Ocean Acidification Effects on the Oceanic Ecosystem around Dutch Harbor

Team: Imagine Dragonfish

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Abstract:

In the waters we rely on for sea food: such as King Crab (*Lithodidae*), Pollock (*Pollachius*), and pteropods (*Limacina*), there are many things seeking to harm, or kill these animals. What if I told you there was a silent killer on the loose, that's getting away with doing just that. This killer's name is carbon dioxide, also known as CO_2. Carbon dioxide is slipping into the water, and lowering the pH levels. Animals that rely on the pH levels in the ocean are not able to properly form their shells. This is their protection from predators, as well as chemicals. If these animals don't have their shells it will make it harder for them to survive in their natural habitat. In the near future the CO_2 levels are expected to rise, and if this happens the crab will be affected greatly, and our fisheries and ports will become an up-and-coming past-time. This will result in many fishermen losing their jobs, and sea food industry will crash. It's apparent that we need to implement solutions to this problem so that we can have healthier bodies of water, and plentiful sea food today and in the future.

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Introduction:

Ocean acidification is becoming more and more of a problem as the decades goes by. This economic issue is becoming prevalent as the ocean keeps storing more carbon dioxide from the pollutants humans release in the air as well the ocean has manufactured naturally. The CO_2 levels are raising from gas that we expel and fossil fuels we burned. The carbon dioxide levels have continued to raise as more people drive rather than walk. These levels keep rising, the risks for organisms living in the oceans that have a shell for protection. The carbon dioxide enlarges the bivalves by dissolving and eating away the shells which they rely on for protection from predators.

Ocean acidification is greatly affecting the environment and entities of Dutch Harbor, Alaska. Dutch Harbor has a major King crab fishing population along with other marine organisms that Alaska's economy and ecosystems depend on. If the King crab and other marine animals that Alaska needs are diminishing, Alaska loses a major profit center. The Sea Butterfly is another example of an organism that is undergoing an attack by carbon dioxide. The Sea Butterfly may seem to be an organism that is irrelevant to maintaining a healthy ecosystem, but this creature is important in the food chain. This animal is the basic food for many marine based organisms, including the pink salmon which the humans feed on. If the Sea Butterfly's population begins to die, the main food for the salmon would decrease, which in turn would decrease the pink salmon population. Pollock is an important fish in the Alaskan diet. Not only is it an important food source for the Pollock's fellow marine inhabitants. An adult may already be suited to either low or high concentrations of CO_2, but Pollock in early development stages such as just produced or still in the egg, could suffer a large by ocean acidification. Depending on the level exposed, the larvae or egg will react differently.

One of the main ways they react to being exposed is that their bodies are shorter than they should be out of the egg. The higher the CO_2 levels exposed to, the longer it will take them to reach maturity. Since the growth rate will take longer, there is more of a chance in being eaten by plankton-eating fish. This process will then decrease the potential number of Pollock in the wild.

Within Dutch Harbor, Alaska, as well as in Avacha Bay, Russia, these three species, along with thousands more are being affected. The following paper will discuss and illuminate in detail the wide problem of ocean acidification and what it does to the chosen marine organisms. Finally a management plan to aid in the reduction of carbon dioxide in the waters of our world will be proposed for consideration.

Physical Description:

Located on the Aleutian Islands, there is a small port and military base called Dutch Harbor. Surrounding it, are the Kulluk Bay, Unalaska Bay, and the Bering Sea. The nearest town is called Unalaska, and is connected by a bridge. Dutch Harbor's unique location and history causes fishermen to be drawn to it. That makes it key place for fishing in the Bering Sea. (Harriman Retraced Expedition, 2001) This is why Dutch Harbor is the number one port in the United States. Because the Japanese bombed Dutch Harbor, there is now a military base there. (June Allen, 2002) Nobody goes to Dutch Harbor to have a good time. Working and drinking are the only things to do there. In fact their bar is one of the most violent bars in America. It's a small town with a population of about 4,000 people. A flight to the nearest city, Anchorage, is about 800 miles and $1,000. The main body of water they fish in is the Bering Sea. Fishermen here are just starting to realize that ocean acidification may be a real problem. CO_2

