Washington State Blue Ribbon Panel on Ocean Acidification

Ocean Acidification: From Knowledge to Action

Summary Report

November 2012

WASHINGTON STATE BLUE RIBBON PANEL ON OCEAN ACIDIFICATION

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Summary

BETWEEN 2005 AND 2009, DISASTROUS production failures at Pacific Northwest oyster hatcheries signaled a shift in ocean chemistry that has profound implications for Washington's marine environment. Billions of oyster larvae were dying at the hatcheries, which raise young oysters in seawater. Research soon revealed the cause: the arrival of low-pH seawater along the West Coast, which created conditions corrosive to shell-forming organisms like young oysters. The problem, in short, was ocean acidification.

What is Ocean Acidification?

Ocean acidification is a reduction in the pH[1] of seawater for an extended period of time due primarily to the uptake of carbon dioxide from the atmosphere by the ocean. Local sources of acidification such as nitrogen oxides and sulfur oxide gases, or nutrients and organic carbon from wastewater discharges and runoff from land-based activities, can also contribute to ocean acidification in marine waters.

Since the beginning of the industrial era more than 250 years ago, the rapid growth in fossil fuel burning (for example, coal and oil) and land use changes have caused a dramatic rise in carbon dioxide emissions. About one-quarter of these human-generated emissions have been absorbed by the oceans. Through a well-understood series of chemical reactions, carbon dioxide gas has an acidifying effect when dissolved in seawater. As a result, the average acidity (as measured by the hydrogen ion concentration) of the surface ocean has increased about 30 percent since 1750.

Today's ocean acidification is important not only for the amount of change that has occurred thus far but also for how quickly it is happening. The current rate of acidification is nearly ten times faster than any time in the past 50 million years, outpacing the ocean's capacity to restore oceanic pH and carbonate chemistry. The rapid pace of change also gives marine organisms, marine ecosystems, and humans less time to adapt, evolve, or otherwise adjust to the changing circumstances. At the current rate of global carbon dioxide emissions, the average acidity of the surface ocean is expected to increase by 100–150 percent over pre-industrial levels by the end of this century.

1 pH is defined as the negative log of the hydrogen ion concentration in a solution. Neutral pH is 7.0. Solutions with pH values less than 7.0 are "acidic," and those with pH values greater than 7.0 are "basic." Because pH is expressed on a logarithmic scale, a small change in pH corresponds to a large change in acidity. This means that a pH of 7 is ten times more acidic than a pH of 8.

Why Does Washington Need to Act on Ocean Acidification?

As will be explained below, Washington is particularly vulnerable to ocean acidification. In addition, acidification has significant implications for Washington's marine environment, our state and local economies, and tribes.

Washington is Particularly Vulnerable to Ocean Acidification

Washington's marine waters are particularly vulnerable to ocean acidification because of regional factors that exacerbate the acidifying effects of global carbon dioxide emissions. One of the most important regional factors is coastal upwelling, which brings offshore water that is rich in carbon dioxide and low in pH up from the deep ocean and onto the continental shelf.

Because upwelled water has spent decades circulating at depth, the carbon dioxide content in today's upwelled water reflects naturally occurring carbon dioxide generated by biological processes in the ocean as well as carbon dioxide absorbed from the atmosphere 30 to 50 years ago when the water was last in contact with the atmosphere. The half-century transit time between contact with the atmosphere and re-emergence along the coast means that today's upwelled water bears the imprint of the atmosphere in about 1970, when the concentration of carbon dioxide in the atmosphere was much lower relative to today's concentration. Since then carbon dioxide concentrations have continued to climb and so has the "carbon loading" of the waters making their way to the Washington coast. Consequently, we will continue to see more acidifying conditions coming from upwelled waters for several decades to come.

