CENTER for BIOLOGICAL DIVERSITY Because life is good.

August 15, 2007

Drew Grant
Division of Water
Department of Environmental Conservation
410 Willoughby Ave., Suite 303
Juneau, AK 99801
Telephone: 907-465-5304
Fax: 907-465-5274
Email: Drew_Grant@dec.state.ak.us

Re: Nomination to Add Ocean Waters of Alaska to the List of Impaired Waterbodies under Section 303(d) of the Clean Water Act due to Carbon Dioxide Pollution Resulting in Ocean Acidification

Dear Drew Grant,

The Center for Biological Diversity respectfully requests that the Alaska Department of Environmental Conservation ("DEC"):

> **Include all ocean water segments in Alaska's List of Impaired Waterbodies ("303(d) List") under section 303(d) of the Clean Water Act as impaired for pH due to absorption of anthropogenic carbon dioxide pollution.**

The Center nominates all Alaska ocean segments to be added to the Clean Water Act's 303(d) List as these waters are impaired for pH due to ocean acidification occurring as a result of past, ongoing, and projected absorption of anthropogenic carbon dioxide pollution.

I. INTRODUCTION

Greenhouse gas emissions pose a serious threat to the Alaskan environment, and some of the impacts of global warming are already apparent in Alaska. Global warming will impact Alaska's terrestrial and marine communities, its social and cultural environment, and its economy. Warming temperatures, sea level rise, and more frequent and intense storms are likely due to greenhouse gas emissions. Carbon dioxide is the most prevalent greenhouse gas causing global warming. Global warming, however, is not the only significant impact of carbon dioxide emissions. In addition to their contribution to global warming, these same carbon dioxide emissions also pose a severe threat to Alaska's and the world's oceans.

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 Alaska 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 Alaska's ocean waters and the designated uses of these waters.

There can be no dispute that pH can be regulated as a pollutant under the Clean Water Act. The Environmental Protection Agency ("EPA") lists pH as a "conventional pollutant" in its regulations. 40 C.F.R. § 401.16. Ocean acidification, the lowering of seawater pH resulting from absorption of anthropogenic carbon dioxide emissions, can and must be regulated pursuant to the Clean Water Act.

Because ocean acidification is impairing the water quality of Alaska's ocean waters and the designated uses of these waters, and existing regulations are inadequate to prevent continued acidification, these waters should be included in the 303(d) List. The data and supporting documents to this nomination are evidence that ocean acidification is a real and ongoing problem. Moreover, these waters rank as a high priority when the Alaska Clean Water Actions ("ACWA") Ranking Criteria are considered (ACWA Decision Tree & Ranking Process 2006). The Center nominates Alaska's ocean waters because they are on a trend toward declining water quality because of increasing acidity, and because ocean acidification is impairing the marine habitat and aquatic life.

DEC must act immediately to curb the acidification of ocean waters by listing Alaska's ocean segments on the 303(d) List and prioritizing the creation of a Total Maximum Daily Load ("TMDL") for carbon dioxide.

II. CLEAN WATER ACT BACKGROUND

The purpose 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(a). 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)

The Clean Water Act requires, inter alia, that states set water quality standards that protect designated uses for water bodies. Each state must develop water quality standards that "specify a water body's 'designated uses' and 'water quality criteria,' taking 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 . . . .' 303(c)(2)." *Pronsolino v. Nastri*, 291 F.3d 1123, 1127 (9th Cir. 2002). These standards are used to set effluent limits and technology standards, and the Act requires compliance with such measures by requiring a permit for the discharge of any pollutant. 33 U.S.C. §§ 1311, 1342.

Relevant here, the Clean Water Act's section 303(d) requires each state to identify waters for which existing regulations are inadequate to protect water quality—resulting in a "303(d) List." 33 U.S.C. § 1313(d). "Each state shall identify those waters within its boundaries for which the effluent limitations … are not stringent enough to implement any water quality standard applicable to such waters." 33 U.S.C. § 1313(d)(1)(a). A water body failing to meet any numeric criteria, narrative criteria, waterbody uses, or antidegradation requirements shall be included as a water-quality limited segment on the 303(d) List. 40 C.F.R. § 130.7(b)(3).

For waters identified on the 303(d) List, the states "shall" establish a TMDL for pollutants "at a level necessary to implement the applicable water quality standards." 33 U.S.C. § 1313(d)(1)(C). "A TMDL defines the specified maximum amount of a pollutant which can be discharged or 'loaded' into the water at issue from all combined sources." *Dioxin/Organochlorine Center v. Clark*e, 57 F.3d 1517, 1520 (9th Cir. 1995). The 303(d) List shall include a priority ranking for all listed segments still requiring TMDLs. 40 C.F.R. § 130.7(b)(4). "TMDLs serve as a link in an implementation chain that includes federally-regulated point source controls, state or local plans for point and nonpoint source pollution reduction, and assessment of the impact of such measures on water quality, all to the end of attaining water quality goals for the nation's waters." *Pronsolino,* 291 F.3d at 1129.