emissions in the Bering Sea could, someday in the near future, cost them their jobs. The Bering Sea is being affected by CO_2 emissions in the water. This is affecting our crab, Pollock, sea butterfly, and other sea creatures that rely on their shells for living. We need to realize that everything happening in the ocean is going to loop around to us. If these animals don't get the vitamins they need to produce their shells, where will all these fishermen go? How will they get a living? The answer is simple. They'll have to either adapt to change, or relocate. This means less work for them and less crab for us. This would be a shame, because Dutch Harbor truly is a beautiful location for fishing, and a wonderful place for sea animals to thrive. In an island of Russia, south of Petropavlovsk- Kamchatsky, west of the Bering Sea, and east of the Sea of Okhotsk there lies Avacha bay. The population of Petropavlovsk- Kamchatsky, a town around Avacha Bay, is about 180,000 people. (United Nations Statistics Division, 2013) This city is known as "the city of fire and ice": because of its volcanoes, geysers, and long icy winters. This, of course, is a safety hazard, but the beauty makes up for the fact that every time you look at the volcano you could be staring at the face of danger. After all, it is still an active volcano. Who knows when it will erupt next? This town used to not be open to the public, and was just a military zone. It's no wonder that when that rule collapsed outsiders started pouring in, like mosquitoes in a camper.

Although pollutions in Avacha Bay are prevalent, most of it comes from solid wastes, radionuclide, and spills. Because of the submarines in Avacha Bay the most popular of these pollutions is the radionuclide. CO_2 is a much unknown source of pollution at this point. Obviously, they have other pollution problems to take care of. This point aside, CO_2 is still affecting this area in ways that they are not currently aware

of. We should be warned that CO_2 is in every body of water, and although it might not matter now, the numbers are expected to rise. Avacha Bay is also a cause of pollution to other bodies of water. This could affect more than we know. Avacha bay is a beautiful place, but after all the pollution they are adding to the water it might make their view a little more tragic in the near future.

Carbon Dioxide:

Carbon dioxide is the proper name for CO_2.Carbon dioxide is a naturally occurring chemical compound, composed of two oxygen atoms; carbon and oxygen. CO_2 comes from burning fossil fuels, which produces 87% of human carbon dioxide emissions. (Andreas Merkl, 2013) The three types of fossil fuels most used are coal, natural gas, and oil. When carbon dioxide appears in the air, it evaporates from the ground and waters. After that it turns into precipitation, but as it falls, it gathers pollutants from the air, becoming acid rain. Since this reaction is made, it contains calcium carbonate and H2O (H2CO3: carbonic acid). Calcium carbonate and pH saturation lowers the pH level. The pH level for water is 7, which is neutral. But when it is lowered (rainwater has a pH of 5.7) it becomes very acidic. Carbon dioxide controls the amount of water vapor in the atmosphere.

Most scientists agree that increased carbon dioxide (CO_2) in the atmosphere resulting from the burning of fossil fuels is causing global warming. Scientists have found that CO_2 is the gas that sets the temperature for the earth. The oceans absorb 22 million tons of carbon dioxide every day, writes Richard Feely, a scientist with the National Oceanic and Atmospheric. Approximately 93 percent of the CO_2 is found in the oceans. (Christopher L. Sabine, 2007) So if there would be too much CO_2, the global

warming would lead the marine life to extinction. Acid is very hazardous for this life to continue living. Too much acidity in the ocean makes it hard for fish to survive.

The right pH level is different for every fish. In fact there is a wide variety of various pH levels that fish live in. This is because different marine life is located in different areas for example in deep or shallow water, in cold or warmer water, and in big or small bodies of water. The pH level can affect many things such as growth, coloration, and breeding. The pH level of water is usually around 8.1. When we look at the fish, Pollock, their eggs are dissolving, because of the pollutants (acids). If the water is too acidic the fish eggs won't even hatch. It may seem that only one species is being affected but in reality it goes far more than just one species. It is like a chain or cycle. When one species is having difficulties surviving its predator's population will decrease and so will another species and so on. CO_2 also kills off plants in the sea; the different classes of fish won't have enough food to live. This makes it almost impossible for all animals to survive.

CO_2 is a compound that has pros and cons. When we look at the pros we see that CO_2 is needed for photosynthesis to occur. Photosynthesis converts a great quantity of sunlight into energy. The outcome of photosynthesis is carbohydrates which humans need in their diet and oxygen that we need to sustain life. The cons of CO_2 are that breathing it in is toxic and marine life is at risk. The animals in the ocean all struggle when there is too much CO_2 in the ocean. The ocean has become 30 percent more acidic since the Industrial Revolution. We should at least attempt and save the ocean and marine life. (Govindjee and Rajni Govindjee N.D.)

