STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
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June 12, 2012

Ms. Miyoko Sakashita, Attorney
Center for Biological Diversity
351 California Street, Suite 600
San Francisco, CA 94104

Subject: Response to comments received on Washington's 2010 Marine Water Quality Assessment

Dear Ms. Sakashita:

This letter provides a more detailed response to the comments we received from the Center for Biological Diversity (CBD) during development of Washington's 2010 Assessment of Marine Waters. The department of Ecology (Ecology) considered all of the information and studies submitted by the Center for Biological Diversity (CBD) via letters sent to Ecology on 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12 and most recently 4/23/12. Of the collective 128 references provided by CBD (see Enclosure 1), Ecology identified eleven that had information that could be relevant to the Washington Water Quality Assessment. Ecology further assessed these articles to determine whether the information demonstrated that Washington waters were failing to attain (or will fail to attain by the next listing cycle) Washington's pH criteria and/or general narrative criteria to protect aquatic life uses because of ocean acidification (see Enclosure 2).

An overall summary of our response to CBD can be found in the updated responsiveness summary submitted as a part of Ecology's record of decision for the 2010 Marine Waters Assessment to the Environmental Protection Agency (EPA) Region 10 Office. This responsiveness summary can be found on our website at: http://www.ecy.wa.gov/programs/wq/303d/2010/2010WQA-ResptoComments122311.pdf.

CBD's detailed comments focused on five areas where they assert Washington coastal waters should be placed in Category 5:

1. Washington's coastal waters are failing to attain numeric water quality standards for pH.
2. Washington's coastal waters are failing to attain general narrative criteria to protect aquatic life uses because of ocean acidification.
3. Ocean acidification is causing degradation of ocean water quality in violation of Washington's antidegradation policy.

4. Ecology should look beyond the data submitted by CBD to identify waters impaired by ocean acidification.
5. CBD disputes Ecology's previous response that the studies provided by them are not specific to Washington and therefore cannot be used as a basis for 303(d) listing, and also asserts that impaired listings can be made without site-specific monitoring data.

Detailed responses to the five comments are provided in the following pages.

Comment #1: CBD submitted numerous studies that they believe document ocean acidification and the decline in acceptable pH in Washington's waters, and should be used as a basis to list some or all coastal waters in Washington as threatened or impaired due to ocean acidification.

Response: Ecology reviewed the information and data supplied and referenced by CBD in their submittals, and concluded that none of the referenced studies showed impairments of Washington water bodies for pH criteria. Washington standards for pH at WAC 173-210(1)(f) require that pH must be within the range of 7.0 to 8.5, with a human-caused variation within the range of less than 0.2 units (for extraordinary marine quality waters) or less than 0.5 units (for excellent marine quality waters).

We reviewed each of the documents referenced by CBD as support for their assertions to see if they included pH data not meeting our water quality standards. None of the documents included data that showed any data outside of the accepted range, and in particular, no data demonstrated a decline in pH at any Washington marine water body of greater than 0.2 or 0.5 pH units (depending on the waterbody use designation) due to a human-caused variation within the accepted range. Therefore, a Category 5 listing of threatened or impaired for coastal waters was not triggered based on the pH numeric criteria.

Comment #2: Washington's coastal waters and Puget Sound include aquatic life uses. Washington's waters are failing to attain general narrative criteria to protect aquatic life uses because of ocean acidification.

Response: Ecology reviewed all of the CBD references to determine if there was sufficient information or data to indicate impairment of aquatic life uses, using our narrative standards. Washington narrative standards at WAC 173-201A-260(2)(a) require that toxic, radioactive, or deleterious material concentrations must be below those which have the potential, either singularly or cumulatively, to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health.

Ecology's listing policy (Water Quality Policy 1-11) states that segments will be placed in Category 5 on the basis of violating narrative standards when the information regarding the waterbody segment includes both documentation of environmental alteration related to deleterious chemical or physical alterations, as measured by indices of resource condition or resource characteristic or other appropriate measure, and documentation of impairment of an

existing or designated use is related to the environmental alteration on the same waterbody segment or grid.

We reviewed each of the documents referenced by CBD as support for their assertions that Washington's waters are failing to attain (or will fail to attain by the next listing cycle) general narrative criteria to protect aquatic life uses because of ocean acidification. We determined that none of the studies provided conclusive evidence that aquatic uses in the natural environment were being threatened or impaired by environmental alterations related to ocean acidification (see Enclosure 2). We also reviewed other relevant studies in Washington and especially Puget Sound, including Ecology studies now being conducted for dissolved oxygen and nutrients. However, we were not able to substantiate impairment to aquatic life due to ocean acidification. There is still research needed to be able to differentiate between the many natural variables that occur in the marine environment from those caused by anthropogenic sources.

We determined that Puget Sound should be listed in Category 2 (waters of concern) for potential impacts to fish and shellfish habitat from human activities, including conditions that make the waters more vulnerable, such as climate change, urbanization, and ocean acidification. This Category 2 listing is based on the Feely 2010 study, as well as studies being conducted in Puget Sound for dissolved oxygen and nutrient loadings. We were not able to extend this Category 2 listing to other Washington coastal waters outside of Puget Sound because of a lack of information suggesting potential impairment to aquatic habitat (except where 303(d) listings are already identified or TMDLs have been done). In conclusion, Washington's coastal waters will not be placed in Category 5 as threatened or impaired for ocean acidification based on narrative standards because of insufficient information.

Comment #3: CBD asserts that ocean acidification is causing degradation of ocean water quality in violation of Washington's antidegradation policy, which provides that existing and designated uses must be maintained and protected, and no degradation may be allowed that would interfere with, or become injurious to, existing or designated uses.

Response: To the extent CBD is claiming either that: 1) pH levels are not meeting applicable pH criteria and thus designated and existing uses are not being maintained or protected; or 2) acidification may be causing or contributing to an impairment of Washington's applicable aquatic life uses and narrative standards; the analysis regarding those specific standards have been addressed in Ecology's responses to Comment #1 and Comment #2. CBD has not clearly identified any other basis for noncompliance with antidegradation requirements. Furthermore, CBD has not identified which specific Washington waters would need to be listed for not meeting antidegradation requirements and has not provided a basis to justify such a listing of waters.