Additionally, the EPA oversees Alaska's implementation of section 303(d) of the Clean Water Act and must approve the identified impaired water bodies and TMDLs. 33 U.S.C. § 1313(d)(2). If EPA disapproves of either, then EPA shall identify such waters and establish TMDLs as necessary to ensure water quality standards are met. 33 U.S.C. § 1313(d)(2).

III. OCEAN ACIDIFICATION BACKGROUND

Carbon dioxide pollution is degrading water quality and harming marine ecosystems. The oceans readily absorb carbon dioxide pollution and this causes ocean acidification. Increasing acidity is stripping the oceans of important compounds needed by marine species to build shells and skeletons (Ruttimann 2006). Within our lifetime, corals are likely to erode more quickly than they can rebuild due to ocean acidification (Feely 2006). Many sea organisms from phytoplankton to snails and crabs are being harmed as acidic waters dissolve protective structures or inhibit growth (Ruttimann 2006; WBGU 2006). Other marine organisms, such as fish, experience impaired metabolism as their tissues become more acidic (Pörtner 2004, Royal Society 2005). Adverse impacts on these species will reverberate throughout the marine ecosystem.

A. Seawater Chemistry and Carbon Dioxide

The oceans freely exchange carbon dioxide with the atmosphere. The oceans have already taken up about 50% of the carbon dioxide that humans have produced since the industrial revolution, and already 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), now they have increased to 380 ppm and if current trends continue they will increase another 50% by 2030 (Turley 2006). These rising carbon dioxide levels are irreversible on human timescales (Kleypas et al. 2006). Over time, the ocean will absorb up to 90% of anthropogenic carbon dioxide released into the atmosphere (Kleypas et al. 2006). Surveys in the 1970s and the 1990s indicate an increase in anthropogenic carbon down to depths of 1,100 meters in the North Pacific (Bindoff 2007).

When carbon dioxide is dissolved in seawater it becomes reactive and changes seawater chemistry along with many other physical and biological reactions. When carbon dioxide combines with water, it forms carbonic acid and releases hydrogen ions (Royal Society 2005). These hydrogen ions determine the acidity of the ocean, accounting for the change in pH. The slightly alkaline pH of the ocean is becoming more acidic. The naturally occurring pH values for the ocean were on average 8.16 in the mid-18th Century, and as a result of carbon dioxide pollution, the average pH value has dropped to 8.05 (Ruttimann 2006). The highest decrease in pH was observed at high latitudes, a decrease of 0.12 units (Bindoff 2007).

Carbon dioxide pollution results in more severe pH changes than experienced in the past 300 million years (Caldeira 2003). Under the business-as-usual scenario of greenhouse gas emissions, carbon dioxide will reach 788 ppm by 2100 and pH will drop another 0.3-0.4 units (Orr 2005). Even under the more modest scenario where carbon dioxide emissions are stabilized, atmospheric carbon dioxide will reach 563 ppm by the end of the century with corresponding ocean acidification.

In addition to changes in pH, carbon dioxide changes the carbon chemistry of the ocean. Seawater is naturally saturated with carbonate ions that are important for marine organisms to build shells and skeletons (WBGU 2006). Calcium carbonate is present in the ocean in two common forms used by organisms for shells and skeletons, calcite and aragonite. Dissolved carbon dioxide reacts with seawater to form carbonic acid, which dissociates to form bicarbonate ions (Turley 2006). The effect lowers pH and decreases the availability of carbonate ions (CO^{2-}_3) (Kleypas 2006). This is represented by the following equation:

$$CaCO_3+CO_2+H_20 \Leftrightarrow Ca^{2+} + CO^{2-}_3+CO_2 + H_20 \Leftrightarrow Ca^{2+}+2HCO^{-}_3$$

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). Changes in carbonate saturation extend below the surface throughout the water column (Orr 2005). Feely et al. (2004) calculated that the uptake of anthropogenic carbon alone has caused a shoaling of the aragonite saturation horizon between

1750 and 1994 by 30 to 200 m in the North Pacific, changes in saturation are more pronounced in higher latitudes (Feely 2004; Bindoff 2007). These changes in saturation make calcium carbonate unavailable for marine organisms to build their protective shells with adverse effects that will spread throughout the ecosystem.

Carbon dioxide pollution into the ocean is causing Alaska's oceans to have a lower pH, increased dissolved carbon dioxide, lower concentration of carbonate ions, and increased bicarbonate ions (Royal Society 2005). The result is that Alaska's oceans have already been seriously degraded by carbon dioxide pollution.