Biological Effects:

The biological effect of ocean acidification is a serious concern to the marine animals in Alaska. As the need for energy increases worldwide the biological effects on our marine animals will continue to be effected. The research indicates that the oceans global PH levels have deceased and the effect on the delicate ecosystem is already being affected.

Walleye Pollock (*Teragra chalcogramma*) can reach three feet in length and weigh thirteen pounds. (Figure 1) (NOOA, 2010) They have a lifespan of twenty two years and their range extends over much of the Northern Pacific Ocean. The Walleye Pollock's skin coloration is dark brown with dark spots on the top of their body and white on the underside. The diet of a Walleye Pollock changes throughout its life. Initially, they feed on krill and zooplankton; however when they reach maturity they become opportunistic feeders eating crustaceans, small fish and even cannibalism is not uncommon.

The Walleye Pollock is at risk due to ocean acidification. High carbon dioxide (CO2) levels interfere with the Walleye Pollock ability to smell out their prey. It can also affect hearing, sight and the ability to make decisions. High CO2 levels even confuse the fish to the extent that they can swim into a predator's path.

The King Crab (*Paralithodes camtschaticus*) is a large species of crab weighing up to 24 pounds, with a carapace length reaching 11 inches and legs that can span 5 feet in length. (Figure 2) They have a life span of 30 years and their range extends from the Arctic Circle to Japan. It takes about 8 years for a King Crab to mature to a harvestable size. The exoskeleton of a king crab is dark reddish brown color. King

Crab larvae eat zooplankton and phytoplankton until the mature and their diet changes to mollusks, sea stars, and scavenging. (ADF&G, 2013)

The embryos and larva of the King Crab are initially affected by the acidified water with a decreased yolk but an overall increased embryo size. The juveniles are not able to form their shell and have a higher death rate. When the ocean becomes more acidic the mature king crabs shell becomes softer, they have a slower growth rate and higher mortality rates. After molting, it takes the King Crab's shell longer to harden, leaving the crab vulnerable to being eaten by predators. Studies show that king crabs were able to maintain their calcification rates but use more energy.

Sea Butterfly (*Limacine helicina*) is a shelled pteropod mollusk that is an important keystone species of the polar ecosystem. A keystone species is a species of animal that other species depend on. They are about the size of an eraser head (5-13 mm) and have a transparent shell with light purple internal structure and propel its self with wing like fins. (Figure 3) The life cycle can span from 1-2 years depending on water conditions. Sea Butterflies are eaten by organisms as big as whales and as tiny a krill making it a key stone species. The Sea Butterfly is also a primary food source for Juvenal salmon. They feed on zooplankton and phytoplankton and are adapted to living in the open ocean. (EOL, N.D)

The Sea Butterfly, in all probability is one of the first victims of Ocean Acidification. The main affects to the Sea Butterfly is its ability to build and maintain their calcium carbonate shell. Depending on the level of acidification the Sea Butterfly must devote more of its energy to sustain its shell than to other area crucial to its life.

Eventually, the shell will weaken and dissolve killing the animal. Weaker shells make the Sea Butterfly more vulnerable to disease and predation. The decline of this animal would dramatically affect the marine food chain.

Economy:

Alaska continues being the major profit for King crab. About 911.3 million pounds of king crab go through Alaska every year, from Dutch Harbor. (Laine Welch, 2003) For the 16th year in a row Dutch Harbor, ranked as the nation's top fishing port, with 752 million pounds crossing the docks last year. Their value is $214 million. The retail value of the Alaska king crab season is worth more than $400 million. This is representing a major source of economic activity for the North West's sea food industry. In 2012, 393 million pounds of king crab landed, and the profit of king crab dropped, because of salmon, halibut, and cod. A man said: "A small business man in a big ocean with big bills, I need to go fishing." This man was explaining that they are selling crab not for the amount as it took them to get it.

