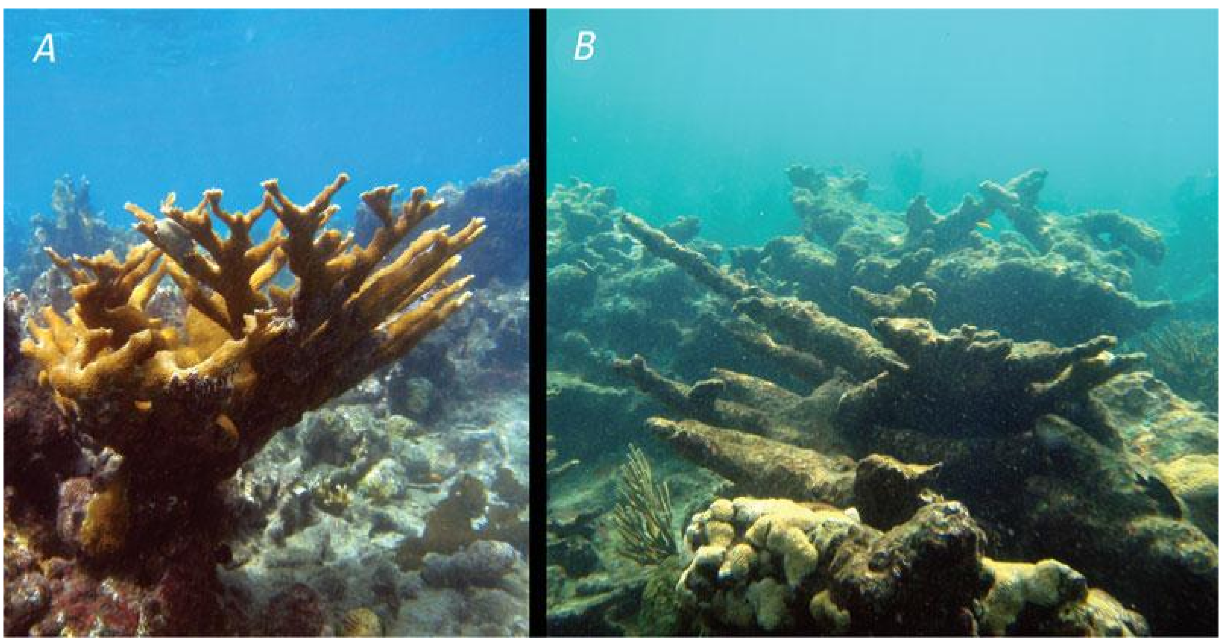
Ocean Acidification in the Eastern Pacific:

The role of the Government of Washington

March 2017

Healthy Vs Dead Coral (a)



Justification:

The urgency to prevent ocean acidification worldwide is multiplied for Washington State for two reasons. First, the coastal waters of Northwest America far exceed the average global acidity. Second, the worldwide influence of the United States means Washington State can set a precedent for other US states and international nations to follow.