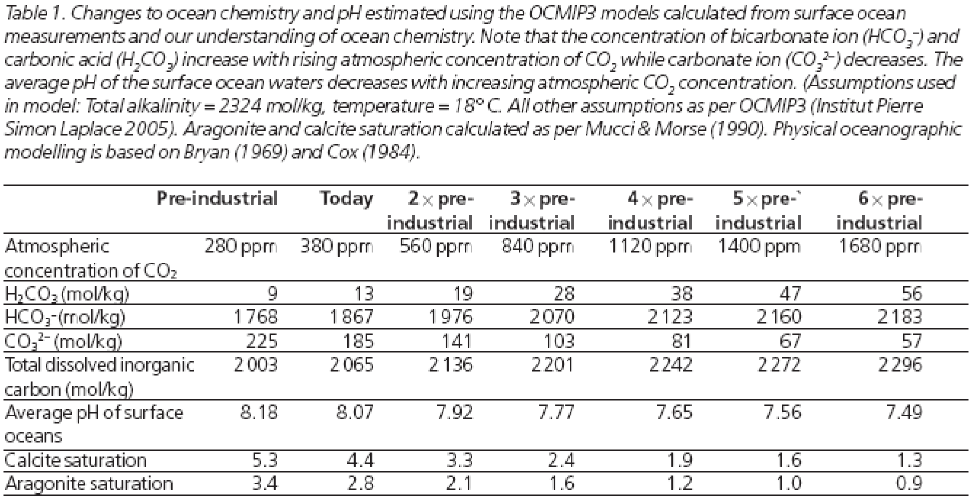

Table 1. Changes to ocean chemistry and pH estimated using the OCMIP3 models calculated from surface ocean measurements and our understanding of ocean chemistry. Note that the concentration of bicarbonate ion (HCO_3^-) and carbonic acid (H_2CO_3) increase with rising atmospheric concentration of CO_2 while carbonate ion (CO_3^{2-}) decreases. The average pH of the surface ocean waters decreases with increasing atmospheric CO_2 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).

	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)	1768	1867	1976	2070	2123	2160	2183
CO_3^{2-} (mol/kg)	225	185	141	103	81	67	57
Total dissolved inorganic carbon (mol/kg)	2003	2065	2136	2201	2242	2272	2296
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

Source: Royal Society (2005)

B. The Adverse Impacts of Carbon Dioxide Pollution on the Marine Environment

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 corals, mollusks, crustaceans, echinoderms, 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. Calcifying planktonic organisms are adversely affected by ocean acidification.

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, foraminifera, and pteropods 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.

Another important planktonic calcifier, foraminifera, 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).

Calcification is an essential mechanism in the biology and ecology for many marine species. Coccolithophorids, pteropods, and foraminifera are the major planktonic calcifying groups and they all experience adverse biological reactions as a result of ocean acidification. Alaska's ocean waters are filled with many of these plankton and they play a significant role in the marine food chain.

2. Large calcifying organisms experience 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, 560 ppm (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). Shallow water benthic organisms such as these are among those that will be the first to experience the adverse impacts of the ocean's uptake of carbon dioxide pollution.

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).

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). 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). There are extensive habitat forming gorgonian corals (*Primnoa*, *Paragorgia* and *Calligorgia* spp) found along the continental shelf and slope along the Gulf of Alaska and Aleutian Islands (http://www.nmfs.noaa.gov/habitat/ead/coldwatercorals.htm). 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. Fitness of other marine animals is compromised 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).

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).

Experiments with elevated carbon dioxide levels have revealed numerous adverse effects on the productivity of a variety of marine organisms (WBGU 2006). Changes were noted in the "productivity of algae, metabolic rates of zooplankton and fish, oxygen supply of squid, reproduction in clams, nitrification by microorganisms, and the uptake of metals" (WBGU 2006; see also Pörtner 2005). Other effects could include decreased motility, inhibition of feeding, reduced growth, reduced recruitment, respiratory distress, decrease in population size, increased susceptibility to infection, shell dissolution, destruction of chemosensory systems, and even mortality (Turley 2006; Royal Society 2005).

Impacts to marine organisms are not confined to the laboratory. Experiments with deep sea injection of carbon dioxide in central California waters killed benthic meiofauna such as nematode worms and amoeba (Barry 2005). Researchers also predict that the long-term hypercapnic conditions caused by absorption of atmospheric carbon dioxide will produce similar physiological stresses for marine organisms (Barry 2005).

Additionally, studies have shown that reproduction can be seriously compromised with pH changes. 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 impacts entire ecosystems.

Changes caused by ocean acidification such as reduced calcification can compromise the fitness and survival of some species resulting in changes in abundance and diversity of species in marine communities (Royal Society 2005, Kleypas 2006). These shifts can lead to even greater ecosystem responses that will alter ecosystem productivity, nutrient availability, and carbon cycling (Kleypas 2006).