This could be because of the CO_2 dissolving the eggs of the marine animals. When it is hard for the marine animals to survive, it's hard for the fisherman to get the correct amount of money to live off of. Most of the money the fishermen earn goes to finding more crabs in the ocean, which is hard to do when most of the eggs of the marine life are dissolved. They get paid very little for the long time they work. A lot of fishermen have a hard time actually finding the crab, because of CO_2, and the pollution that comes with it. The fishermen won't be earning the same amount of money as they used to, especially in rough seasons like the winter, because the waters are in ice. It is

already difficult for the fishermen to pay their taxes furthermore the crab eggs are having a difficult time surviving.

Although when it is a fantastic season, the fishermen get $100 million, because the crab's price is $3.90 a pound. A young crewman who works 40 hours a week earns about $8,500 just enough to pay off his back taxes, from the last season.

To fix this major problem, we decided that a buoy is needed to collect the CO_2 from the ocean. On average, a buoy costs about $300,000. The price of a pool filter is roughly $3,000. There is not a CO_2 filter created for the ocean yet, but it's not difficult to create.

The History of Ocean Acidification

Since humans started burning fossil fuels the oceans of the world have gradually become more acidic. Ocean acidification is a direct result of the escalating levels of carbon dioxide in the atmosphere. Our oceans will absorb most of the carbon dioxide from the burning of fossil fuels and modern farming methods the outcome will be devastating to our marine environment.

Before the Industrial Revolution atmospheric conditions had remained relatively unchanged for 10,000 years. Scientist estimate that the concentrations of carbon dioxide in the atmosphere were 280 parts per million. (Dr. William C.G. Burns, 2008) In Britain in the mid 1700's manufacturing methods changing from manual labor to machine production and the need for more power ensued. Mass production of materials leads to new environmental hazards and the effects on our planet would be staggering. (Admin in Environment, 2012)

Fossil fuel burning factories were invented to manage the manufacturing needs of the growing demand. Wood was quickly replaced by coal to power the new factories due to deforestation in England.(Eric McLamb,2010) Coal was abundant and provided more energy than other alternatives available at the time. It wasn't until the late 1800's that oil began to be used on a large scale basic due to the invention of the automobile. In the 1900's natural gas began being used in place of coal as a cleaner burning option.

Another change during this time was the explosion of the world's population. In the mid 1700's there were approximately 700 million people in the world. That number would grow to 1 billion in 1800's and continue to grow expediential until our current number of 7 billion people. This population boom has taken its toll on the planet and especially our oceans. Twenty two million tons of carbon dioxide enters the atmosphere daily because of cars and power plants that combined with the planets current population of 7 billion people has caused the oceans to be in a hazardous position. This number will grow even more when it is forced to sustain humanity. What is happening now is the pH levels of the oceans are approaching 400 parts per million and the levels are accelerating our oceans decline. Oceans are in peril and it is because of the incursion of carbon dioxide that has been produced by humans since the beginning of the Industrial Revolution. Since the middle of the 1700s the acidity of the oceans has increased by 30%.

Compare/Contrast

Dutch Harbor, Alaska has done a few things to conjure up ways to try to prevent further infiltration of CO_2 levels in the ocean. There have been teams of scientist who have ventured to Dutch Harbor to perform tests on the waters. A team that did this

journey was The USGS Arctic Ocean Acidification Team. This team was on a boat called The Healy which they took out on their cruise to collect their data which they will send to Seattle then to St. Petersburg, Florida, for analyses. (Arctic Scientist, 2011) The University of Fairbanks has a researcher that came up with an idea of having buoys placed into the water to test ocean acidification levels far out into the cold water. One of these buoys was placed right outside of Dutch Harbor in the Bering Sea. The researcher's Assistant professor of chemical oceanography Jeremy Mathis said that other moorings have contained ocean acidification sensors but he had said that this way of censoring was the first dedicated to testing ocean acidification. (Alaska Newspapers Staff, 2013) These buoys cost about $300,000, fully loaded, to be put into the water. Jeremy Mathis, chemical oceanographer and director of Ocean Acidification Research Center at UAF, and his team will initiate ordering and building the equipment.(Laine Welch, 2013) The buoys are to monitor where the stakeholders and fisheries along with being able to answer some of the ecosystem systems that we all have questions on. The OA research center will be able to contact the fishermen and vessels for the buoys distributions and upkeep as well as accumulating water samples to increase the ocean chemistry data base.