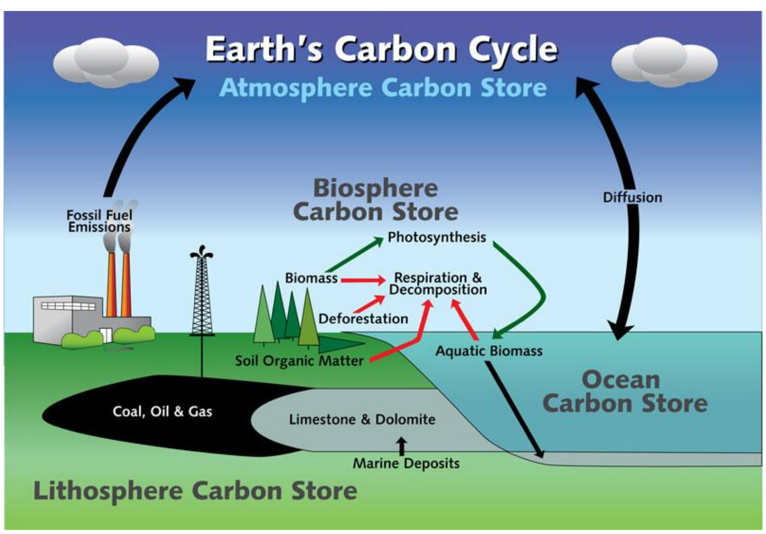
Executive Summary

Ocean Acidification has only recently gained worldwide recognition as a challenge to human's ability to operate on earth. Having said this, it is a very potent threat (1). Oceans act as a 'carbon sink', absorbing naturally occurring atmospheric carbon dioxide (CO2), but since pre-industrial times the increasing amounts of atmospheric CO2 generated by human activity have forced the oceans to absorb an excess of it (2). This excess of CO2 results in the seawater becoming more acidic (3) which causes numerous problems to marine life, particularly along the Northwest coast of America (4). The consequences include corrosion of coral and shellfish (5) and disease expression (6) as well as indirect effects on tourism and local economic stability. To prevent further ocean acidification, immediate action is required. Three recommendations are proposed: Reduce anthropogenic CO2 emissions, invest in research and experimentation, and raise public awareness.

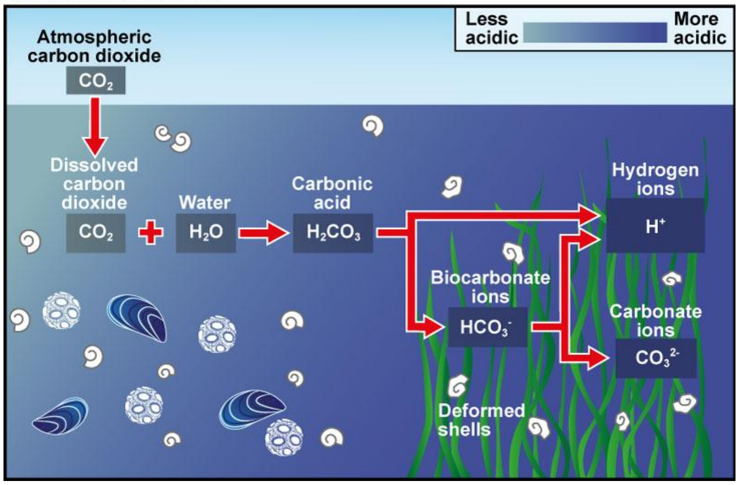
Empirical Analysis

The global ocean has absorbed roughly a third of anthropogenic carbon emitted over the industrial period (7). It has acted as a 'carbon sink', limiting increases in atmospheric CO2 concentrations through its role in the carbon cycle, demonstrated in the diagram below.

The Carbon Cycle (b)



The process of ocean acidification (c)



However, human activities such as burning fossil fuels and deforestation have caused an increase in atmospheric CO2 of nearly 40%, from preindustrial levels of approximately 280 ppmv (parts per million volume) to nearly 384 ppmv in 2007 (8). Moreover, such anthropogenic CO2 emissions are largely irreversible in the future (9). As a result, since 1980 the ocean has been forced to absorb increasing levels of CO2, leading to 'ocean acidification' (2).

As the diagram above shows, ocean acidification occurs when CO2 dissolves in seawater to produce aqueous CO2 and carbonic acid. The carbonic acid splits into bicarbonate ions and then in turn, carbonate ions. This also creates protons, which lower the pH of the solution, i.e. the water becomes more acidic (3). As a result, the pH of surface ocean waters has fallen by 0.1 (pH units) since the industrial revolution, representing roughly a 30% rise in acidity (10). If carbon emissions continue as they are, surface ocean waters could become almost 150% more acidic by the end of the 21st Century (10).