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.

Other effects of climate change are also likely to combine synergistically with ocean acidification, intensifying the adverse affects on marine communities. For example, ocean temperatures are already changing, while runoff from more storms may alter salinity. The combined impact of all of these changes will influence the productivity, interactions, and distribution of many phytoplankton and zooplankton, resulting in impacts on the rest of the food chain (Haugan 2006). Ocean acidification can increase organisms' sensitivities to such environmental extremes (Pörtner 2005). For example, decreased metabolism can result in narrowing the thermal tolerance of an organism (Haugan 2006).

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 Alaska's ocean ecosystem and are extremely vulnerable to changes in marine habitat. Ocean acidification jeopardizes the continued existence of some of these species. The southwest population of sea otters in Alaska that prey on calcifying organisms are protected under the Endangered Species Act. Also, the Steller's and spectacled eiders prey on shelled organisms. Humback whales, North Pacific right whales, and bowhead whales eat krill and other zooplankton. 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.

These ecosystem responses will have serious effects on Alaska's ocean biodiversity and productivity. While the worst effects of ocean acidification are forecasted for the future, other impacts are already underway. Changes in pH are a significant threat in marine habitats. At present, the water quality of Alaska's ocean waters is declining due to carbon dioxide pollution, putting entire marine communities at risk.

IV. ALASKA'S OCEAN WATERS ARE IMPAIRED AND MUST BE ADDED TO THE 303(D) LIST

All segments of Alaska's ocean waters must be included on the State's 303(d) List because current measures are not stringent enough to prevent ocean acidification and maintain water quality standards. 33 U.S.C. § 1313(d). The Clean Water Act requires that Alaska protect the water quality for designated uses of its waters. Alaska's marine water protected uses include water supply for aquaculture, seafood processing, and industrial use; contact and secondary recreation, growth and propagation of fish, shellfish, and other aquatic life, and wildlife; and harvesting for consumption of raw mollusks or other raw aquatic life. 18 AAC §§ 70.020(a)(2)(A)-(D); 70.050(3).

Ocean acidification threatens the protected uses of Alaska's oceans. For example, ocean acidification threatens growth and propagation of many marine species including fish and shellfish. Even under conservative estimates of future carbon dioxide emissions, scientists predict chemical changes that threaten the ability of marine life to adapt to the acidifying ocean (Orr 2005). All these impacts would severely impair aesthetic and recreational enjoyment of Alaska's ocean waters and marine life.

The declining pH of Alaska's ocean waters due to carbon dioxide emissions is degrading Alaska's coastal and oceanic waters. Available science demonstrates a trajectory toward non-attainment of the water quality standard for pH and this violates Alaska's antidegradation policy by failing to maintain existing water quality. Additionally, ocean acidification threatens to impair the designated uses of Alaska's ocean waters such as support of aquatic life. For these reasons, which are described in detail below and supported by the attached scientific evidence, Alaska's ocean should be placed on the 303(d) List as impaired for pH as a result of anthropogenic carbon dioxide emissions.

A. Alaska's Ocean Waters Are on a Trajectory for Declining Water Quality

At present, Alaska's ocean segments are on a trajectory of declining attainment of water quality standards for pH. EPA identifies pH as a conventional pollutant. 40 C.F.R. § 401.16. Alaska requires that pH not vary more than 0.2 untis outside of the naturally occurring range to support aquatic life uses. 18 AAC 70.020(b)(18).

(18) pH, FOR MARINE WATER USES	**(variation of pH for waters naturally outside the specified range must be toward the range)**
(A) Water Supply (i) aquaculture	May not be less than 6.5 or greater than 8.5, and may not vary more than 0.2 pH unit outside of the naturally occurring range.
(A) Water Supply (ii) seafood processing	May not be less than 6.0 or greater than 8.5.
(A) Water Supply (iii) industrial	May not be less than 5.0 or greater than 9.0.
(B) Water Recreation (i) contact recreation	May not be less than 6.0 or greater than 8.5. If the natural pH condition is outside this range, substances may not be added that cause any increase in buffering capacity of the water.
(B) Water Recreation (ii) secondary recreation	Same as (18)(A)(iii).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (18)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (18)(A)(ii).

