CENTER for BIOLOGICAL DIVERSITY
Because life is good.

August 15, 2007

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Re: Request to Add Washington Oceans to the 303(d) List of Impaired Waters Due to Carbon Dioxide Pollution and Ocean Acidification and Revise Current Water Quality Standards for pH

Dear Susan Braley,

The Center for Biological Diversity respectfully requests that the Washington Department of Ecology include all coastal water segments on the list of impaired waters pursuant to section 303(d) of the Clean Water Act. These waters are impaired due to decreases in pH resulting from anthropogenic carbon dioxide emissions. The Center seeks to have the narrative data included with this letter considered during the next Water Quality Assessment cycle.

In addition, the Center for Biological Diversity requests that the Department of Ecology revise the current marine water quality criteria for pH to reflect the latest scientific information, which indicates that even pH levels just 0.2 units lower than the current ocean pH would have significant negative consequences for marine ecosystems.

I. Introduction

Washington is committed to addressing the impacts of climate change. The state recognizes the dramatic impacts of global warming and has pledged significant resources toward combating the climate change. Most of the impacts of climate change are identified with an increase in the greenhouse gas content in the atmosphere. Yet, a significant threat that remains unaddressed is the acidification of our oceans due to carbon dioxide.

Approximately half of the carbon dioxide emitted from fossil fuel burning over the past 200 years has been absorbed by the oceans. The absorption of carbon dioxide by the oceans is altering the basic chemistry of seawater, rendering the oceans more acidic. Anthropogenic emissions have already lowered average ocean pH by 0.11 units, with a pH change of 0.5 units projected by the end of the century under current emission trajectories.

The primary known impact of ocean acidification is to impair the process of calcification, by which animals such as mollusks and corals build shells and skeletons. Other calcifying organisms, such as many species of phytoplankton and zooplankton, will also be harmed by ocean acidification as acidic waters dissolve their protective structures or inhibit growth. These species represent fundamental components of the marine food web. Absent significant reductions in anthropogenic carbon dioxide emissions, ocean acidification will accelerate, ultimately leading to the collapse of oceanic food webs and catastrophic impacts on the oceans, and by extension the global environment.

The ocean waters of Washington are a major source of biological diversity, productivity, and social and economic activity. Protection of these waters is of the highest interests of the state and its citizens. Ocean acidification is impairing the water quality of Washington's ocean waters and the beneficial uses of these waters. This is evidence that the current regulations have failed to maintain water quality. Thus, the coastal waters must be listed on Washington's 303(d) List.

II. Clean Water Act Background

The goal of the Clean Water Act is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." 33 U.S.C. § 1251. According to the Supreme Court "[T]he Act does not stop at controlling the 'addition' of pollutants,' but deals with 'pollution' generally…which Congress defined to mean 'the manmade or man-induced alteration of the chemical, physical, biological, and radiological integrity of water.'" *S.D. Warren v. Maine Bd. Of Envt'l Protection*, 126 S.Ct. 1843, 1852-53 (2006).

Under the Clean Water Act, all polluting discharge into waters is prohibited except where allowed by permit. Each state must establish water quality standards that take into account the water's "use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes." 33 U.S.C. § 1313(c)(2). Furthermore, section 303(d) of the Act protects water quality by establishing a list of water bodies that do not meet water quality standards. 33 U.S.C. § 1313(d). Once a water body is listed as impaired, the agency must also promulgate Total Maximal Daily Loads (TMDLs) of pollutants to protect the water quality. The states that choose to take stewardship over their waters must obtain 303(d) List approval from the EPA. If the EPA does not approve the state's 303(d) list and associated TMDLs, it must promulgate a replacement. 33 U.S.C. § 1313(d)(2).

One of the conventional pollutants recognized under the Clean Water Act is pH. 33 U.S.C. § 1314(a)(3). Consequently, an unacceptable change in pH constitutes a basis for inclusion in the 303(d) List.