Russia is one of several countries that implement these following laws: (i) increase understanding and improve quantification of the organismal and ecosystem responses to ocean acidification; (ii) include the human aspect by increasing alliance and amalgamation efforts between natural and social sciences; (iii) rationalize, improve and focus monitoring and data gathering, management, handling and accessibility efforts; (iv) increase diffusion, outreach and capacity-building efforts, in particular

correlated to communicating ocean acidification to stakeholders; and (v) improve synchronization of ocean acidification research and partnership both at the national and international levels.(European Science Foundation, 2009)

Russia and Dutch Harbor, Alaska both have laws or actions they are taking to try to limit or stop ocean acidification from turning some marine mammals to extinction. They have started taking these actions and they shall continue to use them until the oceans are back to their safe amount of ocean acidification.

Future Effects of Ocean Acidification:

Over the next century the potential effects of ocean acidification could devastate the global oceanic environment. The immediate impact of ocean acidification is a decrease in the oceans global pH levels. Because of this reduction in pH calcium carbonate which is vital to the construction of the shells and exoskeletons of many marine species is not as available. This causes the shells of mollusks and corals to dissolve leaving them venerable to predators and exposure. One of the species that are on the front lines of being affected by ocean acidification is the pteropods. Pteropods are one of the keystone species necessary for a successful ocean ecosystem. Negative changes to a keystone species will damage the whole food web from the smallest creatures to the largest in the ocean. Scientists worldwide are monitoring, testing, and modeling what affects acidification will have on the pteropods and the composition of the ocean. While some species are affected in a negative way like the pteropods others may flourish.

As time goes on the acidity of the of the world's ocean will increase to the point that it could cause the quaternary mass extinction similar to what occurred during at the climax of the Permian 252 million years ago.

Scientists have been studying coral reefs in the volcanic waters off the shores of Papua New Guinea, where naturally high amounts of carbon dioxide occur around fissures. The results indicate high amounts of brown algae and sea grass replacing the coral reefs. This project simulated what the effects of ocean acidification will have on the oceans in 60 to 80 years if carbon dioxide levels aren't reduced. All of humanity will be eventually affected by ocean acidification. Whether it is caused by loss of careers due to the crashed fishing industry, or the loss of tourist revenue from affected areas everyone will be affected by ocean acidification if changes are not made worldwide. Scientist are investigating how marine species are responding to ocean acidification and how this will affect the marine ecosystem.

Management Plan

In order to condense CO_2 pollution, we are going to implement CO_2 filters, near Dutch Harbor, in the Bering Sea. This will lower the CO_2 in the water, therefore raising the pH. Some animals, however, depend on CO_2 in the water, so our goal isn't to diminish the CO_2, but to lower it to levels suited for the animals in jeopardy. This will greatly benefit the fishermen in places like Dutch Harbor who, wretchedly, are just discovering that CO_2 is a problem. It's also imperative that we raise awareness in areas that depend strongly on the imperiled waters, such as Dutch Harbor. Although the levels of CO_2 are not high enough to be noticed, in a couple of years we'll be singing a different tune. CO_2 rates in the water are expected to upsurge, and need to be

measured before they grow too large. This is where our idea comes in.

Phase One: Be Aware

The first thing we should do before we start to solve the problem is make it a bigger problem. This sounds senseless, I know, but allow me to clarify. What I mean is, make the problem larger is to make it well-known. If we start to make this transformation, and we put the buoys in the water and nobody knows that they have a purpose, are we really making an alteration? In order to make a difference we need people to discourse about it. Advertise the problem as well as the resolution. We can call it "Operation Save the Sea Shells." We can do this through adds, documentaries, news, posters, etc. How we publicize doesn't matter, but that we do it is just as significant as taking action. What if everybody knew about CO_2 contaminating the ocean? I'm not saying that's an attainable goal, but envision the difference. If people care, the problems already half solved.

Phase Two: The Other Half

This is the phase for action. No more waiting. When the time is right and CO_2 is, in some places, common knowledge, that's when we attack. Maybe attack is the wrong word. It's more like implement our plan for saving a contaminated area of water. The water will actually start to be conserved when the buoys are placed in the proper proximity from each other. That's when the healing procedure begins. Little by little this area of water will start to become less polluted, and a better place for animals to flourish. This will take some time, but CO_2 filters are a rational way to approach the problem.