KEY TERMS

UPWELLING: Winds blowing across the ocean surface push water away. Water then rises from beneath the surface to replace the water that was pushed away. (11)

SUPER-SATURATED: Currently, the surface ocean is super-saturated with respect to both calcite and aragonite, but under-saturated below a depth called the 'saturation horizon' where calcium carbonate dissolves. (12)

The ocean absorption of anthropogenic CO_2 is not evenly distributed spatially (13) or temporally (14). The California Current System (CCS) is a Pacific Ocean current extending from the North Pacific Current along the West coast of North America to off Baja California, Mexico (15). In the CCS, alongshore wind forces the surface water away from the coast which causes the upwelling of nutrient-rich, high acidity water (16). This natural process is increasingly become a severe problem as atmospheric CO2 further lowers the pH of the surface waters. At present, most surface ocean waters (up to 200m) are supersaturated with regards to aragonite (17). Yet in the CCS by 2050, only the top 50m will be supersaturated in the nearshore regions (18).

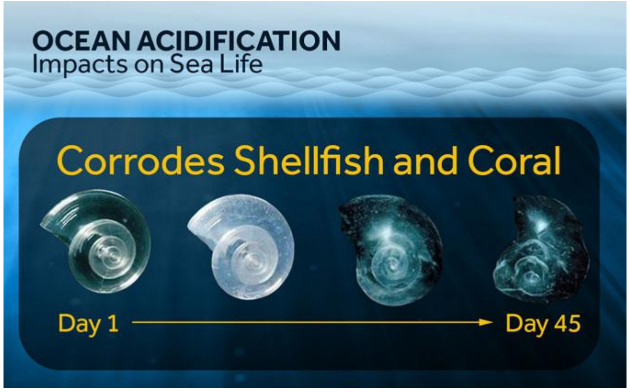
One of the worst affected areas is Puget Sound; an inlet of the Pacific Ocean along the border of Washington. Researchers discovered that values of dissolved CO2 in Puget Sound are more than 650 parts per million (19), far exceeding the 400 parts per million threshold that Earth's atmosphere crossed in 2014. Atmospheric CO2 increases from burning fossil fuels can be blamed for 13 to 22 percent of the unusual acidity in Puget Sound, which has only been worsened because of the CCS (19).

Assessment/Analysis of Evidence

Ocean acidification is becoming an increasingly important aspect of the planetary boundaries, within which humanity can operate safely (7). Given that Northwest US coastal waters are among the most acidic in the world (4), both the local and global consequences of ocean acidification must be treated with urgency.

On a global scale, decreasing ocean pH affects ocean life because all organisms must expend metabolic energy to maintain a particular pH inside of their cells to ensure biochemical processes operate efficiently (20). Moreover, the formation of shells by calcification is essential for many organisms, including molluscs, corals, echinoderms, foraminifera and calcareous algae (20). When acidification reduces the carbonate saturation of the water, calcification becomes harder and any structures that have been formed are weakened (20). This means the affected organisms must either adapt to the changing seawater chemistry, shift their distributions to more carbonate ion–rich regions, or be adversely impacted (5). Decreasing pH is also linked to enhanced disease expression, particularly for shellfish, corals and fish (6). In Washington State, it has led to the re-emergence of Vibrio tubiashii, a pathogen toxic to oyster larvae (6).

How acidification affects shellfish and coral (d)



'Acidification impacts processes so fundamental to the overall structure and function of marine ecosystems that any significant changes could have far-reaching consequences for the oceans of the future and the millions of people that depend on its food and other resources for their livelihoods.' (5:p.184)

On a local scale, increasing temperatures in local waters such as Puget Sound can lead to an increasing presence of harmful blooms of algae, of which the toxicity is worsened by acidification, and which can lead to paralytic shellfish poisoning (4). Furthermore, research on a rocky reef community in the Eastern Pacific found a correlation between an eight-year decrease in pH and a decrease in the abundance of calcifying species (21). It is important to resolve this urgently as coral reefs support up to 25% of marine biodiversity and provide sources of income, food, and coastal protection for more than 100 countries around the world, despite covering less than 1% of the ocean floor (22).