Comment #4: Ecology should look beyond the data submitted by CBD to identify waters impaired by ocean acidification. Washington has several coastal monitoring datasets, including many with quality assurance. Washington has data available on pH, salinity, temperature, and other parameters that may be useful for determining changes in pH and anthropogenic signal.

Response: Ecology used all data that met credible data requirements for the Water Quality Assessment. The Ecology marine monitoring unit conducted an assessment of pH data collected via electrode probe, performing comparative analyses during the same 2008 research voyage where NOAA scientists (Drs. Feely & Alin) collected measurements of DIC and total alkalinity to calculate pH changes in Puget Sound waters. Based on the results of these comparative surveys and communicated by Dr. Feely to Ecology's marine monitoring unit, the data generated by electrode pH probe could be subject to large ($\pm$0.5 pH units), non-quantifiable error and inadequate to assess changes in pH due to anthropogenic contribution. Based on this, a decision was made that the pH data does not represent credible data in accordance with Water Quality Policy 1-12 and was not used for the Water Quality Assessment.

Comment #5: CBD disputes Ecology's previous response that the studies provided by them are not specific to Washington and therefore cannot be used as a basis for 303(d) listing. CBD also asserts that impaired listings can be made without site-specific monitoring data.

Response: Washington State law (Water Quality Data Act codified in RCW 90.48.570 through 90.48.590) requires Ecology to use credible data to determine whether any water of the state is to be placed on or removed from any section 303(d) list and whether any surface water of the state is supporting its designated use or other classification. See: http://www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf.

Data are considered credible data if:

- Appropriate quality assurance and quality control procedures were followed and documented in collecting and analyzing water quality samples;
- The samples or measurements are representative of water quality conditions at the time the data were collected;
- The data consist of an adequate number of samples based on the objectives of the sampling, the nature of the water in question, and the parameters being analyzed; and
- Sampling and laboratory analysis conform to methods and protocols generally acceptable in the scientific community as appropriate for use in assessing the condition of the water.

Most of the studies submitted by CBD did not provide sufficient or appropriate information to assess whether or not Washington waters were attaining the water quality standards (see Enclosure 1). Ecology identified eleven studies that could be relevant to the Washington Water Quality Assessment (see Enclosure 2). However, none of these studies showed impairment (or impairment by the next listing cycle) of Washington water bodies for pH criteria (discussed in more detail under comment #1) or narrative aquatic life use standards (discussed in more detail under comment #2). Therefore, a category 5 impaired or threatened listing was not triggered.

Ecology appreciates the dedication CBD has in its campaign to combat effects from ocean acidification. Ecology received more than 21,000 emails from around the globe as part of the CBD email action campaign in support of the issue. Despite the conclusion that Washington coastal waters cannot be listed in Category 5 as threatened or impaired for ocean acidification,

we want to assure you that Washington takes the issue of ocean acidification very seriously. The state is working to identify science and data gaps in understanding ocean acidification and what steps the state can take to curb effects from ocean acidification at the regional and local level.

To demonstrate the state's commitment, Washington's Governor Gregoire convened a Blue Ribbon Panel (Panel) on Ocean Acidification in February 2012. The Panel, which includes scientific experts, relevant agencies, and stakeholders, is to develop clear, actionable recommendations on understanding, monitoring, adapting, and mitigating ocean acidification in Puget Sound and Washington waters. The Panel results will be delivered in a report to the Governor by October 1, 2012. To follow efforts of the Blue Ribbon Panel and to get more information on what the department is doing to address climate change, go to http://www.ecy.wa.gov/climatechange/index.htm.

Coinciding with the work of the Blue Ribbon Panel is our determination that Puget Sound waters should be listed in Category 2 (waters of concern) for potential impacts to fish and shellfish habitat from human activities, including conditions that makes the waters more vulnerable, such as climate change, urbanization, and ocean acidification. This listing is based on narrative critiera (WAC 173-201A-260(2)) intended to protect existing and designated uses.

Category 2 is the appropriate category because it applies when some credible data create concerns of possible impact to designated uses, but fall short of demonstrating that there is a persistent problem. Category 2 listings are intended to help Ecology and the public be aware of, track, and investigate these water quality concerns. The results of the Governor's Blue Ribbon Panel on Ocean Acidification will provide key information that Ecology will use for future efforts in Puget Sound and elsewhere to try to deal with ocean acidification at the regional and local level.

If you have further questions regarding our responses, please feel free to contact me at 360-407-6414 or by email at subr461@ecy.wa.gov.

Sincerely,

Susan Braley

Susan Braley
Unit Supervisor
Watershed Management Program

cc: Jill Gable, USEPA Region 10

Center for Biological Diversity
Cited References on Ocean Acidification
June 2012

The Center for Biological Diversity (CBD) submitted several letters to Ecology and EPA in support of their request for Ecology to list coastal waters in Washington on Category 5 as threatened or impaired for ocean acidification. These letters collectively include 128 references as documentation for their request. Ecology reviewed all of the references to determine if the studies provided relevant documentation of declines in pH not within the acceptable limits or documenting violations of the narrative standards for protecting existing and designated aquatic life uses.

The following table provides the results of the initial review of the references. The far right column (potentially relevant to Washington) is marked "yes" if the reference contains data or information that could potentially be used in Washington's Water Quality Assessment. The Grey Highlighted references marked "yes" were then further reviewed for relevance to the Water Quality Assessment, and whether information or data demonstrated attainment or nonattainment of Washington's water quality standards, particularly the pH criteria and aquatic life designated use standards. References that were not found to be relevant to Washington's Assessment were marked "no" according to one or more of these reasons:

(a) Study location was not within, near or representative of Washington waters and/or study includes organisms not found in Washington waters; or study methods not documented.
(b) Methods used in the study are not appropriate for Assessment of ambient waters (i.e. lab or hatchery studies, not representative of natural populations).
(c) Data and methods were not readily available (i.e. news articles or conference proceedings did not include ambient monitoring data for Washington).
(d) Modeled results are not appropriate to determine that standards in Washington are being met because of spatial scale (i.e. global model) or data inputs not within, near, or representative of Washington waters, or uncertainties in model.