18 AAC 70.020(b)(18).

As a preliminary matter, it is important to note that this pH standard does not reflect the latest scientific information. Alaska's water quality standard for pH is insufficient because it allows pH changes so severe that marine ecosystems could collapse. This standard was derived before much was known about ocean acidification.. The antiquated standard is now unreasonable because it only addresses localized discharges that can mix and dilute with seawater, rather than the chronic problem of ocean acidification. In contrast, the pH change caused by carbon dioxide uptake is pervasive and a decrease of 0.2 units will be devastating for marine life, and changes will be irreversible on a human timescale (Kleypas 2006)

Alaska based its water quality standard for pH on standards created in 1976 by the United States Environmental Protection Agency ("Red Book" Quality Criteria for Water, 1976). It is evident that these 30-year-old criteria do not reflect the most recent scientific information. The old standards were based on poor measurement techniques (pH meters), but current methods compute pH from dissolved inorganic carbon and alkalinity thus providing more accuracy. Scientific knowledge has also advanced making it easier to account for localized and seasonal variations in pH. It is, now, therefore possible for the DEC to adopt standards that are more stringent and conduct more accurate monitoring of pH. Additionally, changes in pH due to anthropogenic carbon dioxide are relatively easy to predict compared to other climate change patterns caused by greenhouse gases.

Applying the existing standard for pH, all Alaskan ocean waters should still be included on the 303(d) List because they are experiencing degradation. The Clean Water Act and Alaska's antidegradation policy prohibit any degradation of water bodies that are currently meeting water quality standards. Alaska's antidegradation policy provides that:

> 1) existing water uses and the level of water quality necessary to protect existing uses must be maintained and protected;
>
> 2) if the quality of a water exceeds levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality must be maintained and protected unless … the department finds that a) allowing lower water quality is necessary to accommodate important economic or social development, … b) reducing water quality will not violate the applicable criteria, c) the resulting water quality will be adequate to fully protect existing uses of the water; d) the methods of pollution prevention, control, and treatment found by the department to be the most effective and reasonable will be applied to all wastes and other substances to be discharged; and e) all wastes and other substances discharged will be treated and controlled …;
>
> 3) if a high quality water constitutes an outstanding national resource, such as a water of a national or state park or wildlife refuge or a water of exceptional recreational or ecological significance, the quality of that water must be maintained and protected; and
>
> 4) if potential water quality impairment associated with a thermal discharge is involved, the antidegradation policy described in this section is subject to 33 U.S.C. 1326 (commonly known as sec. 316 of the Clean Water Act).

18 AAC 70.015.

The trend toward lower pH fails to maintain water quality and threatens non-attainment of designated uses. Absent DEC approval to degrade water quality, ocean waters must be protected against ocean acidification. As described above, dissolved carbon dioxide lowers the pH of seawater and acidifies the ocean. Surface ocean pH has already declined by 0.11 units on average from preindustrial values (Caldeira 2003). The naturally occurring pH values for the ocean were on average 8.16 in the mid-18th Century, and as a result of carbon dioxide pollution, the average pH value has dropped to 8.05 (Ruttimann 2006). This is a significant change in water quality since each step is a tenfold change in acidity. Alaska's ocean waters have likely experienced even more severe decreases in pH than rest of the surface ocean, because measurements showed more pH change in higher latitudes (Bindoff 2007).

Recently, a monitoring station was established in the Gulf of Alaska. DEC should monitor this station to determine and abate the impacts of ocean acidification. The Ocean Station Papa surface mooring monitors atmospheric and surface water pCO2. In addition to monitoring air-sea carbon dioxide fluxes, this is the first open-ocean mooring specifically designed to monitor ocean acidification by monitoring pCO2 and pH. Data from the Papa station can be found at: http://www.pmel.noaa.gov/stnP/index.html. Other stations have provided several years of credible data that atmospheric carbon dioxide is causing ocean acidification (Bindoff 2007).