Ocean acidification also has profound impacts on coastal communities, both economically and socially. Since 1990 the global marine fish catch has averaged 80-85 million tons annually and has provided livelihoods for over 500 million people (23). If the marine food web continues to decline, it will have a devastating impact before the end of the Century. Tourism is fundamental to many coastal communities and is another livelihood which will be disrupted by continued acidification. For example, paralytic shellfish poisoning in Puget Sound may cause beach closures due to health concerns (4).

The current rate in acidity change is about 50 times faster than any known historical change, making it difficult for marine life to adapt (24). The pH of surface ocean waters has already fallen by 0.1 units (4), but continued CO_2 emissions may drive the fall in pH to 0.3 or 0.4 units by the end of this Century (25). The potential annual value of lost ecosystem services is estimated as US $21 Trillion, by 2100 (26). It is therefore of paramount importance that the international community acts immediately.

Conclusion and Recommendations

There are a variety of methods to reduce and control ocean acidification. The Washington State government has the opportunity not only to deal with local issues by preventing further acidification in its coastal waters, but also to address the issue on a global scale by acting as a successful example for other states and nations to follow. To achieve this, the following three policy recommendations must be actualized immediately.

1. **Reduce CO_2 emissions**
   Anthropogenic emissions are a major cause of acidification (21), yet they are directly preventable through human action. Ocean acidification adds to the myriad threats posed by climate change to life on earth (21), however the two planetary boundaries (ocean acidification and climate change) are intimately linked (27). The proposed boundary for ocean acidification is to maintain oceanic aragonite saturation state at 80% or higher of average global pre-industrial surface levels. (1). This figure currently stands at 84% of the pre-industrial value (28) but the boundary would not be transgressed if the climate change boundary of 350 ppm CO_2 were to be respected (27). Following the Paris Agreement, Washington State government must continue to work alongside national governments and the global community, to reduce CO_2 emissions. This should involve the Department of Natural Resources increasing their protection of Washington State's 11 forests. This should also involve encouraging the national government to force transitions to renewable energy sources before 2030, in line with Sustainable Development Goal 7: Affordable and Clean Energy. This should involve using stringent market based policies, such as taxing fossil fuels and offering subsidies for low-emission technologies, as well as promoting public transport and cycling or walking. Increasing taxes on gasoline and making public transport more attractive modes of transport both proved very effective in Germany (29). In 2010, Germany had a 40-50% more fuel-efficient vehicle fleet and a greater share of trips by foot, bicycle, and public transport (42 % vs. 14 %), compared to the US who did not employ such policies (29).

2. **Research**

The researching and monitoring of the acidification process must be accelerated. Data is limited at present and solutions to highly specific challenges can only be created with the relevant scientific knowledge. This may also enable the evolution of methods for dealing with the consequences of ocean acidification that we cannot prevent. The state government should engage federal agencies like NOAA and NSF to work alongside them.

As stated by the Washington Shellfish Initiative: Blue Ribbon Panel on Ocean Acidification (6), the state government should focus on four main strategies. Firstly, understanding acidification trends in Washington's marine waters. Second, quantifying the acidifying influences. Third, understanding the biological responses of local species. And finally, it is imperative to make short-term forecasts and long-term predictions of global and local acidification effects. Without research and monitoring, we would not be so aware of the causes and consequences of ocean acidification (30). Careful monitoring of ocean pH for over 30 years led scientists to recognize the extreme shift in acidity in 2003 as the ocean absorbed an excess of CO_2 (30). Since then, biological studies have already discovered the effects of acidification on a huge variety of marine life, though there is still much to be understood (30).

3. **Awareness**

Raising public awareness of the causes and consequences of ocean acidification will be instrumental in the fight to prevent it. The state government must work alongside businesses, national governments and international organizations (e.g. United Nations) to educate and engage as many people as possible. To be successful, the power of social media to help generate tangible action from citizens should be exploited, as well as using events, poster campaigns, websites, documentaries and visits to schools and workplaces (31). The State government should also consider offering recognition or financial award schemes for businesses who contribute significantly to reducing CO_2 emissions and preventing ocean acidification. If citizens are engaged alongside governments and international organizations, the devastating consequences of ocean acidification can be prevented.

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