CBD[1] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
11	Abbasi	2011	Ocean Acidification: The Newest Threat to the Global Environment. *Critical Reviews in Environmental Science and Technology*	A worldwide and historical perspective on changes in the ocean's pH levels due to increasing COs	NO(a)(c)
07	Anderson et al	2006	Coastal Ocean CO—Carbonic Acid Carbonate Sediment System of the Anthropocene	Global effects of increasing CO2	NO(a)(d)
11	Anderson and Bows	2010	Beyond 'dangerous' climate change: emission scenarios for a new world.	Philosophical Transactions of the Royal Society	NO(a)(c)
07 **09**	Barry et al.	2005	Utility of Deep Sea CO2 Release Experiments in Understanding the Biology of a High-CO2 Ocean: Effects of Hypercapnia on Deep Sea Meiofauna	California central coast deep sea CO2 release experiments	NO(a)(b)
09	Barton, et al.	2009	Larval Performance at Whiskey Creek Shellfish Hatchery	Lab study of hatchery oyster larvae at Tillamook, Ore.	NO(b)(c)
09	Beesley et al.	2008	Effects of CO2-induced seawater acidification on the health of Mytilus edulis	60 day mesocosm experiment on mussels	NO(a)(b)
12	Barton et al	2012	The Pacific oyster, Crassostrea gigas, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects.	Study linking laboratory results to oyster hatchery conditions in Oregon	YES

[1] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[2] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
08 **09**	Bibby et al.	2007	Ocean acidification disrupts induced defences in the intertidal gastropod Littorina Littorea	Laboratory investigations on snails in the UK	NO(a)(b)
09	Bibby et al.	2008	Effects of Ocean Acidification on the Immune Response of the Blue Mussel (Mytulis edulis)	Lab investigation of blue mussels in UK	NO(a)(b)
07 **09**	Bindoff et al.	2007	Observations: Oceanic Climate Change and Sea Level	Global Observations on Climate Change	NO(c)
12	Bonfils	2010	Ocean acidification hits Northwest oyster farms	News article on Oregon oyster hatchery and negative effects	YES
11	Byrne et al	2010	Direct observations of basin-wide acidification of the North Pacific Ocean.	Large scale review of historic and recent data on the North Pacific (between Oahu, HI and Kodiak, AK)	NO(a)(d)
07 **09**	Caldeira and Wickett	2003	Anthropogenic carbon and ocean pH	General overview of Anthropogenic carbon and ocean pH	NO(c)
09	Caldeira and Wickett	2005	Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean	General Ocean Modeling studies to predict CO2 changes	NO(a)(d)
08 **09**	Caldeira et al.	2007	Comment on ‘‘Modern-age buildup of CO2 and its effects on seawater acidity and salinity’’	Outside the US	NO(a)(c)

[2] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[3] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
11	Canadell et al	2007	Contributions to accelerating atmospheric CO2 growth from economic activity, carbon intensity, and efficiency of natural sinks	Large scale review of atmospheric CO2 and evidence of changes in carbon cycle that are affecting climate forcing	NO(a)(c)
09	Cao and Caldeira	No Date	Atmospheric CO2 stabilization and ocean acidification	Modeling simulation of CO2 stabilization	NO(c)(d)
07	Chavez et al	2007	Chapter 15: Coastal Oceans, North American Carbon Budget and Implications for the Global Carbon Cycle	Global review and study of changing carbon cycle	NO(c)
09	Cohen et al.	2009	Morphological and compositional changes in skeletons of new coral recruits reared in acidified water	Lab investigations on coral	NO(a)(b)
11	Cohen	2010	Acidity in much of the Sound can be lethal Scientists	Article in Seattle P.I.	YES
09	Comeau et al.	2009	Key Arctic pelaic mollusc (Limacina helicina) threatened by ocean acidification	Lab investigation of pteropods in Sweden	NO(a)(b)(c)
09	Cooley and Doney	2009	Anticipating ocean acidification's economic consequences for commercial fisheries	Economic study	NO(c)
11	Cooley and HiKite-Powell	2009	Ocean acidification's potential to alter global marine ecosystem services	Synthesis of Peer-reviewed articles, not specific to WA waters	NO(a)(c)
08 **09**	Cooper et al.	2007	Declining coral calcification in massive Porites in two nearshore regions of the northern Great Barrier Reef	Field investigation of coral reef growth in the Great Barrier Reef	NO(a)

[3] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[4] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
09	Cribb	2008	Acid Oceans	International paper describing decline of oceans due to acidification	NO(a)(c)
11	Crimm et al	2011	Elevated seawater CO2 concentrations impair larval development and reduce larval survival in endangered northern abalone (Haliotis kamtschatkana)	Results of Laboratory study on abalone from CB Canada	NO(a)(b)
09	Dashfield et al.	2008	Impacts of ocean acidification and burrowing urchins on within-sediment pH profiles and subtidal nematode communities	Lab experiment conducted in UK	NO(a)(b)
09	De'ath	2009	Declining Coral Calcification on the Great Barrier Reef	Field investigation of coral reef growth in the Great Barrier Reef	NO(a)
09	Denman et al	2007	Couplings Between Changes in the Climate System and Biogeochemistry	Paper observing changes in land surface to increasing CO2	NO(a)(c)
09	Doney, et al.	2007	Impact of anthropogenic atmospheric nitrogen and sulfur deposition on ocean acidification and the inorganic carbon system	Overview of Impacts Worldwide	NO(c)
09	Doney et al.	2008	Ocean Acidification: The Other CO_2 Problem	Observations of worldwide impacts from rising CO2	NO(c)
09	EPA	2009	Ocean Acidification and Marine pH Water Quality Criteria Federal Register 74: 17484	Federal Register Notice	NO(c)
11	EPA	2010	Memo: Integrated reporting and listing decisions related to ocean acidification	Overview for all states	NO(c)
09	Dore et al.	2009	Physical and biogeochemical modulation of ocean acidification in the central North Pacific	Measuring long term trends-time series measurements in Hawaii	NO(a)(d)