III. Ocean Acidification Science

Carbon dioxide absorbed from the atmosphere is polluting ocean waters. Carbon dioxide is readily exchanged between the atmosphere and the sea surface. The result of increased carbon dioxide is a decrease in pH. This in turns impairs the ability of calcifying organisms to form shells and has detrimental effects on metabolic function in other marine animals. The decline in calcifying organisms has effects throughout the food web.

The oceans have already taken up about 50% of the carbon dioxide that humans have produced since the industrial revolution, and this has lowered the average ocean pH by 0.11 units

(Sabine 2004). Although this number sounds small, it represents a significant change in acidity. The ocean takes up about 22 million tons of carbon dioxide each day (Feely 2006). While preindustrial levels of atmospheric carbon dioxide hovered around 280 ppm (Orr 2005), they have now increased to 380 ppm; if current trends continue they will increase another 50% by 2030 (Turley 2006). These rising carbon dioxide levels are irreversible on human timescales (Kleypas 2006). Over time, the ocean will absorb up to 90% of anthropogenic carbon dioxide released into the atmosphere (Kleypas 2006).

Present day levels of atmospheric carbon dioxide are the higher than they have been for at least 420,000 years, and likely for over 20 million of years. (Royal Society 2005). Historically, carbon dioxide levels increased relatively slowly, allowing marine ecosystems time to adapt. In stark contrast, the current rate of rise in atmospheric carbon dioxide is an unprecedented 100 times faster than any other rise in the last hundreds of thousands of years (Ruttimann 2006). Unlike future climate change, the pH change in response increased atmospheric carbon dioxide is relatively easy to predict because it involves basic chemical reactions and is unlikely to be affected by global temperature change (McNeil 2006). Thus, there is a strong consensus in the field that the oceans will undergo extensive acidification as the atmospheric carbon dioxide concentration rises.

Studies have established that anthropogenic carbon dioxide is the direct cause of the decrease in ocean pH. For instance, a tracer technique can be used to separate naturally occurring and dissolved carbon from that due to human activity (Gruber 1996). Oceans absorb carbon dioxide more slowly than humans are currently releasing it. Current levels of anthropogenic carbon dioxide have virtually guaranteed that ocean pH will decrease by more than 0.2 units in the foreseeable future. If action is not taken until those changes occur, it will be too late to effectively address the problem.

Although much of the air-sea exchange of carbon dioxide occurs in open water, a recent report underscored the potentially massive impacts on coastal waters (Kleypas 2006). Shallow waters are affected before deeper waters. These areas constitute only 7% of the ocean's surface and yet support up to 30% of marine production. A model based on "business as usual" carbon dioxide emissions scenarios predicts that calcification could decrease by 40% by 2100, and that calcium carbonate would dissolve faster than it could be produced by 2150 (Andersson 2006).

