2015).

Pollock plays an integral role in the State of Alaska's economy. Commercial pollock fishing creates many jobs throughout the State, both directly through the fisheries themselves and indirectly through the support industry that has developed around it. The employment of the fishing industry is greater than any other industry sector within Alaska because the seafood companies which harvest and process pollock employ thousands of people in areas which don't have any other industries (Alaska Pollock: Sustainable Seafood, 2008). Pollock is also one of the most important species in relation to monetary value (Alaska Fisheries Service, 2010). Figure 2 shows that in an average taken of the annual harvest from 1998 to 2002, pollock alone accounted for 2,872 million pounds, while the next highest species, salmon, only accounted for 747 million pounds. Furthermore, data which was collected from years 1998-2002, crab brought $191 million, salmon brought $260 million, halibut brought $127 million, and pacific cod brought $145 million, while pollock remained the top dollar fish within Alaska, bringing in $267 million (The Seafood Industry in Alaska's Economy, 2009).

Alaska Fisheries, Average Annual Harvest 1998-2002		
Species	**Million Pounds**	**Million Dollars**
Pollock	2,872	267
Salmon	747	260
Pacific Cod	555	145
Flatfish	484	37
Crab	137	191
Halibut	58	127

Figure 2: The Seafood Industry in Alaska's Economy. (2009, January). Data retrieved October 29, 2016, from http://www.marineconservationalliance.org/wpcontent/uploads/2010/06/SIAE_Jan2009_ES.pdf

If the pollock population were to decrease, this would be very detrimental for communities around Alaska. As mentioned earlier, the pollock industry employs thousands of people in areas that do not have other industries. Because of this, if the pollock industry was to drastically decrease in the future due to increased sea surface temperatures, these small communities would take a huge cut in revenues, and may even eventually cease to exist without the pollock industry there as an employment opportunity.

Effects on U.S.

Alaska's seafood industry not only has a substantial effect on Alaska's economy, but also the economy of the United States. Alaska's seafood industry alone accounts for 111,800 jobs in the United States--including seafood distribution, production, and retail change. 54,600 of those jobs are in processing, fishing, transportation, distribution, and fishery management, while the other 57,200 jobs in the seafood industry are secondary jobs, which are created as an outcome of spending by businesses in the supply chain of their employees. Nationally, Alaska's seafood industries account for over $14.6 billion in economic output.

In 2007, 62% of the volume from the commercial seafood harvested in the U.S. was from Alaska. As mentioned earlier, Alaska has one of the largest groundfish fisheries in the world, with the pollock industry being not only one of the largest, but one of the most sustainable industries in the United States. This is due to the fact that harvest levels are constantly monitored by scientists to prevent overfishing, which signifies the importance of pollock in the country's economy (Alaska Pollock: Sustainable Seafood, 2008). If pollock levels were to decrease, not only would Alaska's economy suffer losses, but the U.S. economy as well.

MANAGEMENT PLAN

Current Management Plan

The current management plan for the Bering Sea pollock fishery is currently to establish an annual TAC for each species based on species-specific data. Catch, observer, and survey data is sent to a biometrician, who applies a statistical analysis to this biological data and creates several mathematical models to predict the total biomass of the pollock population. These models are then sent to the Groundfish Plan Team, who reviews the models, offers suggestions, and decides on the best model. They then send this model to the Scientific and Statistical Committee. This committee also reviews this model, and advises the North Pacific Fishery Management Council on industry interest. The North Pacific Management Council then sets an overall TAC for the fisheries to follow based on this model. The TAC is then sent to the management entity, the National Marine Fisheries Service, a branch of NOAA. A given portion of this TAC is then allocated to individuals as individual fishing quotas (IFQ) or to community formed corporations as community development quotas (CDQ). IFQ's can be bought, sold or leased, while corporations can lease their CDQ's with existing industries. This plan has proved sustainable for Alaska fisheries under current conditions. However, considering the recent rising of sea surface temperatures, as well as species range shifts, a long-term ecosystem-based plan is needed in order to more deeply understand the effects of specific species on the ecosystem as a whole and how to preserve this pristine environment (Milani, 2016).

Proposed Management Plan

Due to the fact that climate change will not only affect the pollock population, but rather the entire Bering Sea ecosystem as a whole, we believe that in order to account for this ecosystem-wide change, an ecosystem-wide management plan is vital for the fishery industries to implement. The idea of Ecosystem-Based Fisheries Management, or EBFM, takes into account climate, habitat, and predation in order to come up with a management plan for a specific fishery. EBFM was introduced to fisheries management in the 1990's, but hasn't been widely implemented by managers of various fisheries. This is largely due to many myths surrounding the plan, and the notion that implementing a plan that accounts for the entire ecosystem is too complex and too information-intensive. However, EBFM should be seen as more of a framework for fisheries to help managers work with the information they have to effectively address their specific objectives--in our case, the pollock fisheries. In other words, EBFM should be set as a guideline so that pollock fisheries understand and account for the entire ecosystem as a whole when deciding the TAC. If such a plan is put in place for the pollock fishery in the Bering Sea, we would be able to more accurately assess the impact that commercial fishing for pollock has on the entire ecosystem.

The National Oceanic Atmospheric Association, or NOAA, recognizes six main steps needed to implement EBFM for a commercial fishery. If we follow this model, the first step would be to implement ecosystem-level planning. This would occur between the entities that normally calculate and create the TAC model for pollock; however, instead of creating the TAC simply by looking at catch data, observer data, and survey data, these entities would be looking at the entire ecosystem, and begin to look at where they want the ecosystem to be in X number of years. The second step would occur largely at the same time as the first step. The entities would look at climate, currents, sea ice levels, as well as numerous other factors in order to create a greater understanding of how the ecosystem functions as a whole. Assessing risks and vulnerabilities, the third step in the plan, would include considering vessel traffic, commercial fishing industries, bycatch, climate change, and other factors. Looking at these risks and vulnerabilities would also explore trade-offs, the fifth step in the six-step plan. The final thing that these entities would do at this meeting would be to incorporate these ecosystem considerations into management advice. They would need to take into consideration the things that they had just discussed and include this information in other management advice that has been given from other fisheries managers. The sixth and final step happens later, which is maintaining ecosystem resilience and social well-being. Keeping the marine ecosystem in good condition is vital due to its economic impact on Alaska and the rest of the United States. Reassessing this plan on a yearly basis will be crucial in order to keep the plan functioning at an optimal level.

CONCLUSION

Overall, climate change is a crucial yet irreversible issue. With possible species range shifts occurring because of this change, a comprehensive ecosystem wide plan will need to be implemented in order to adequately adjust to these shifts. Although there is a current management plan for the pollock fisheries within the Bering Sea and Aleutian Islands area, it is a year-by-year plan, species specific, and only looks at pollock fishery catch data, observer data, and survey data. In order to keep fisheries at the landing levels they are currently at, and continue to have the pollock industry as sustainable as it has been in previous years, a more sustainable plan needs to be instituted. An ecosystem-based plan would take into account many additional factors. Implementing EBFM for the pollock fishery would be more effective in managing the pollock fisheries in conjunction with other fisheries in the Bering Sea, and would take into account various factors as well. Being able to take into account a changing climate will be crucial for the years to come, as a reduction in the pollock industry in Alaska would be a huge cut in revenues. Maintaining these fisheries in a changing environment should be one of the state's priorities, and implementing EBFM would be an effective way to do so. Due to the large changes and effects on species due to climate change, this management plan is more sustainable for the long run in this changing, delicate environment.

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