[4] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[5] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
07 **09**	Feely et al.	2004	Impact of Anthropogenic CO2 on the CaCO3 System in the Oceans	Observations of Rising CO2 and ocean threats	NO(a)(c)
07 **09**	Feely et al.	2006	Carbon Dioxide and Our Ocean Legacy	Overview of Impacts Worldwide from rising CO2	NO(a)(c)
09 **11** **12**	Feely et al.	2008	Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf	Pacific Continental Shelf	YES
11 **12**	Feely et al	2010	The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary	Washington	YES
09	Findlay et al.	2009	Novel microcosm system for investigating the effects of elevated carbon dioxide and temperature on intertidal organisms	Mesocosm experiment on intertidal organisms	NO(a)(b)
11	Friedlingstein et al	2010	Update on CO2 emissions	Paper on Global Carbon Project	NO(c)
12	Friedrich et al	2012	Detecting regional anthropogenic trends in ocean acidification against natural variability	Global observations of historic and current effects from ocean acidification	NO(c)
11	Fussel	2009	An updated assessment of the risks from climate change based on research published since the IPCC Fourth Assessment Report	Broad overview of global effects of climate change	NO(c)

[5] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[6] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
09	Gangsto et al.	2008	Modeling the marine aragonite cycle: changes under rising carbon dioxide and its role in shallow water CaCO3 dissolution	Modeling studies on a worldwide basis	NO(a)(d)
11 **12**	Gaylord et al	2011	Functional impacts of ocean acidification in an ecologically critical foundation species	Laboratory study on affects of mussel larvae cultured in seawater infused with CO2	NO(a)(b)
07	Gattuso et al	1998	Effect of Calcium Carbonate Saturation of Seawater on Coral Calcification	Lab investigation of corals	NO(a)(b)
12	Gazeau et al	2011	Effect of Carbonate Chemistry Alteration on the Early Embryonic Development of the Pacific Oyster (Crassostrea gigas)	Laboratory experiment on Pacific oyster and CO2 effects	NO(a)(b)
07 **09**	Gazeau et al.	2007	Impacts of elevated CO2 on shellfish calcification	Laboratory experiment on Pacific oyster and CO2 effects	NO(a)(b)
07	German Advisory Council on Global Change	2006	The Future Oceans—Warming Up, Rising High, Turning Sour	Global view of changing ocean chemistry and options to store CO2	NO(c)
11	Global Carbon Project	2010	Carbon Budget 2009	Global Review & estimates of carbon	NO(c)
07	Gruber et al.	1996	An improved method of detecting CO_2 in the oceans	Study on separating anthropogenic CO2 from the large natural background variability of dissolved inorganic carbon in the ocean	NO(b)(c)

[6] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[7] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
07 **09**	German Advisory Council on Global Change	2006	The Future Oceans, Warming Up, Rising High, Turning Sour	Overview of Impacts Worldwide from rising CO2	NO(c)
09	Gledhill et al.	2008	Ocean acidification of the Greater Caribbean Region 1996–2006	Field investigation of rising CO2 in the Caribbean region	NO(a)(d)
09	Green et al	2009	Death by dissolution: Sediment saturation state as a mortality factor for juvenile bivalves	Lab investigations on bivalves on the East Coast U.S.	NO(a)(b)
07 **09**	Guinotte et al.	2006	Will human-induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals?	Observations on seawater changes and affects on corals	NO(c)
09	Guinotte and Fabry	2008	Ocean Acidification and Its Potential Effects on Marine Ecosystems	Observations on seawater changes and affects on marine organisms	NO(c)
09	Hall-Spencer et al.	2008	Volcanic carbon dioxide vents show ecosystem effects of ocean acidification	Field and lab investigations near volcanic vents	NO(c)
08	Halpern	2008	Global Map of Human Impact on Marine Ecosystems	Global review	NO(c)
09	Hansen et al.	2008	Target Atmospheric CO_2: Where Should Humanity Aim	Global overview	NO(c)
09	Harrould-Kolieb and Savitz	2008	Acid Test: Can We Save our Oceans From CO_2	Worldwide overview	NO(c)
07	Haugan et al.	2006	Effects On the Marine Environment of Ocean Acidification Resulting From Elevated Levels of CO_2 in the Atmosphere	Overview of reports and studies on changing ocean CO2 in North Atlantic	NO(c)

[7] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[8] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
11	Hauri et al.	2009	Accelerated Acidification in Eastern Boundary Systems	Abstract regarding the California Current System	NO(a)(d)
12	Hauri et al	2009	Ocean acidification in the California current system	Observations and modeling to determine the carbonate chemistry of California currents in relatont o increased ocean CO2	NO(a)(d)
09	Hester et al.	2008	Unanticipated consequences of ocean acidification: A noisier ocean at lower pH	Study of ocean sound absorption in relation to lower pH	NO(a)(c)
08 **09**	Hoegh-Guldberg et al.	2007	Coral Reefs Under Rapid Climate Change and Ocean Acidification	Observations of coral reefs under climate change and increasing CO2	NO(a)(c)
12	Honisch et al	2012	The Geological Record of Ocean Acidification	Study of geologic record to demonstrate global effects of ocean acidification	NO(c)
09	Interacademy Panel	2009	Interacademy Panel Statement On Ocean Acidification	Overview of Impacts Worldwide	NO(c)
09	Intergovernmental Panel on Climate Change	2007	Climate Change 2007: Synthesis Report	Global Observations	NO(c)
07 **09**	Ishimatsu et al.	2004	Effects of CO2 on Marine Fish: Larvae and Adults	Laboratory investigations of fish larvae effects from increasing CO2	NO(a)(b)

[8] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[9] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
11 **12**	Juranek et al	2009	A novel method for determination of aragonite saturation state on the continental shelf of central Oregon using multi-parameter relationships with hydrographic data	Modeling study on the central Oregon coast to determinate aragonite saturation state during periods of upwelling	NO(a)(d)
11	Kelly et al	2011	Mitigating Local Causes of Ocean Acidification with Existing Laws	Policy paper on using existing laws to mitigate potential causes of OA	NO(c)
0709	Kleypas et al.	2006	Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers	Overview of Impacts Worldwide with some general California locations	NO(a)(c)
0709	Kolbert	2006	The Darkening Sea	Policy paper on working to eliminate increasing CO2 in oceans	NO(c)
11 **12**	Kroeker et al	2010	Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms	Article analyzing existing peer-reviewed literature on OA effects on biological responses	NO(c)
09	Kuffner et al.	2007	Decreased abundance of crustose coralline algae due to ocean acidification	Outdoor Lab Investigation in Hawaii)	NO(a)(b)
09	Langdon et al.	2003	Effect of elevated CO2 on the community metabolism of an experimental coral reef	Mesocosm experiment on corals	NO(a)(b)
09	Langdon et al.	2005	Effect of elevated pCO2 on photosynthesis and calcification of corals and interactions with seasonal change in temperature/irradiance and nutrient enrichment	Laboratory experiment to determine elevated affects of pCO2 on corals	NO(a)(b)
11 **12**	Langston	2011	*Sightline Daily*: The Puget Sound Shuffle The Acid Test Coming to a Shore Near You	Overview of articles highlighting ocean acidification studies and information	NO(c)