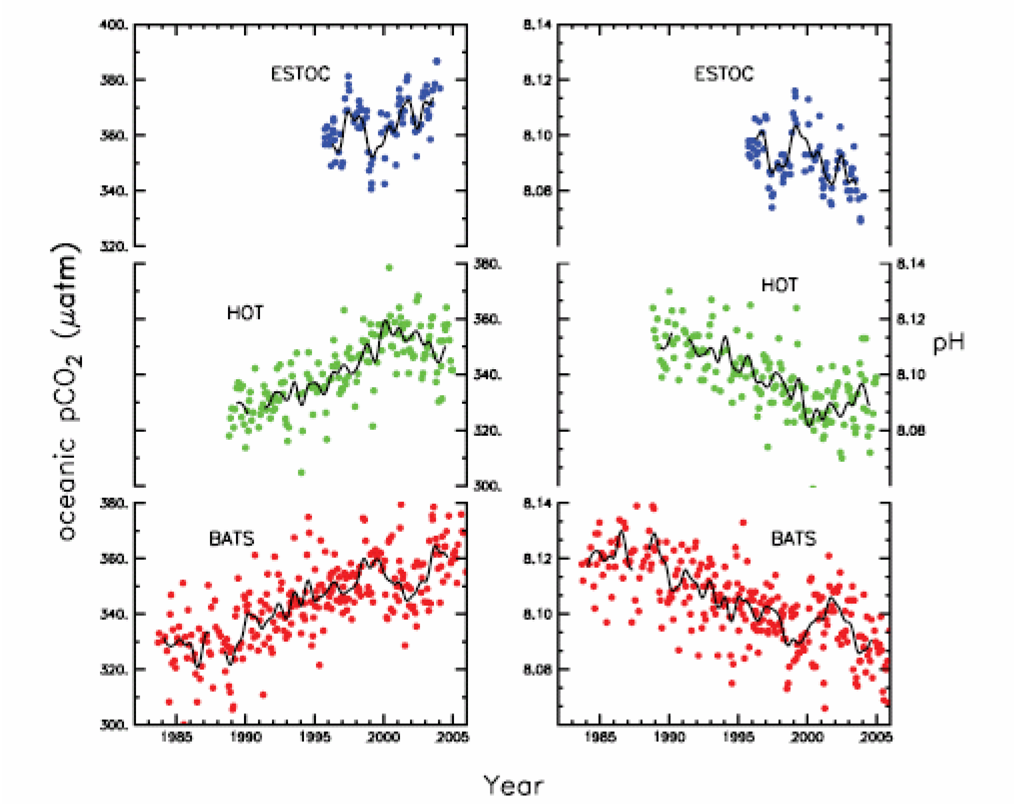
A. Carbon dioxide is changing seawater chemistry

The carbonate system is the ocean's buffer. The three dominant forms of carbon dioxide in the ocean are: aqueous carbon dioxide, bicarbonate, and carbonate. True carbonic acid is also present in small quantities. The ocean pH increases as the concentration of carbonate increases and decreases, or becomes more acidic, as the concentrations of bicarbonate and carbon dioxide/carbonic acid increase.

Carbon dioxide that is absorbed by seawater reacts to form carbonic acid, which dissociates to form bicarbonate and releases hydrogen ions. This reaction reduces the amount of carbonate ions and decreases pH. Carbonate is an important constituent of seawater because many organisms form their shells and skeletons by complexing calcium and carbonate. Calcium carbonate is present in the ocean in two common forms, calcite and aragonite.

The ocean acidification that has already occurred, a decline of 0.l1 pH, represents a 30% increase in the concentration of hydrogen ions (Royal Society 2005), and a decrease in the carbonate concentration of 10% (Orr 2005). At present, the effects are greatest in surface waters (< 1000 m) where carbon dioxide exchange occurs with the air, but the decline in aragonite and calcite saturation will extend throughout the water column in some areas by 2100 (Orr 2005). This is important because calcifying organisms form their shells from calcium carbonate, and can not do so when carbonate is not available to complex with calcium. The loss of these organisms has catastrophic implications for the entire food web.

Washington's coastal waters are directly impacted by anthropogenic carbon dioxide. Carbon dioxide absorption varies across locations depending on various factors. The coastal oceans of the North Pacific between 8° and 55° north absorb, on average, 0.2 g C/m^2/yr (Chavez 2007). The Pacific Ocean as a whole has absorbed 44 Pg C, or 41% of total ocean absorption, since the Industrial Revolution (Sabine 2004). Thus, the coastal waters of Washington are a zone of concern for ocean acidification.



From *IPCC Working Group I 2007 Report, Chapter 5*: Changes in surface oceanic $p\mathrm{CO}_2$ (left; in µatm) and pH (right) from three time series stations: Blue: European Station for Time-series in the Ocean (ESTOC, 29°N, 15°W; Gonzalez-Dávila et al., 2003); green: Hawaii Ocean Time-Series (HOT, 23°N, 158°W; Dore et al., 2003); red: Bermuda Atlantic Time-series Study (BATS, 31/32°N, 64°W; Bates et al., 2002; Gruber et al., 2002). Values of $p\mathrm{CO}_2$ and pH were calculated from DIC and alkalinity at HOT and BATS; pH was directly measured at ESTOC and $p\mathrm{CO}_2$ was calculated from pH and alkalinity. The mean seasonal cycle was removed from all data. The thick black line is smoothed and does not contain variability less than 0.5 years period.