The Details

CO_2 filters are presently just a way to remove carbonation from drinks and carbon dioxide from the air. They are not yet created for water purifying purposes. Not seeing this as a problem, we plan to disrupt that barrier easily during the first phase. When we get the word out, we can have prototypes made by people who comprehend that line of business. Instead of pretending we have the awareness, we can find people that do, and learn from them. One of our main concerns, however, is getting power to the filter. As of now, we are not sure whether this is an obstruction to worry about, or if it's easier than what we're giving it recognition for. For this matter, it's best to roll with the punches. As for other apprehensions, we are not positive on the distance that they need to be placed apart for this to work effectively, or how powerful the filters are. Once we have a model, this information will be assembled. Most of the things we aren't sure about are just a matter of waiting. We can't know everything without having a product to base it off of. What we do know however is that the CO_2 filter will be stowed in the lower proximity of a buoy, and the filter will take in a certain amount of water at a time, while the same quantity is exiting. This enterprise is much like the water filters we connect to our sinks. Water goes in dirty, and comes out pure. We aren't concerned about the animals getting indignant, because buoys don't immensely affect the life in the water. There will be a couple holes in the buoy that water goes through, but we will make it fish-friendly by putting a protection unit over it so that nothing but the polluted waters can get through. The size of the filters will be about the size of a pool filter, although an altered design, it's about the same notion.

To Conclude

The places that count on the ocean the most, don't appreciate that the waters could initially be at risk. This is not something we should be proud of, or mortified of, but something to be addressed and dealt with properly, and abruptly. This is a statement, not just to ocean-lovers, but to everyone who will listen. Hearing and understanding are two completely different things. We need to recognize the pros and cons not just hear the words and disregard them. If we continue to pollute the waters we could drive out animals that rely so greatly on the pH levels. This does affect you and those around you no matter where you are, who you are, or if you choose to ignore it. How can you help us produce a cleaner world?

Conclusion

Ocean acidification is a problem happening now in our waters. This tragedy will continue to spread worldwide and carry on abolishing our ecosystem which we rely on greatly in our way of life. This abomination needs to stop. This is why we had come up with our buoy filter system to help restore the natural balance of water and the natural amount of CO_2 that was already being produced before humans starting building machines to pollute the water in the first place. This filter will help with lowering the CO_2 levels in by taking in the acidified waters in one way and coming out uncontaminated fresh water the other way. Without the human made carbon dioxide in the water, the ocean will continue to produce the needed carbon dioxide for the marine organisms that do rely on it to continue with their life cycle. With this system, we can be on our means to safer oceans.

Figures:

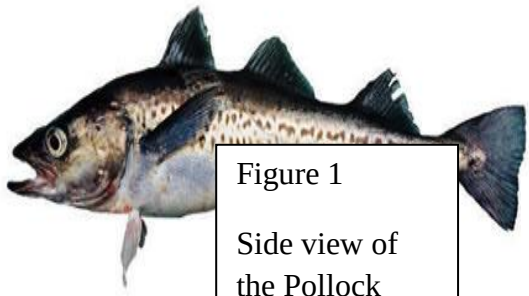

Figure 1

Side view of the Pollock

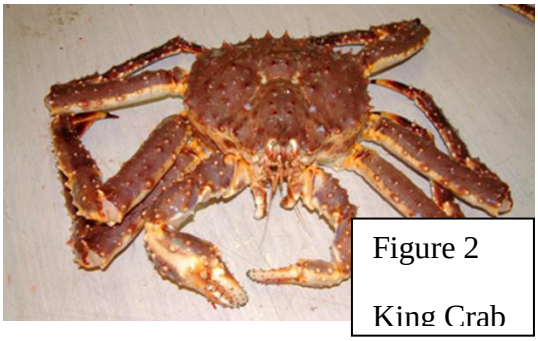

Figure 2

King Crab

Figure 3

Sea Butterfly

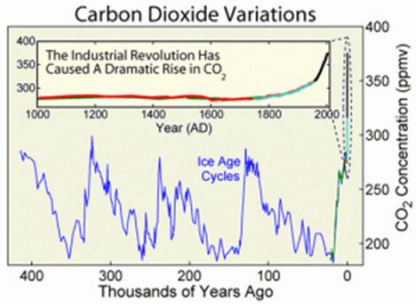

Figure 4

Carbon Dioxide increase since the Industrial Revolution.

Source: Global Warming Art Project

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