[9] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[10] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
11	Langston	2011	Trouble on the Half Shell	Article highlighting information on oyster hatchery declines from corrosive sea water in Washington	YES
11	Lenton	2008	Elements in the Earth's climate system	Global view of tipping elements in the global climate system under anthropogenic forcing.	No(c)
11	Lischka et al	2011	Impact of ocean acidification and elevated temperatures on early juveniles of the polar shelled pteropod *Limacina helicina*:mortality, shell degradation, and shell growth	Field and lab study of impacts to shellfish in arctic waters	NO(a)(b)
09	Maier et al	2009	Calcification of the cold-water coral Lophelia pertusa under ambient and reduced pH	Research study on cold water corals in the North Atlantic	NO(a)(b)
09	Marine Ecology Press Series	2008	Effects of ocean acidification on marine ecosystems	Overview of ocean acidification effects	NO(c)
09	McMichael et al.	2006	Climate Change and Human Health: Present and Future Risks	Overview of increasing risks of climate change	NO(c)
11	McMullen and Jabbour	2009	Climate Change Science Compendium 2009	Global perspectives of Climate Change	NO(c)
07 **09**	McNeil and Matear	2006	Projected Climate change impact on ocean acidification	General overview	NO(c)
09	McNeil and Matear	2008	Southern Ocean acidification: A tipping point at 450-ppm atmospheric CO2	Observations of ocean acidification in Australia	NO(a)(d)

[10] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

CBD[11] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
09	Meehl et al	2007	Global Climate Projections	Global observations	NO(c)
09	Miles et al.	2007	Effects of anthropogenic seawater acidification on acid-base balance in the sea urchin	Field and lab Investigation of sea urchin in UK	NO(a)(b)
09 **11** **12**	Miller et al.	2009	Shellfish Face Uncertain Future in High CO_2 World: influence of acidification on oyster larvae calcification and growth in estuaries	Lab investigations on oyster larvae on the Atlantic Coast U.S.	NO(a)(b)
09	Monaco Symposium	2008	Monaco Declaration - Symposium on the Ocean in A High CO_2 World:	Declaration of observation and concern	NO(c)
07	Morgan et al	2006	Status of Deep Sea Coral in US Waters, with Recommendations for their Conservation and Management	Scientific paper on damage to deep sea corals from human activities	NO(a)(c)
09	Moy et al.	2009	Reduced calcification in modern Southern Ocean planktonic foraminifera	Field and lab investigation of shellfish	NO(a)(b)
09	Munday et al.	2008	Ocean acidification impairs olfactory discrimination and homing ability of a marine fish	Laboratory investigations of fish from Australia	NO(a)(b)
11	Munday and Dixston	2010	Replenishment of fish populations is threatened by ocean acidification	Laboratory and field studies on effects of elevated CO2 on fish from Australia	NO(a)(b)
07 **09**	Murray et al.	2006	Reefs of the Deep: The Biology and Geology of Cold-Water Coral Ecosystems	Overview of Coral Reefs	NO(c)

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CBD[12] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
11	National Research Council	2010	*Ocean Acidification : A National Strategy to Meet the Challenges of a Changing Ocean*	National level recommendations on ocean acidification	NO(c)
08 **09**	Nelleman et al.	2008	In Dead Water, Merging of Climate Change With Pollution, Over Harvest, and Infestations in the Worlds Harvest Grounds	General Discussion regarding the Pacific Northwest	NO(c)
07 **09**	Orr et al.	2005	Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms	Overview of Impacts Worldwide	NO(c)
11	Pelejero and Calvo	2010	Paleo-perspectives on ocean acidification	Scientific observations not specific to location	NO(c)
07 **09**	Pörtner et al.	2004	Biological Impact of Elevated Ocean CO2 Concentrations: Lessons from Animal Physiology and Earth History	General observations not specific to location	NO(c)
07 **09**	Portner et al.	2005	Synergistic effects of temperature extremes, hypoxia, and increases in CO2 on marine animals: From Earth history to global change	General overview of effects from increased CO2	NO(c)
11	Quesne and Pinnegar	2011	The potential impacts of ocean acidification: scaling from physiology to fisheries	Global paper on ocean acidification	NO(c)
11	Raupach et al	2007	Global and regional drivers of accelerating CO2 emissions.	Global paper on increasing CO2	NO(c)
11	Richardson et al	2009	Synthesis Report from Climate Change: Global Risks, Challenges and Decisions	Global paper on climate change	NO(c)
07 **09**	Riebesell et al.	2000	Reduced calcification of marine plankton in response to increased atmospheric CO2	General observations of conditions off the coast of California	NO(a)(c)

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CBD[13] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
09	Rosa and Seibel	2008	Synergistic Effects of Climate Related Variables Suggest Future Physiological Impairment In A Topic Oceanic Predator	Expansion of Jumbo Squid migration	NO(a)(b)
07 **09**	Royal Society	2005	Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide	Overview of studies in California	NO(c)
07 **09**	Ruttimann	2006	Sick Seas: The Rising Level of Carbon Dioxide in the Atmosphere is Making the World's Oceans More Acidic	General overview	NO(c)
07 **09**	Sabine et al.	2004	The Oceanic Sink for Anthropogenic CO2	Overview of Impacts Worldwide	NO(c)
07 **09**	Shirayama and H. Thornton	2005	Effect of increased atmospheric CO2 on shallow water marine benthos	Outdoor Lab Investigation - Japan	NO(a)(b)
09	Silverman et al.	2009	Coral reefs may start dissolving when atmospheric CO2 doubles	Observations of increasing CO2	NO(c)
11 **12**	Southern California Coastal Water Research Project	2010	Ocean acidification effects on shellfish workshop: Findings and recommendations	Findings of SCCWRP and Presentation on Taylor Shellfish Hatchery in Puget Sound, WA	YES
09	Steinacher et al.	2008	Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model	Modeling study in Arctic	NO(a)(d)
09	Stone	2007	A World Without Coral	Global overview of increasing CO2	