B. Carbon dioxide is harming the aquatic ecosystem at many levels

Scientists agree that carbon dioxide pollution is causing ocean acidification with adverse impacts on many marine organisms. Available evidence suggests that the consequences of anthropogenic carbon dioxide accumulation have already begun in surface waters (Pörtner 2005).

One of the most alarming effects of ocean acidification is the impact on the availability of carbonate for calcifying organisms such as mollusks, crustaceans, echinoderms, corals, calcareous algae, foraminifera and some phytoplankton. Nearly all marine species that build shells or skeletons from calcium carbonate that have been studied have shown deterioration when exposed to increasing carbon dioxide levels in seawater (Feely 2006). Estimates suggest that calcification rates will decrease up to 50% by the end of the century (Ruttimann 2006). Snails, sea urchins, starfish, lobster, crabs, oysters, clams, mussels, and scallops all build shells that are vulnerable to ocean acidification. Other marine species may experience physiological effects from acidification including lowered immune response, metabolic decline, and reproductive and respiratory problems (Feely 2006).

1. Ocean acidification threatens calcifying planktonic organisms

Plankton, which play a fundamental role in the marine ecosystem, are threatened by ocean acidification. Carbon dioxide uptake by the ocean causes impaired growth and development for calcifying plankton, and acidification dissolves the protective armor of some plankton. Coccolithophorids, pteropods, and foraminifera are the dominant calcifying planktonic organisms and provide an essential role in marine production.

Coccolithophorids are one of the most important calcite producers and studies show that carbon dioxide in seawater reduces calcification of coccolithophorids (Reibesell 2000). Coccolithophorids are one-celled marine plants in the upper layers of the ocean that bloom in large numbers like many phytoplankton. Phytoplankton, such as coccolithophorids, contribute much of the organic material entering the marine food chain and are responsible for about 50% of the earth's primary production (Royal Society 2005). Coccolithophorids have calcium carbonate structures surrounding them called coccoliths. Studies of coccolithophorids showed that carbon dioxide related changes to seawater caused reduced calcification, malformed coccoliths, and incomplete coccospheres (Riebesell 2000). These phytoplankton not only provide food for other marine organisms but they also influence the global environment by reflecting light from the ocean.

Another example of plankton at risk from ocean acidification are pteropods. Pteropods form their shells from aragonite. Experiments show that the shells of pteropods dissolve as seawater becomes undersaturated with aragonite (Orr 2005). If carbon dioxide pollution continues unabated then large areas of the ocean, especially at higher latitudes, will become undersaturated with aragonite by 2050 (Orr 2005). Krill, whales, salmon, and other fish eat pteropods, and they contribute significantly to marine production. Ocean acidification impedes the calcification of pteropods and even dissolves their protective shells. Not only are pteropods at risk, but also the many organisms that depend on them for food.

Foraminifera, also an important planktonic calcifier, experiences reduced shell mass when exposed to elevated carbon dioxide (Kleypas 2006). There is a strong reduction in foraminifera calcification that corresponds to pH decreases (Royal Society 2005).

2. *Large calcifying organisms exhibit reduced calcification due to ocean acidification*

Larger calcifying animals such as corals, crustaceans, echinoderms, and mollusks are also threatened by ocean acidification. These important members of marine ecosystems are vulnerable to ocean acidification because, like calcifying plankton, they are experiencing reduced calcification and erosion of their protective shells.