Other regional factors affecting ocean acidification in Washington include runoff of nutrients and organic carbon (such as plants and freshwater algae) from land, and local emissions of carbon dioxide, nitrogen oxides, and sulfur oxides, which are absorbed by seawater from the atmosphere. The relative importance of these local drivers varies by location. For example, acidification along the outer coast of Washington and Puget Sound is strongly influenced by coastal upwelling while acidification in shallow estuaries, including those in Puget Sound, may be particularly influenced by inflows of fresh water (which is naturally lower in pH than seawater) carrying nutrients and organic carbon from human and natural sources. The added organic carbon, as well as nutrients that stimulate excessive algal growth, can make seawater more acidic when algae and other organic matter decompose.

Ocean Acidification is a Risk to Washington's Marine Species and Ecosystems

Many life processes, including photosynthesis, growth, respiration, recruitment, reproduction, and behavior are sensitive to carbon dioxide and pH. As a result, ocean acidification has the potential to affect a wide range of organisms, from seagrasses to fish, in many different ways.

Research shows that organisms that use the mineral calcium carbonate (usually in the form of calcite or aragonite) to make shells, skeletons, or other vital body parts are particularly affected. These organisms, known generally as calcifiers, are found throughout Washington's marine environment (Box S-1).

Ocean acidification leads to conditions that are chemically corrosive for shellfish and other calcifiers. When carbon dioxide concentrations in seawater increase, the availability of carbonate ions (a key component of calcium carbonate) decreases, making it more difficult for calcifiers to form, build, and maintain calcium shells and other calcium carbonate-based body parts. If the carbonate ion concentration dips too low, the seawater becomes chemically corrosive to calcium carbonate. Some calcifiers will therefore experience greater difficulty in making or maintaining their shells, slower growth rates, and higher mortality. Shellfish larvae and juveniles are especially vulnerable.

Box S-1. Ocean acidification can affect many Puget Sound species.

More than 30 percent of Puget Sound's marine species are vulnerable to ocean acidification by virtue of their dependency on the mineral calcium carbonate to make shells, skeletons, and other hard body parts. Puget Sound calcifiers include oysters, clams, scallops, mussels, abalone, crabs, geoducks (pictured above), barnacles, sea urchins (pictured below), sand dollars, sea stars, and sea cucumbers. Even some seaweeds produce calcium carbonate structures.

Ocean acidification also has implications for the broader marine environment. Many calcifiers provide habitat, shelter, and/or food for various plants and animals. For example, rockfish and sharks rely on habitat created by deepwater corals off the Washington coast. Pteropods, the delicate free-swimming snails eaten by seabirds, whales, and fish (especially Alaska pink salmon), can experience shell dissolution and grow more slowly in acidified waters (Figure S-1). Some species of copepods, the small crustaceans eaten by juvenile herring and salmon, experience similar problems with growth. Impacts on species like pteropods and copepods are a significant concern because of their ability to affect entire marine food webs.

Figure S-1. The pteropod, or "sea butterfly," is a tiny sea snail about the size of a small pea that plays an integral role in marine food webs. The photos above show what happens to a pteropod's shell when placed in seawater with pH and carbonate levels projected for the year 2100. The shell slowly dissolved over 45 days. *Used with permission from National Geographic.*

Ocean Acidification is a Risk to Washington's Marine Economy and Tribes

Washington is the country's top provider of farmed oysters, clams, and mussels. Annual sales of farmed shellfish from Washington account for almost 85 percent of U.S. West Coast sales (including Alaska).[2] The estimated total annual economic impact of shellfish aquaculture is $270 million, with shellfish growers directly and indirectly employing more than 3,200 people.[3] Shellfish are also an integral part of Washington's commercial wild fisheries, generating over two-thirds of the harvest value of these fisheries.[4] Shellfish of ecological and economic importance include oysters, mussels (native and Mediterranean), clams (e.g., geoduck, razor, littleneck, Manila), scallops, Dungeness crab, shrimp (e.g., spot prawns, pink shrimp), pinto abalone, and urchins.

Pike Place Market, Seattle. Local seafood is an important economic driver for the state's economy.