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					NO(c)
CBD[14] Letters	**Author**	**Date of Study**	**Name of Article/Study**	**Area of Study**	**Potentially Relevant to Washington**
11	Talmadge and Gobler	2009	The effects of carbon dioxide concentrations on the metamorphosis, size, and survival of larval clams, bay scallops, and Eastern oysters	Results of lab experiments conducted on clams, scallops, and oysters	NO(a)(b)
11	Tans	2009	An accounting of the observed increase in oceanic and atmospheric CO2 and an outlook for the future	Review of data on global changes in CO2 and future effects	NO(a)(c)
07 **09**	Turley et al.	2005	Reviewing the Impact of Increased Atmospheric CO2 on Oceanic pH and the Marine Ecosystem	General overview	NO(c)
08 **09**	Turley et al.	2007	Corals in deep-water: will the unseen hand of ocean acidification destroy cold-water ecosystems?	Global Observations	NO(c)
09	USGS	2007	Mercury in the Environment Fact Sheet 146-00	Impacts to US as a Whole	NO(c)
09	Walther et al.	2009	Impact of anthropogenic ocean acidification on thermal tolerance of the spider crab	Field and lab investigation of spider crab	NO(a)(b)
11	Welch	2010	Shellfish at risk: Puget Sound becoming acidified. *Seattle Times*.	Article on hatchery problems in Puget Sound, WA	YES
09 **11** **12**	Welch	2009	Oysters in deep trouble (article in Seattle Times)	Impacts in the Pacific Northwest (Willapa Bay, WA)	YES
09	Widdicombe and Needham	2007	Impact of CO_2-induced seawater acidification on the burrowing activity of Nereis virens and sediment nutrient flux	35 day mesocosm experiment on Nereis virens	NO(a)(b)

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CBD[15] Letters	Author	Date of Study	Name of Article/Study	Area of Study	Potentially Relevant to Washington
09	Widdicombe and Spicer	2008	Predicting the impact of ocean acidification on benthic biodiversity: What can animal physiology tell us?	Predictions of ocean acidification effects at global level	NO(c)
09 **11** **12**	Wootton et al.	2008	Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset	Tatoosh Island on Makah Tribal Reservation, Washington	YES
09	Wootton	2009	Dataset from Tatoosh Island	Tatoosh Island on Makah Tribal Reservation, Washington	YES
09	Zeebe et al.	2008	Carbon Emissions and Acidification	General overview of increasing CO2	NO(c)

[15] Center for Biological Diversity submitted letters to Ecology and EPA on the following dates: 8/15/07, 3/20/08, 9/25/09, 8/8/11, 1/12/12, and 4/23/12. This column denotes letters that provided the reference, by year.

Center for Biological Diversity
Ecology Assessment of Relevant CBD References
June 2012

1) **Barton et al, 2012:** *The Pacific oyster, Crassostrea gigas, shows negative correlation to naturally elevated carbon dioxide levels: Implications for near-term ocean acidification effects*.

Document summary: This scientific paper reports results from an oyster hatchery on the Oregon coast, where intake waters experienced variable carbonate chemistry (aragonite saturation state , 0.8 to . 3.2; pH , 7.6 to . 8.2) in the early summer of 2009. Both larval production and midstage growth of the oyster Crassostrea gigas were significantly negatively correlated with the aragonite saturation state of waters in which larval oysters were spawned and reared for the first 48 hours of life. The effects of the initial spawning conditions did not have a significant effect on early-stage growth, suggesting a delayed effect of water chemistry on larval development. The study results highlight the ecological significance of windows of opportunity for successful recruitment in the natural environment. However, the study also notes they have evaluated hatchery production and therefore minimized the typically extreme mortality of larval oysters in the wild by growing them under otherwise ideal conditions. The study further notes that two significant shortcomings exist with regard to understanding acidification effects on natural populations of organisms in variable coastal and estuarine habitats: prediction of how carbonate conditions will vary in coastal and estuarine environments with increasing atmospheric CO2 and a better understanding of the fundamental biology underlying the responses of multicellular organisms to acidification. The first of these will be addressed by development of better predictive capability such that stakeholders may be able to plan production operations for the most favorable conditions. The second can be addressed only by more focused experimental work on physiological mechanisms of early larval response in conditions with tightly controlled carbonate chemistry.

Ecology Assessment: This paper provides important findings that validate and help link laboratory-based acidification experimental results to less controlled hatchery production system conditions that are strongly influenced by ambient water quality characteristics. The results show that influent water drawn from Netarts Bay is causing mortality in the Whiskey Creek Hatchery system when the bay is under more acidic (lower pH) conditions. However, the authors note that there are significant shortcomings with regard to understanding acidification effects on natural populations of organisms in the variable natural environment. The highly variable carbonate chemistry in the bay, natural coastal upwelling of more acidic water, and the uncertainty associated with a specific biological response does not allow the hatchery results to be simply extrapolated to the natural system with any certainty. Although the findings support Ecology's concern that ocean acidification could be having detrimental effects on the ecological conditions in Washington's waters, it does not definitively link oyster mortalities in Oregon hatcheries to ocean acidification in the natural coastal environments of Washington. This study does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being

impaired by ocean acidification. Therefore, the study does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

2) Bonfils, 2010: *Ocean acidification hits Northwest oyster farms*

Document summary: This ABC News article and video on the Whiskey Creek Shellfish Hatchery in Tillamook, Oregon highlights problems experienced with reproducing oyster larvae in their hatchery starting in 2007. The article provides a broad overview of the increasing complexity of carbon dioxide in ocean waters and suggests estimates of how much carbon has been absorbed by the oceans in historic and recent times. It also suggests that the entire U.S. shellfish industry could be impacted by ocean acidity. The article does not draw any conclusions.

Ecology Assessment: This article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the article does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

3) Cohen, 2010: *Acidity in much of the Sound can be lethal*

Document Summary: This Seattle P.I. news article provides an overview of NOAA's research on ocean acidification, and highlights concerns expressed by scientist, shellfish growers, and tribal members that Washington's coastal waters are being impacted by ocean acidification. It describes plans by NOAA and the University of Washington to install sophisticated monitoring equipment off the coast at LaPush, Washington, to monitor the weather, atmosphere, water chemistry, and plankton growth. It also notes that a sensor has been installed at the top of the Space Needle to monitor increasing carbon dioxide. The article does not draw any conclusions.