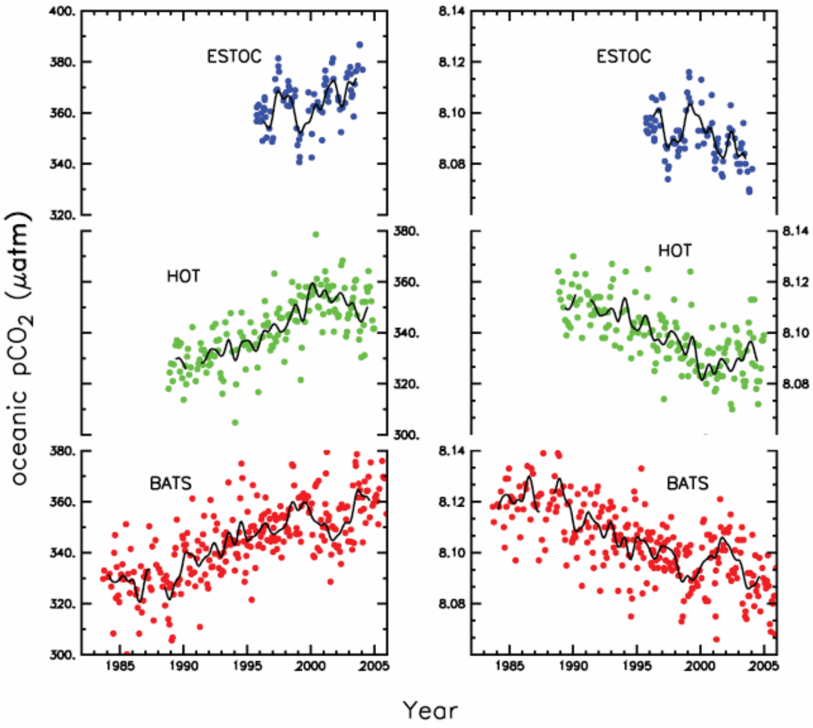

Figure 5.9. *Changes in surface oceanic pCO_2 (left; in μatm) and pH (right) from three time series stations: Blue: European Station for Time-series in the Ocean (ESTOC, 29°N, 15°W; Gonzalez-Dávila et al., 2003); green: Hawaii Ocean Time-Series (HOT, 23°N, 158°W; Dore et al., 2003); red: Bermuda Atlantic Time-series Study (BATS, 31/32°N, 64°W; Bates et al., 2002; Gruber et al., 2002). Values of pCO_2 and pH were calculated from DIC and alkalinity at HOT and BATS; pH was directly measured at ESTOC and pCO_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.*

The ongoing acidification of the ocean is the most severe change in ocean pH in several million years (Turley 2006). These changes are occurring at about 100 times the rate of changes seen naturally in geological history. Natural changes occur more slowly with a greater opportunity for the impacts of pH changes to be lessened (Royal Society 2005).

Meanwhile, human activities continue to release carbon dioxide, and the ocean is continuing to absorb such pollution. With the oceans absorbing about 22 millions of carbon dioxide each day (Feely 2006), seawater pH will continue to decrease. Assuming current trends of greenhouse gas emissions, the global average pH of seawater will drop another 0.3-0.4 units (Orr 2005). Having already absorbed half of anthropogenic carbon dioxide, scientists predict that the oceans will absorb up to 90% (Kleypas et al. 2006). Unabated, carbon dioxide pollution will degrade seawater quality beyond Alaska's water quality standards. By the end of this century, absent significant reductions in carbon dioxide emissions, this will result in a pH change up to 0.5 units (Royal Society 2005). These impacts of carbon dioxide are relatively easy to predict compared to other global warming impacts of greenhouse gases.

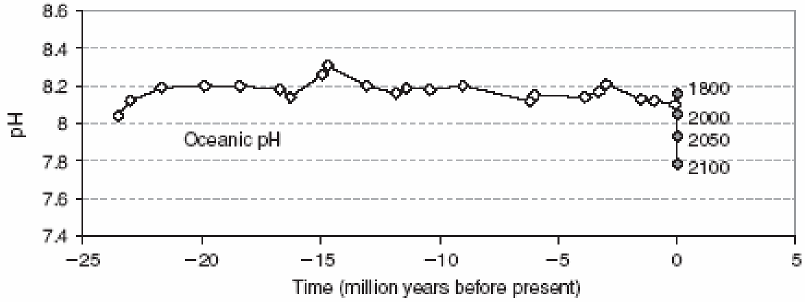

Figure 8.2 Past (white diamonds, data from Pearson and Palmer, 2000) and contemporary variability of marine pH (grey diamonds with dates). Future predictions are model derived values based on IPCC mean scenarios.

Source: Turley 2006

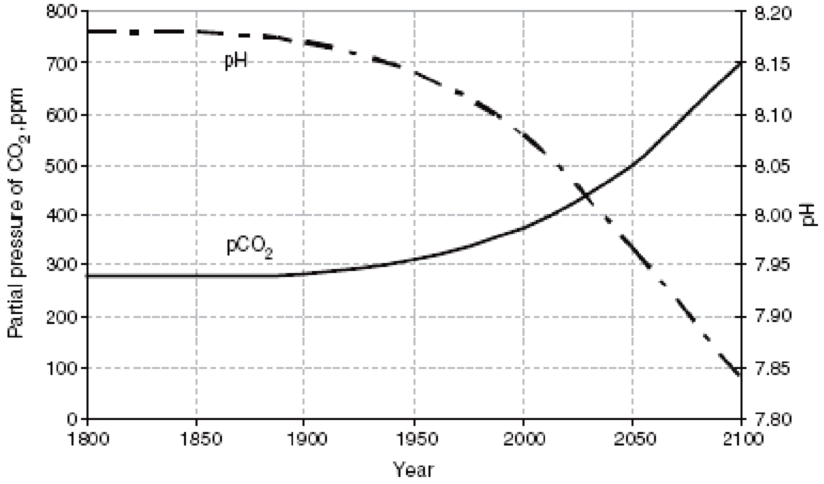

Figure 8.1 The past and projected change in atmospheric CO_2 and seawater pH assuming anthropogenic emissions are maintained at current predictions (redrawn from Zeebe and Wolf-Gladrow 2001).