The economic benefits of Washington's wild and hatchery-based seafood harvests extend well beyond the value of the harvest when it arrives on shore. For example, licensing for recreational shellfish harvesting generates $3 million annually in state revenue and recreational oyster and clam harvesters contribute more than $27 million annually to coastal economies.[5] Overall, Washington's seafood industry generates over 42,000 jobs in Washington and contributes at least $1.7 billion to gross state product through profits and employment at neighborhood seafood restaurants, distributors, and retailers.[6] While our understanding of how ocean acidification affects the range of species driving this economic activity is limited at this time, it is clear that the impacts of ocean acidification on Washington's marine industry could extend far into and beyond the state's local and regional economies.

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2 See Pacific Coast Shellfish Growers Association table of production statistics, 2011, **http://pcsga.net/wp-content/uploads/2011/02/production_stats.pdf**

3 Washington Shellfish Initiative white paper, December 2011, **http://www.governor.wa.gov/news/shellfish_white_paper_20111209.pdf**

4 National Marine Fisheries Service, Office of Science and Technology. (2012). Commercial Fisheries Statistics: Annual Landings by Species for Washington, accessed 9/28/12. **https://www.st.nmfs.noaa.gov/commercial-fisheries/index**

5 See Washington Shellfish Initiative white paper, December 2011, referenced above

6 U.S. Department of Commerce, National Atmospheric and Oceanographic Administration. (2011). Fisheries Economics of the U.S. 2009: Economics and Sociocultural Status and Trends Series. **www.st.nmfs.noaa.gov/st5/publication/index.html**

Ocean acidification also has important cultural implications. To Washington's tribal communities, ocean acidification is a natural resource issue and a significant challenge to their continued identity and cultural survival. With salmon at just a fraction of their former abundance, tribal fishers are depending more on shellfish to support their families; almost all of the commercial wild clam fisheries in Puget Sound are tribal. The tribes also harvest wild shellfish for ceremonial and subsistence purposes.

A Lummi family digs clams in Puget Sound. Shellfish are an important source of nutrition for Indian people in western Washington.

Ocean Acidification: From Knowledge to Action

Recognizing the risks of ocean acidification to Washington, Governor Christine Gregoire created the Washington State Blue Ribbon Panel on Ocean Acidification (referred to here as "the Panel") to chart a course for addressing the causes and consequences of acidification. The Panel, convened in February 2012, was assembled under the auspices of the Washington Shellfish Initiative, a regional partnership established to implement the National Oceanic and Atmospheric Administration's (NOAA) National Shellfish Initiative.[7] Members included scientists; public opinion leaders; industry representatives; state, local, federal, and tribal policymakers; and conservation community representatives. The Governor charged the Panel to:

- Review and summarize the current state of scientific knowledge of ocean acidification,
- Identify the research and monitoring needed to increase scientific understanding and improve resource management,
- Develop recommendations to respond to ocean acidification and reduce its harmful causes and effects, and
- Identify opportunities to improve coordination and partnerships and to enhance public awareness and understanding of ocean acidification and how to address it.

7 NOAA's National Shellfish Initiative recognizes the broad suite of benefits provided by shellfish production and restoration. Its goal is to stimulate coastal economies and improve the health of estuaries by increasing commercial shellfish production and native shellfish populations.

This report, and the accompanying technical document *Scientific Summary of Ocean Acidification in Washington State Marine Waters*,[8] constitute the Panel's report of its findings and recommendations for action.

Panel Recommendations

The strategies and actions recommended by the Panel recognize the need for action across a range of areas (Box S-2).

First is the urgent need to slow the pace of ocean acidification by reducing the sources that cause the problem. Global carbon dioxide emissions are the biggest driver of acidification in the oceans overall and, broadly speaking, in Washington's marine waters. The Panel calls on Washington to continue its efforts to reduce carbon dioxide emissions while providing leadership in regional, national, and international forums to advocate for comprehensive carbon dioxide emissions reductions.

Washington's shellfish industry and native ecosystems cannot rely on emissions reductions alone, however. Our marine waters are continuing to acidify and reducing carbon dioxide emissions takes time. To rely solely on those reductions would result in significant—and in some cases irreversible—economic, cultural, and environmental impacts. Additional local actions, including local source reduction and adaptation and remediation, are necessary to "buy time" while society collectively works to reduce global carbon dioxide emissions.