Ecology Assessment: This article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the study does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

4) Feely et al, 2008: *Evidence for Upwelling of Corrosive "Acidified" Water onto the Continental Shelf*

Document summary: To better understand the extent of ocean acidification in coastal waters, this study conducted hydrographic surveys along the continental shelf of western North America from central Canada to northern Mexico. Authors observed seawater that is under-saturated with respect to aragonite upwelling onto large portions of the continental shelf, reaching depths of approximately 40 to 120 meters along most transect lines and all the way to the surface on one transect off northern California. Although seasonal upwelling of the under-saturated waters onto the shelf is a natural phenomenon in this region, the ocean uptake of anthropogenic CO2 has increased the areal extent of the affected area. The article reports that the causes of this decrease

were a result of upwelling processes, respiration processes and anthropogenic effects. The authors concluded that due to anthropogenic increases in CO2 since the preindustrial era, under-saturated waters have shoaled closer to the surface and near the coast. They also state that further research is needed to understand how these under-saturated waters will affect calcifying organisms. The authors state that the strongest upwelling is not predicted to occur in open-ocean waters until 2050.

Ecology Assessment: This is a significant and instructive study, with important implications for estuaries and bays on the U.S. west coast. For most of the transects where chemical data were collected, including those closest to Washington waters, the study reported pH values as less than 7.75, which cannot be used to determine whether the standard is being met since it is not an exact value. While the study estimated that these lower pH values are affecting waters closer to the surface, it did not demonstrate non-attainment of Washington's pH standard, which requires that pH must be within the range of 7.0 to 8.5 units, with a human-caused variation within the range of less than 0.2 units (for extraordinary marine quality waters) or less than 0.5 units (for excellent marine quality waters). The study does not demonstrate whether there was a pH change greater than 0.2 units due to human causes. Instead it reported estimated changes in aragonite saturation.

This study did not collect any biology data, but did cite laboratory studies suggesting negative impacts to calcifying organisms and highlighted the need for further research on the impacts of ocean acidification to aquatic life under field conditions. Since this information was for discussion purposes, and the study did not report any observed impairments to aquatic life in the field, it is not appropriate to use in assessing the narrative standards for aquatic life. In summary, this article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the study does not provide a basis for coastal waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

5) **Feely et al, 2010***: The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary*

Document summary: In order to study the combined effects of ocean acidification and other natural and anthropogenic processes on Puget Sound waters, this study involved the first inorganic carbon measurements in this estuary on two survey cruises in February and August of 2008. The study states: "The patterns of low pH and aragonite saturation states observed in the Puget Sound estuary complex are largely the result of natural mixing, circulation, and biological processes at the present time. Ocean acidification currently plays a smaller but important role in further lowering the natural pH levels by 0.05-0.15 units, with decreases in aragonite saturation state on the order of 0.02-0.33. By the end of this century, ocean acidification may become the dominant process reducing the pH and saturation state of this large, economically important estuary. However, it may be possible to mitigate the continued development and impacts of corrosive conditions by addressing and reducing the regional-scale anthropogenic stressors that contribute to their formation, such as additional nutrient inputs associated with development and urbanization."

The study notes that since there are no high-quality, long-term, carbon times-series measurements in Puget Sound, it is not possible to directly determine the increase of anthropogenic CO2 in the region. While field data on the impacts of CO2 on the local marine ecosystems of Puget Sound do not exist, laboratory and field experiments with related species of calcifying organisms suggest that there is a real cause for concern for the health of this economically important marine ecosystem. Similar processes may be causing decreases of pH and aragonite saturation states in other coastal estuaries and embayments of the Pacific Northwest and elsewhere. Further study of ocean acidification in estuaries is thus warranted because natural factors, including acidic river inputs and restricted circulation, can predispose these ecologically and economically important habitats toward corrosive, hypoxic conditions, and anthropogenic stressors, such as nutrient enrichment, may compound them.

Ecology Assessment: This is a significant and instructive study, with important implications for Puget Sound estuaries. However, the study is based on estimates that do not provide actual values to make Category listing decisions on. While the study estimated that lower pH values (<7.5) are occurring in deep waters of Hood Canal and Juan de Fuca, it does not demonstrate non-attainment of Washington's pH standard, which requires that pH must be within the range of 7.0 to 8.5, with a human-caused variation within the range of less than 0.2 units (for extraordinary marine quality waters) or less than 0.5 units (for excellent marine quality waters). The study reported estimated values that were within the acceptable pH criteria range of 7.0-8.5. Further, the study does not demonstrate a pH change greater than 0.2 units due to human causes. Instead, it reported an estimated anthropogenic pH decrease of up to 0.11 units.

This study did not collect any biology data, but did cite laboratory studies suggesting negative impacts to calcifying organisms and highlighted the need for further research on the impacts of ocean acidification to aquatic life under field conditions. Since this information was for discussion purposes, and the study did not report any observed impairments to aquatic life in the field, it is not appropriate to use in assessing the narrative standards for aquatic life. In summary, this article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being threatened or impaired by ocean acidification. Therefore, the study does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life. The study does provide credible information suggesting contributions from climate change, urbanization and ocean acidification are putting Puget Sound at risk, and we did use this study as a basis for listing Puget Sound waters in Category 2 as a "waters of concern".

6) Langston, 2011: *Trouble on the Half Shell*

Document Summary: This Sightline Institute article highlights problems with oyster larvae die-offs occurring at hatcheries in Oregon and Washington due to ocean acidification coming from seasonal upwelling events off the Pacific coast. The article notes the uncertainties in whether the acidification is the sole cause of the hatchery die-offs and why the upwelled water is so lethal. It also notes the uncertainties with relating what is happening in the hatcheries to natural fluctuations. The article tries to estimate what might happen in future years to the oyster industry if ocean acidification continues to affect the hatcheries. It also expresses concerns about

the future of wild creatures having to fend for themselves in more acidic seas. The article does not draw any conclusions.