Experiments revealed that moderate increases in atmospheric carbon dioxide had significant effects on the survival and growth of sea urchins and snails (Shirayama 2005). These adverse effects on echinoderms and gastropods are alarming because they mimicked long-term exposure to carbon dioxide levels that are likely to be reached within decades (Shirayama 2005). Echinoderms are especially sensitive to ocean acidification because lower pH inhibits the formation of their skeletons which depend on highly soluble calcite precursors (Royal Society 2005, Shirayama 2004). At a pH change of 0.3 units, echinoderms are significantly impacted (Shirayama 2004). Crustacea also are especially vulnerable to sea chemistry changes during molting (Royal Society 2005).

Juvenile calcifying organisms are also more vulnerable to pH changes than adults. Most benthic fauna have a planktonic larval phase when they are especially vulnerable to carbonate undersaturation. For example, young sea urchins were smaller and deformed when grown at a lower pH (Haugan 2006, Shirayama 2004). Also, the success of bivalve larvae is greatly reduced by ocean acidification because they experience high mortality while settling, while undersaturation of carbonates weakens their shells (Royal Society 2005).

A recent study found that the calcification rates of the edible mussel and Pacific oyster decrease linearly with increases in carbon dioxide (Gazeau 2007). This study predicted that under the IPCC scenarios for carbon dioxide emissions the calcification rates would decrease by 10% for oysters and 25% for mussels, probably because mussel shells are largely composed of aragonite. Besides the obvious implications for Washington’s commercial shellfish industry, these organisms also play in important role in aquatic ecosystems. They govern nutrient flow, provide habitat for benthic organisms, and are a part of the shoreline food web.

Due to ocean acidification, within our lifetimes coral reefs may erode faster than they can rebuild (Feely 2006). Coral reefs provide vital functions for marine ecosystems, and studies reveal that coral is extremely vulnerable to ocean acidification (Gattuso 1997). In 2006 a team of NOAA researchers discovered deep-sea corals off the coast of the Olympic Peninsula (www.publicaffairs.noaa.gov/releases2006/jun06/noaa06-062.html). They observed six species of soft coral and one of stony coral. Based on studies of other corals, it is predicted that calcification of cold-water corals will also be reduced by ocean acidification (Royal Society 2005). Some of the cold water coral species in the Pacific calcify and are vulnerable to impacts from anthropogenic carbon dioxide (Guionette 2006, Morgan 2006). Cold water corals may be even more sensitive to reduced carbonate saturation because they already live in conditions less favorable to calcification (Royal Society 2005; Murray 2006). Moreover, because cold water corals depend on calcifying plankton as food, the productivity of coral prey is also compromised by ocean acidification (Morgan 2006).

3. Other marine animals are adversely impacted by ocean acidification

Even marine animals that do not calcify are threatened by carbon dioxide increases in their habitat. Changes in the ocean's carbon dioxide concentration result in accumulation of carbon dioxide in the tissues and fluids of fish and other marine animals, called hypercapnia, and increased acidity in the body fluids, called acidosis. These impacts can cause a variety of problems for marine animals including difficulty with acid-base regulation, calcification, growth, respiration, energy turnover, and mode of metabolism (Pörtner 2004).

An animal's ability to transport oxygen is reduced by pH changes (Pörtner 2005). Water breathing animals have a limited capacity to compensate for changes in the acidity (Haugan 2006). For example, fish that take up oxygen and respire carbon dioxide through their gills are vulnerable because decreased pH can affect the respiratory gas exchange (Royal Society 2005). Changes in metabolic rate are caused by the changes in pH, carbonates, and carbon dioxide in marine animals (Haugan 2006).

Squid, for example, show a very high sensitivity to pH because of their energy intensive manner of swimming (Royal Society 2005). Because of their energy demand, even under a moderate 0.15 pH change squid have reduced capacity to carry oxygen and higher carbon dioxide pressures are likely to be lethal (Pörtner 2004). Even species more tolerant to pH changes experience decreased metabolism from increased carbon dioxide in the water (Pörtner 2004). For example, as much as 50% mortality was observed in copepods after only six days of exposure to waters with a pH level 0.2 units below the control (Pörtner 2005).