Box S-2. Major Action Areas.

The Panel recommends 42 actions in the following areas. Collectively, these focal points form the structure of a comprehensive strategy for addressing ocean acidification in Washington's marine waters.

1. Reduce emissions of carbon dioxide;
2. Reduce local land-based contributions to ocean acidification;
3. Increase our ability to adapt to and remediate the impacts of ocean acidification;
4. Invest in Washington's ability to monitor and investigate the causes and effects of ocean acidification;
5. Inform, educate, and engage stakeholders, the public, and decision makers in responding to ocean acidification; and
6. Maintain a sustainable and coordinated focus on ocean acidification at all levels of government.

Each action includes a brief description. Implementation leads, partners, time frame, and estimated costs are included in Appendix 1.

8 Available at **https://fortress.wa.gov/ecy/publications/SummaryPages/1201016.html**

Local source reduction requires reducing local land-based pollutants that enhance acidification in marine waters by generating additional carbon dioxide. Most notable are inputs of nitrogen and organic carbon from point, nonpoint, and natural sources. Panel recommendations in this area focus on strengthening existing local source control programs to achieve the needed reductions in nutrient and organic carbon pollutants. In some cases, more stringent controls of nutrients and organic carbon pollutants may be required.

Adaptation and remediation help ensure the continued viability of native and commercial shellfish species and healthy marine ecosystems in Washington. The adaptation and remediation actions recommended by the Panel provide tools and information that resource managers and shellfish growers can use to strategically adjust to changing conditions and to restore and enhance the resilience of Washington's shellfish and natural systems. The recommendations also utilize both new and tested technologies for remediating local seawater conditions.

Critical to all of these efforts is research, monitoring, and public engagement. While we have a broad foundation of information on which to build recommendations, important knowledge gaps remain. Investing in research and monitoring will help fill those gaps and ensure that our efforts to reduce the risks of ocean acidification are appropriately focused and effective. Major objectives in the Panel's research and monitoring recommendations include increasing our understanding of the status and trends of ocean acidification in Washington's marine waters, characterizing biological responses of local species to acidification, and developing capabilities for short-term forecasting and long-term prediction.

Outreach and public engagement connects Washingtonians to the problem of ocean acidification by informing them about the science and the significance of changing ocean chemistry for Washington's economy, environment, and tribes. This can empower citizens and businesses to help develop and implement solutions. Key elements of the Panel's outreach and public education recommendations include sharing information on acidification with the public and other audiences, facilitating the exchange of information and ideas between stakeholders, and increasing ocean acidification literacy.

Finally, the Panel recognizes that ocean acidification is not a one-time problem with quick and easy solutions. It is a long-term challenge that requires a sustained effort across all these fronts—global and local source reduction, adaptation and remediation, research and monitoring, and public education—and continued engagement by and with governmental and non-governmental entities, industry, and the public. Maintaining a sustainable and coordinated focus on ocean acidification is necessary for ensuring our long-term success. To that end, the Panel recommends creating a coordinating mechanism

to facilitate implementation of the Panel's recommendations, continued engagement with stakeholders, and scientific collaboration.

The recommended strategies and actions included in this report each have a role in reducing the impacts of ocean acidification and action should be taken on each of them. The Panel recognizes, however, that it is not possible to implement all the recommendations simultaneously. Consequently, it has designated a subset of actions as "Key Early Actions" (KEAs). KEAs are actions the Panel considers to be essential next steps for reducing the risks associated with acidification and are independent of assumptions about the availability of funding or political feasibility. A list of KEAs is provided in Table S-1. A complete list of the Panel's strategies and actions is provided in Table 1.

A Time to Act

Washington State will need to respond vigorously to ocean acidification if we are going to avoid significant and possibly irreversible losses to our marine environment and all it supports, including shellfish farming and wild harvest of shellfish and other commercially and culturally important marine species. Public investment by the state is needed, as are public-private partnerships that promote innovative solutions to acidification. Additionally, the Panel calls on Congress, the White House, NOAA, and other federal agencies to support our efforts to address acidification and, in particular, to take a leading role in the recommended research agenda so the nature of the problem facing Washington and the majority of other coastal states can be better understood and more effectively addressed.