Source: Turley 2006

As described above, and documented in the scientific literature submitted with this request, carbon dioxide absorption into the ocean is causing Alaska's ocean waters to have a lower pH, increased dissolved carbon dioxide, lower concentration of carbonate ions, and increased bicarbonate ions (Royal Society 2005). The result is that Alaska's ocean waters have already been degraded by carbon dioxide pollution. Alaska's ocean waters are on a trajectory toward nonattainment of water quality standards and therefore should be added to the 303(d) List.

B. Ocean Acidification Is Impairing Aquatic Life

Alaska's ocean waters should also be placed on the 303(d) List because ocean acidification threatens to impair aquatic life uses. As described above, the impacts of ocean acidification on marine organisms, and ultimately, marine communities are significant, diverse, and will greatly increase in severity over time. There is no scientific dispute that anthropogenic atmospheric carbon dioxide is causing ocean acidification and that such acidification will have adverse impacts on many marine organisms. Available evidence suggests that the adverse consequences of anthropogenic carbon dioxide accumulation are already being felt in surface waters (Pörtner 2005).

Ocean acidification is adversely affecting calcifying planktonic organisms such as coccolithophorids, foraminifera, and pteropods, larger calcifying organisms such as crustaceans, echinoderms, corals, and mollusks, non-calcifying organisms such as fish and squid, and such adverse affects will reverberate though the marine ecosystem to marine mammals, seabirds and ultimately human communities reliant upon ocean resources. In short, the addition of controllable carbon dioxide pollution is likely to harm aquatic life in breach of the water quality standards.

Listing and development of a TMDL for Alaska's oceans should be a high priority for the DEC because oceans should receive a high score in the ACWA Ranking Process. See below for an example:

Water Quality		
Allocation	High (5)	Allocation is high because there are many dischargers of carbon dioxide and effluent limitations do not apply to their discharges.
Condition	High (5)	Condition is high because the duration of water quality impairment is irreversible on human timescales.
Protection	High (5)	Protection is inadequate to prevent degradation of water quality because there are no controls on carbon dioxide pollution.
Future Use	Moderate (3)	Future use, future activities are likely to cause degradation.
Present Use	High (5)	Present use is moderate for fish and wildlife production and high with salmon spawning and rearing.
Value	High (5)	Value is moderate to high with pristine qualities and some legislatively assigned designation.
Water Quantity		Quantity of ocean waterbodies is generally not an issue.
Habitat		
Allocation	High (5)	Several activities threaten habitat including those that emit carbon dioxide. Offshore drilling permits affect marine habitat during all stages including burning of extracted fossil fuels.
Condition	High (5)	The duration of habitat impairment due to ocean acidification is long-term.
Protection	High (5)	Protections are inadequate to prevent ocean acidification form degrading habitat
Future Use	Moderate (3)	Future activities are projected that will increase impairment by ocean acidification
Present Use	High (5)	Ocean waters are incredibly important for fish and wildlife production, salmon, wildlife viewing, and subsistence fisheries.
Value	Moderate (3)	Although marine habitat is abundant in the area, the value of the habitat is nonetheless moderate because it is essential for marine productivity.

V. CONCLUSION

While the worst effects of ocean acidification are forecasted for the future, the adverse changes to Alaska's ocean waters from ocean acidification are already underway. These changes will, if not addressed, have serious, and likely catastrophic effects on Alaska's ocean biodiversity, productivity, and ultimately, economy.

All segments of Alaska's ocean waters must be added to the Clean Water Act's 303(d) List as impaired for pH from absorption of anthropogenic atmospheric carbon dioxide. Such listing is necessary because anthropogenic carbon dioxide pollution is degrading water quality and impairing the ocean's designated uses. Alaska's specific listing criteria are met because these ocean waters are on a trajectory of non-attainment of water quality standards, and because ocean acidification is impairing aquatic life, and the water quality of Alaska's ocean waters is not being maintained in violation of the antidegredation policy.

Alaska's ocean waters are among the most productive, diverse, and ecologically and economically important of any ocean waters in the United States and the world. Ocean acidification threatens the fundamental health of these waters and all species dependent upon them. These waters can only be protected if prompt and decisive action is taken to reduce ocean acidification by reducing anthropogenic atmospheric carbon dioxide emissions.

The goals of the Clean Water Act can only be met by taking steps to slow ocean acidification. The changing pH of the ocean and associated impacts on marine resources are unlike any that have been experienced on this earth for millions of years. Alaska must take actions now to abate carbon dioxide pollution by listing its ocean segments as impaired on the 303(d) List and establishing a TMDL for carbon dioxide.