In fish, pH also affects circulation. When fish are exposed to high concentrations of carbon dioxide in seawater cardiac failure causes mortality (Ishimatsu 2004). At lower concentrations sublethal effects can be expected that can seriously compromise the fitness of fish. Juvenile and larval stages of fish were found to be even more vulnerable (Ishimatsu 2004).

An increased concentration of carbon dioxide not only produces pH changes that affect animals, but also the internal accumulation of carbon dioxide in the body of the organism adversely impacts many marine species (Haugan 2006). Marine animals are likely to have difficulty reducing carbon dioxide in their bodies with consequent effects on development and reproduction (Turley 2006). Hypercapnia can cause decreased protein synthesis which results in reduced growth and reproduction (Haugan 2006). This effect has been observed in mollusks, crustaceans, and fish (Haugan 2006). Additionally, studies have found loss of sperm motility for Pacific oysters, decreases in egg production by copepods, decreased hatching of egg sacs for gastropod mollusks, and impacts on reproductive success for silver sea bream and sea urchins (Royal Society 2005).

In sum, ocean acidification can have many adverse effects on marine animals that can reduce their fitness and survival (Royal Society 2005). Many marine animals have low thresholds for long-term carbon dioxide exposure (Pörtner 2005). Studies demonstrate that many marine species are threatened with population declines and changes in species composition due to the decreased fitness of individuals and compromised reproductive success that is occurring or will result from ocean acidification.

4. Ocean acidification has the potential to destroy the aquatic food web

Declining populations of species that are unable to adjust to ocean acidification will cause major changes in interactions among species in marine ecosystems. For example, the shift from coccolithophores to diatoms in the plankton community can cause a restructuring of the ecosystem at all trophic levels (Royal Society 2005). Additionally, a decrease in pteropod abundance can also increase predation of juvenile fish (Royal Society 2005). Changes to the carbonate chemistry and reduced calcification by plankton will change the amount of sinking and settling to deeper waters, which may reduce delivery of food to deeper waters and benthic organisms (Haugan 2006).

Most of the ocean’s biological activity happens near the surface waters, and ocean acidification will have substantial effects on organisms and habitats in those areas. Impacts on surface waters will cycle down to affect deep-ocean communities. Changes in acidity occur more quickly near the surface where most marine organisms occur, but deep-ocean species may be more sensitive to pH changes (Caldeira 2003).

Changes in pH also affect the availability of marine nutrients that are essential for marine production (Turley 2006). Changes in nutrients such as phosphorus and nitrogen could cause eutrophication (Turley 2006). The aggregation of these changes may have potentially devastating effects on marine communities.

Due to the specific habitat tolerances of many species, some species may become imperiled from the impacts of high concentrations of carbon dioxide. Additionally, many threatened and endangered species depend on Washington’s ocean ecosystem and are extremely vulnerable to changes in marine habitat. Ocean acidification jeopardizes the continued existence of some of these species. For example, numerous threatened and endangered species such as blue, humpback, and fin whales, and sea otters prey on calcifying species. Declining fitness of fish due to acidification could not only impact depleted fish populations, but also already imperiled fish-eating species such as the brown pelican, marbled murrelet, and orcas. Similarly, impacts to squid, among the most sensitive of marine species to changes in pH, would likely impact squid-eating species such as sperm whales.

IV. Washington's Ocean Waters Are Impaired and Must Be Included on the 303(d) List

All Washington ocean segments must be added to the 303(d) list because the current effluent limitations are not stringent enough to implement the applicable water quality standards. 33 U.S.C. § 1313(d)(1). The coastal waters in Washington are designated as extraordinary quality for aquatic life uses. W.A.C. 173-201A-612.

These aquatic life uses include "salmonid and other fish migration, rearing, and spawning; clam, oyster, and mussel rearing and spawning; crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, etc.) rearing and spawning." W.A.C. 173-201A-210(1)(a). Marine waters that are rated of extraordinary quality must have a pH between 7.0 and 8.5 with human-caused changes in pH less than 0.2 pH units. W.A.C. 173-201A-210(1)(f). Additional beneficial uses include shellfish harvesting and recreational uses. W.A.C. 173-201A-201(2) and (3).