Ecology Assessment: This article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. In fact, the article notes significant uncertainties with relating what is happening in hatcheries to what is happening in the natural environment. Therefore, the article does not provide a basis for coastal waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

7) **Southern California Coastal Water Research Project, 2010**: *Ocean Acidification Impacts on Shellfish Workshop: Findings and recommendations*

Document Summary: This workshop was planned to bring together stakeholders from the US west coast who are working to understand and address ocean acidification. The workshop summary states that the extent of ocean acidification effects is unknown at present, though it could threaten valuable west coast fisheries for oysters, mussels, clams, sea urchins and other shellfish. The findings state that workshop participants generally agreed that existing datasets cannot be used to explain impacts of ocean acidification on shellfish productivity. These datasets are physically and spatially dissociated and standardized protocols for data collection have not been applied.

Addressing questions about ocean acidification requires integration of ocean observing measurements, laboratory exposure studies, shellfish recruitment and production data, and field studies of organism performance in relation to ocean conditions. To date, these data have been collected by different sectors with limited interaction. The final recommendations highlight the need to: 1) coordinate chemical data collection at the best biological monitoring sites, leveraging long-term data sets and employing standardized methods, 2) supplement correlative data with an understanding of biological processes, and 3) develop predictive models at smaller scales.

Ecology Assessment: The workshop findings do not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. In fact, the findings emphasize that existing datasets cannot explain the impacts of ocean acidification on shellfish productivity, and that there is a need for more coordinated data collection at good reference sites, the need for supplemental correlative data with the understanding of biological processes, and the need for predictive models at smaller scales. Therefore, the study does not provide a basis for coastal waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

8) Welch, 2009: *Shellfish at risk: Puget Sound becoming Acidified*

Document summary: This Seattle Times news article highlights concerns from oyster growers that ocean acidification is harming their industry and harming wild oysters. The article states that waters in Puget Sound's main basin are acidifying as fast as those along the Washington Coast, where wild oysters have not reproduced since 2005. The article states that the pH of ocean surface waters has dropped about 30 percent, and is expected to drop far more over the next century. The article also states that because of the way marine water circulates in our part of the Pacific Ocean, waters were becoming even more corrosive closer to shore, where most sea creatures live. The articles states that scientists have estimated that a quarter to a half of the increased corrosiveness in Hood Canal was due to man-made carbon dioxide dissolving in the water, and that percentage could increase to more than 80 percent in coming decades.

Ecology Assessment: This article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the study does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

9) Welch, 2010: *Oysters in deep trouble: Is Pacific Ocean's chemistry killing sea life?*

Document summary: This Seattle Times article highlights oyster larvae die-offs due to ocean acidification and concerns about the future of the shellfish industry and the ability of wild oysters to survive in more acidified waters. The article states that oyster larvae have been dying by the billions and that pacific oysters haven't successfully reproduced in the wild in Willapa Bay since 2004. The article does note that it is too soon to say for certain if the negative issues being seen in hatcheries are localized or part of a broader phenomenon. The hatchery is not far from a low-oxygen dead zone off the Oregon coast. There also isn't sophisticated enough equipment in place to get precise pH readings. The article does not draw specific conclusions.

Ecology Assessment: This article does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the article does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

10) Wootton et al, 2008: *Dynamic patterns and ecological impacts of declining ocean pH in a high-resolution multi-year dataset*.

Note: CBD submitted the Wootton et al (2008) study as evidence that pH criteria are being violated off the Tattoosh Island where the pH monitoring problems were located, and further asserts that Washington should list all adjacent coastal waters as impaired due to ocean acidification based on this study. Tim Wootten and Cathy Pfister from the University of Chicago also submitted a public comment letter further describing the methods and findings in the Wootton et al (2008) study (see the response to comments for the 2010 Water Quality Assessment, Commenter 20).

Document Summary: This study used a high-resolution dataset spanning eight years to demonstrate that pH at a north-temperate coastal site declined with increasing atmospheric CO_2 levels and varied substantially in response to biological processes and physical conditions that fluctuate over multiple time scales. Applying a method to link environmental change to species dynamics via multispecies Markov chain models revealed strong links between *in situ* benthic species dynamics and variation in ocean pH, with calcareous species generally performing more poorly than noncalcareous species in years with low pH. The models project the long-term consequences of these dynamic changes, which predict substantial shifts in the species dominating the habitat as a consequence of both direct effects of reduced calcification and indirect effects arising from the web of species interactions. The study results indicate that pH decline is proceeding at a more rapid rate than previously predicted in some areas, and that this decline has ecological consequences for near shore benthic ecosystems.

Ecology Assessment: Ecology reviewed the Wooten (2008) study to determine if the pH and biology data collected as part of the study could be used as a basis for listing on Category 5 in the 2010 Marine Assessment. While the Wootten study may be valid for Tatoosh Island, a spatial extrapolation of long-term trends from the study area to a larger regional change would exhibit high uncertainty since the data are from only one sampling location. Also, the study does not provide conclusive evidence that the cause of the pH change is due to human sources. For instance, the change could be caused by natural sources related to inputs from river discharges, long-shore shelf transport and planktonic specifies composition (i.e., the pH changes could be related to changes in physical conditions due to the location and changes in the patterns of primary productivity and species composition).

Further follow-up studies would be needed before Ecology could support using the data for documenting human-caused variations in pH or aquatic life impairment for Washington's coastal water bodies leading to a Category 5 listing. This study does not provide any pH data showing impairments of Washington waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the study does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.

We further note that the monitoring site where the Wootton study was conducted is located within the boundaries of the Makah Indian reservation and is unique in that it is where oceanic waters mix with outgoing water from the Strait of Juan de Fuca. The monitoring site is not subject to Washington State's authority because it is located within a tribal boundary. Tribes have independent authority for setting water quality standards and implementing regulations for waters on reservation lands under the Clean Water Act.

11) Wootton, 2009: Dataset from Tatoosh Island.

Document summary: Dataset taken from Tatoosh Island, used as part of the Wootton et al 2008 study.

Ecology Assessment: Please see Ecology's response above for Wootton et al 2008. The dataset was reviewed by Ecology's marine monitoring unit as part of the 2010 Water Quality Assessment. This dataset does not provide any pH data showing impairments of Washington

waters, nor does it provide conclusive evidence that Washington's coastal aquatic life in the natural environment are being impaired by ocean acidification. Therefore, the dataset does not provide a basis for waterbody listings in Category 5 for violations of either pH or narrative standards for aquatic life.