Respectfully submitted,

Miyoko Sakashita
Ocean Program Attorney
CENTER FOR BIOLOGICAL DIVERSITY
1095 Market Street, Suite 511
San Francisco, CA 94103
Phone: 415-436-9682 x 308
Fax: 415-436-9683
miyoko@biologicaldiversity.org

VI. SOURCES

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

1. Andersson, A.J., et al., Coastal Ocean CO_2—Carbonic Acid—Carbonate Sediment System of the Anthropocene, *Global Biogeochemical Cycles*, 20: GB1S92 (2006).
2. Barry, J.P., et al. Utility of Deep Sea CO2 Release Experiments in Understanding the Biology of a High-CO2 Ocean: Effects of Hypercapnia on Deep Sea Meiofauna, *Journal of Geophysical Research* 110:(C09)S12 (2005).
3. Bindoff, N.L., et al., Chapter 5: Observations: Oceanic Climate Change and Sea Level, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC (2007).
4. Caldeira, K. & Wickett M.E., Anthropogenic Carbon and Ocean pH, *Nature* 425: 365 (2003).
5. Chavez, F.P., et al., Chapter 15: Coastal Oceans, North American Carbon Budget and Implications for the Global Carbon Cycle, U.S. Climate Change Science Program (2007).
6. Feely, R.A., et al., Carbon Dioxide and Our Ocean Legacy (2006).
7. Feely, R.A., et al., Impact of Anthropogenic CO2 on the CaCO3 System in the Oceans, *Science* 305: 362-366 (2004).
8. Gattuso, J.P., et al. Effect of Calcium Carbonate Saturation of Seawater on Coral Calcification, *Global and Planetary Change* 18: 37-46 (1998).
9. Gazeau, F., et al., Impact of Elevated CO_2 on Shellfish Calcification, *Geophysical Research Letters*, 34: L07603 (2007).
10. German Advisory Council on Global Change (“WBGU”), The Future Oceans—Warming Up, Rising High, Turning Sour (2006).
11. Gruber, N., Sarmiento J.L., Stocker, T.F., An Improved Method for Detecting Anthropogenic CO2 in the Oceans, *Global Biogeochemical Cycles*, 10: 809-837 (1996).
12. Guionette, J.M, et al., Will Human-induced Changes in Seawater Chemistry Alter the Distribution of Deep-Sea Scleractinian Corals?, *Frontiers in Ecol. Environ.* 4: 141-146 (2006).
13. Haugan, P.M, Turley, C., & Poertner H-O, Effects on the Marine Environment of Ocean Acidification Resulting from Elevated Levels of CO2 in the Atmosphere, OSPAR Commission Report (2006)
14. Ishimatsu, Atsushi, Effects of CO2 on Marine Fish: Larvae and Adults. *Journal of Oceanography* 60(4) (2004).
15. Kleypas, J.A., et al., Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers (2006).
16. Kolbert, E., The Darkening Sea, *The New Yorker* (Nov. 11, 2006).
17. McNeil, B.I. & Matear, R.J., Projected Climate Change Impact on Oceanic Acidification, *Carbon Balance and Management*, 1: 2 (2006)

18. Morgan, LE, C-F Tsao, JM Guinotte, Status of Deep Sea Coral in US Waters, with Recommendations for their Conservation and Management (2006).
19. Murray, J.R., et al. Reefs of the Deep: The Biology and Geology of Cold-Water Coral Ecosystems, *Science* 312: 543-547 (2006).
20. Orr, J.C., et al., Anthropogenic Ocean Acidification over the Twenty-first Century and Its Impact on Calcifying Organisms, *Nature* 437: 681-686 (2005).
21. Pörtner, H.O., Langenbuch, M. & Reipschläger, A, Biological impact of elevated ocean CO2 concentrations: lessons from animal physiology and earth history, *Journal of Oceanography* 60: 705–718 (2004).
22. Pörtner, Hans O., Synergistic effects of temperature extremes, hypoxia, and increases in CO on marine animals: From Earth history to global change, *Journal of Geophysical Research* 110(c9) (2005).
23. Riebesell, U, et al., Reduced Calcification of Marine Plankton in Response to Increased Atmospheric CO_2, *Nature* 407: 364-367 (2000).
24. Royal Society, Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide (2005).
25. Ruttimann, J. Sick Seas, *Nature News Feature* 978-980 (2006).
26. Sabine, C.L., et al. The Oceanic Sink for Anthropogenic CO2, *Science* 305: 367-371 (2004).
27. Shirayama, Y., Effect of increased atmospheric CO on shallow water marine benthos, *Journal of Geophysical Research* 110(c9) (2005).
28. Turley, C., et al. Chapter 8: Reviewing the Impact of Increased Atmospheric CO2 on Oceanic pH and the Marine Ecosystem, Avoiding Dangerous Climate Change (2006).