Washington water quality standards are guided by the public policy of "maintain[ing] the highest possible standards to insure the purity of all waters of the state consistent with public health and public enjoyment thereof, the propagation and protection of wild life, birds, game, fish and other aquatic life, and the industrial development of the state." R.C.W. 90.48.010.

Present and future levels of carbon dioxide emissions threaten the ability of aquatic organisms to survive. Furthermore, the loss of calcifying organisms will devastate shellfish harvesting uses and commercial and recreational fishing. The shellfish industry in Washington is the second largest employer in Pacific and Mason counties. Furthermore, the production of mussels, oysters, clams, and geoduck produce approximately $77 million in sales annually. Shellfish are in extreme danger due to ocean acidification; a recent study showed that mussel and oyster calcification rates decrease linearly with increased CO_2 (Gazeau 2007).

Ocean pH has already changed by over 0.1 pH units. Thus, the ocean is on a declining trend and must be listed as impaired. The "saturation horizon" for aragonite and calcite has already shifted toward the surface by 50 to 200 m. This means that calcareous organisms can not survive at the same depths they once could. The depth of water in which they can survive will continue to become shallower in the coming decades (Feely 2004).

The Department of Ecology can consider both narrative and numeric data when assessing a water segment for addition to the state's 303(d) list and when revising water quality standards. Narrative data must be high quality "credible literature" under the Water Quality Data Act. RCW 90.48.570-590. Narrative data can be the basis for placement in Category 5 of the 303(d) list when it: (1) documents environmental alteration related to deleterious chemical or physical alterations and (2) documents an impairment of an existing or designated use that is related to the environmental alteration. Water Quality Program Policy 1-11, Ch. 1. The attached data fulfill both of these requirements.

A. The current trends violate the Washington anti-degradation policy and warrant listing

The continual decrease in oceanic pH violates the state's antidegradation policy (W.A.C. 173-201A-300) and requires listing under section 303(d) of the Clean Water Act. The purpose of the Washington antidegradation policy is to "restore and maintain the highest possible quality of the surface waters of Washington." W.A.C. 173-201A-300(2). The policy applies to human activities that are likely to impact water quality and ensures that these activities are minimized. Id.

Existing water quality must be maintained or returned to the designated standard (Tier I). If the waterbody currently exceeds the established criterion, new activities that would measurably alter water quality are not to be allowed except under exceptional circumstances (Tier II). A measurable change in pH is defined as 0.1 pH units or greater.

The ocean pH has already declined by 0.11 units as a direct consequence of human activity. Anthropogenic carbon dioxide emissions will result in a decrease in oceanic pH of 0.4 units by 2100 according to a model based on IPCC scenarios (Caldeira 2003). Thus, human activity has already caused a measurable change in pH and has violated the antidegradation policy. The continued release of anthropogenic carbon dioxide threatens the current level of water quality. Thus, the ocean waters must be listed as impaired on the 303(d) list.

	Pre-industrial	**Today**	**2 pre-industrial**	**3 pre-industrial**	**4 pre-industrial**	**5 pre-` industrial**	**6 pre-industrial**
Atmospheric concentration of CO_2	280 ppm	380 ppm	560 ppm	840 ppm	1120 ppm	1400 ppm	1680 ppm
H_2CO_3 (mol/kg)	9	13	19	28	38	47	56
HCO_3^{-} (mol/kg)	1 768	1 867	1 976	2 070	2 123	2 160	2 183
CO_3^{2-} (mol/kg)	225	185	141	103	81	67	57
Total dissolved inorganic carbon (mol/kg)	2 003	2 065	2 136	2 201	2 242	2 272	2 296
Average pH of surface oceans	8.18	8.07	7.92	7.77	7.65	7.56	7.49
Calcite saturation	5.3	4.4	3.3	2.4	1.9	1.6	1.3
Aragonite saturation	3.4	2.8	2.1	1.6	1.2	1.0	0.9