Washington has many resources to leverage in implementing the Panel's recommended actions. We have world-class scientists in our region who are already working in a variety of applicable fields. Additionally, we have an important source of understanding in the traditional and historical knowledge of tribes. State agencies, businesses, and tribes are taking the lead in developing innovative approaches that reduce carbon dioxide and nutrient runoff in Washington, and state and tribal leaders are actively engaging with our federal partners to find solutions to ocean acidification. We also have a shellfish industry committed to protecting native ecosystems as well as farmed resources, and a diverse nonprofit community ready to work with the public on understanding the problem of ocean acidification and how we might solve it. Finally, we have citizens who value the rich and diverse ecosystems in Washington's marine waters.

It is time to coordinate and harness these resources and start tackling the many challenges that will come with ocean acidification. It is time to act.

Table S-1. Blue Ribbon Panel Recommendations: Key Early Actions

Reduce Carbon Dioxide Emissions	Work with international, national, and regional partners to advocate for a comprehensive strategy to reduce carbon dioxide emissions. *(Action 4.1.1)*
	Enlist key leaders and policymakers to act as ambassadors advocating for carbon dioxide emissions reductions and protection of Washington's marine resources from acidification. *(Action 4.1.4)*
Reduce Local Land-Based Contributions	Implement effective nutrient and organic carbon reduction programs in locations where these pollutants are causing or contributing to multiple water quality problems. *(Action 5.1.1)*
	Support and reinforce current planning efforts and programs that address the impacts of nutrients and organic carbon. *(Action 5.1.2)*
Increase Our Ability to Adapt to and Remediate the Impacts of Ocean Acidification	Develop vegetation-based systems of remediation for use in upland habitats and in shellfish areas. *(Action 6.1.1)*
	Ensure continued water quality monitoring at the six existing shellfish hatcheries and rearing areas to enable real-time management of hatcheries under changing pH conditions. *(Action 6.2.1)*
	Investigate and develop commercial-scale water treatment methods or hatchery designs to protect larvae from corrosive seawater. *(Action 6.2.3)*
	Identify, protect, and manage refuges for organisms vulnerable to ocean acidification and other stressors. *(Action 6.3.2)*

Invest in Washington's Ability to Monitor and Investigate the Effects of Ocean Acidification	Establish an expanded and sustained ocean acidification monitoring network to measure trends in local acidification conditions and related biological responses. *(Action 7.1.1)*
	Quantify key natural and human-influenced processes that contribute to acidification based on estimates of sources, sinks, and transfer rates for carbon and nitrogen. *(Action 7.2.1)*
	Determine the association between water and sediment chemistry and shellfish production in hatcheries and in the natural environment. *(Action 7.3.1)*
	Conduct laboratory studies to assess the direct effects of ocean acidification, alone and in combination with other stressors, on local species and ecosystems. *(Action 7.3.2)*
	Establish the ability to make short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern. *(Action 7.4.1)*
Inform, Educate, and Engage Stakeholders, the Public, and Decision Makers in Addressing Ocean Acidification	Identify key findings for use by the Governor, Panel members, and others who will act as ambassadors on ocean acidification. *(Action 8.1.1)*
	Increase understanding of ocean acidification among key stakeholders, target audiences, and local communities to help implement the Panel's recommendations. *(Action 8.1.2)*
	Provide a forum for agricultural, business, and other stakeholders to engage with coastal resource users and managers in developing and implementing solutions. *(Action 8.1.4)*
Maintain a Sustainable and Coordinated Focus on Ocean Acidification	Charge, by gubernatorial action, a person in the Governor's Office or an existing or new organization to coordinate implementation of the Panel's recommendations with other ocean and coastal actions. *(Action 9.1.1)*
	Create an ocean acidification science coordination team to promote scientific collaboration across agencies and organizations and connect ocean acidification science to adaptation and policy needs. *(Action 9.1.2)*