From: *Royal Society 2005*: Changes to ocean chemistry and pH estimated using the OCMIP3 models calculated from surface ocean measurements and our understanding of ocean chemistry. Note that the concentration of bicarbonate ion (HCO_3^{-}) and carbonic acid (H_2CO_3) increase with rising atmospheric concentration of CO_2 while carbonate ion (CO_3^{2-}) decreases. The average pH of the surface ocean waters decreases with increasing atmospheric CO2 concentration. (Assumptions used in model: Total alkalinity = 2324 mol/kg, temperature = 18° C. All other assumptions as per OCMIP3 (Institut Pierre Simon Laplace 2005). Aragonite and calcite saturation calculated as per Mucci & Morse (1990). Physical oceanographic modelling is based on Bryan (1969) and Cox (1984).

V. The Current pH Criteria Are Inappropriate Given the Latest Scientific Knowledge and Must Be Revised

Water quality criteria are to be established at levels that "protect the public health or welfare" and "enhance the quality of water" while taking into account "use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes." 33 U.S.C. § 1313(c). Furthermore, water quality criteria must reflect the latest scientific knowledge. 33 U.S.C. § 1314(a). The current pH standards, a range of 7.5 to 8.5 with no changes greater than 0.2 units, reflect scientific information that was first published by the EPA in the 1976 "Red book". Yet, recent studies have greatly changed our understanding of the effects of ocean pH. Consequently, the criteria need to be revised.

The results of reduced carbonate availability and hypercapnia have been studied in organisms from plankton to fish. The negative impacts have already begun to be apparent. Large declines in viability and health are predicted by the end of the century, when pH is predicted to be 0.4 units lower. The current ocean pH ranges from 8.3 to 7.9 (Bindoff 2007). Catastrophic losses will already have occurred by the time that the oceans in some areas reach the lower limit of Washington's current marine pH standards—7.0. This is unacceptable and violates the guidelines for water quality criteria.

If the Department of Ecology does not revise the current water quality criteria, aquatic ecosystems will be irreparably damaged, recreational uses will be diminished, and commercial uses will be thwarted. New methods allow more exact measurement of total dissolved inorganic carbon and alkalinity, from which pH can be measured. It is also possible to make observations deeper in the water column than it was at the time the initial criteria were established. Thus, it is practicable to implement a more stringent pH standard.

While the federal Environmental Protection Agency publishes recommended guidelines for water quality criteria under § 304 of the Clean Water Act, it is the responsibility of the states to ensure that the criteria are appropriately adopted and updated. 33 U.S.C. § 1313(c). It is obvious that the current pH standards must be revised.

VI. Conclusion

The materials submitted with this petition support the finding that Washington's oceans are impaired. Ocean pH has decreased by 0.11 units since the industrial age and will continue to decrease at an accelerated rate if carbon dioxide emissions continue to increase as predicted. The decrease in ocean pH has already begun to impair the calcification of some aquatic organisms, and catastrophic effects are predicted for the next decades.

The purpose of water quality standards is to protect the biological diversity of Washington's waters as well as recreational and commercial uses. Ocean acidification will have significant negative impacts on the survival of calcareous organisms as well as fish and other marine species. Commercial and recreational uses will be harmed as a result, which will particularly affect the shellfish and fishing industries that are so important to Washington citizens.

The coastal waters must be listed as impaired under section 303(d) now so that TMDLs can be established to protect the extraordinary quality of Washington's coastal waters.

Respectfully submitted,

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Ocean Program Attorney

Anna Moritz

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Ocean and Climate Program Law Clerk

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cc: Ken Koch, Water Quality Assessment; Andrew Kolosseus, Water Quality Standards

VII. SOURCES

For supporting documents listed below, please see the attached articles submitted with this letter.

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