IPC / SAC OA Working Group
Final Report

Ocean acidification is caused by the ocean's uptake of carbon dioxide, which converts to carbonic acid in seawater, decreasing the water's pH. The world's oceans have served as a sink for up to 30% of all anthropogenic CO_2 produced since the Industrial Revolution, and this overload of atmospheric carbon dioxide is slowly changing ocean chemistry by increasing the dissolved carbon dioxide concentration and reducing the concentration of carbonate ions in seawater[1]. Ocean acidification has the potential to seriously threaten the future health of Washington's oceans and the significant economic benefits they provide.

Marine calcifiers, organisms that build calcium carbonate shells and skeletons, will likely be the most vulnerable to the impacts of ocean acidification. Examples of economically and ecologically important marine calcifiers include shellfish, sea urchins, and calcareous plankton[2] (e.g., pteropods, which are integral to the survival of pink salmon in their first year of life). Other marine calcifiers, such as deep sea corals, will need to be assessed for vulnerability to ocean acidification and those results evaluated in a risk assessment.[1] Corrosive seawater has the potential to severely disrupt the marine food chain by decreasing the overall health and increasing mortality of essential components of the food systems and physical environment[3]. Observations along the Pacific Northwest coast, including sites within Olympic Coast National Marine Sanctuary (OCNMS), suggest that the coastal ecosystem is seasonally exposed to corrosive waters (i.e., lower pH and reduced availability of carbonate ions) primarily due to upwelling. Model projections suggest that corrosive waters will expand in both spatial and temporal extent over the coming century[2].

The communities of the outer Washington Coast share much in common: they are located far from the central core of urban development in Washington and they have maintained an unusually high level of dependence on marine resources[4]. The marine-based economy of the outer coast includes important commercial fisheries as evidenced by the 1,093 active coastal commercial fishing licenses issued by the Washington Department of Fish and Wildlife in 2012 (razor clam, salmon, crab pots, shrimp, baitfish, etc.)[4]. There are several commercial fisheries that operate on the west coast and the ex-vessel value from just one of these, the state coastal commercial Dungeness crab fishery, averaged approximately 30 million dollars in revenue between 2007 and 2011. The coastal communities of Grays Harbor, Neah Bay, La Push and Ilwaco are dependent on the financial benefit from the operation of this fishery, and others, via income from not only the ex-vessel value, but additional income and jobs produced from fish processing, housing, food, fuel etc. In addition, coastal dependence on marine resources cannot be addressed without including popular recreational activities such as fishing and razor clamming, both of which are vital to coastal economies.

Four Tribes with treaty-reserved fishing rights have lived on the outer coast since time immemorial. The ocean and its fishery resources are important to the cultures of their people, contribute to the subsistence and survival of their communities, and are significant drivers of local economies on the coast. One of those four Coastal Treaty Tribes, the Quinault Indian Nation, has averaged 2.7 million pounds of Dungeness crab between 2007-2011, with more being harvested by the Quileute and Makah Tribes. Razor clams are also harvested by the Coastal Treaty Tribes including a significant commercial fishery conducted by Quinault on the beaches north of Grays Harbor.

In 2009 the Olympic Coast National Marine Sanctuary's Sanctuary Advisory Council (SAC) passed a resolution that read "The Advisory council of the Olympic Coast National Marine Sanctuary recognizes ocean acidification and associated stressors as substantial threats to the long-term persistence of sanctuary resources and qualities..." In 2013 they and the Intergovernmental Policy Council (IPC) formed a joint Ocean Acidification Working Group to review recommendations of the Washington State Blue Ribbon Panel on Ocean Acidification and: 1) identify recommendations most relevant to the outer coast of the Olympic Peninsula and 2) provide advice on potential responses and actions for consideration by OCNMS, the SAC, IPC and other authorities on the outer Olympic Coast.

Identify recommendations most relevant to the outer coast of the Olympic Peninsula

The Working Group identified and prioritized actions from the Washington State Blue Ribbon Panel on Ocean Acidification Actions within two Tiers. Tier One Actions have been identified as "Key Early Actions" by the Blue Ribbon Panel, while Tier Two Actions have been identified as "Near Term Actions". **The OA Working Group has identified the following eight Actions, in order of highest priority, for immediate implementation along the outer coast of Washington:**

Tier One

1. **Action 7.1.1**: Establish an expanded and sustained ocean acidification monitoring network to measure trends in local acidification conditions and related biological responses.

   Recommendation: The outer coast should be a high priority for OA monitoring. With appropriate monitoring, corrosive waters that appear seasonally due to upwelling could be identified along the outer coast prior to appearing in Puget Sound. Some monitoring capacity exists along the outer coast via the OCNMS oceanographic mooring program and others. However, this capacity should be enhanced to better monitor OA.

2. **Action 9.1.2**: Create an ocean acidification science coordination team to promote scientific collaboration across agencies and organizations and connect ocean acidification science to policy and program needs.

   Recommendation: The outer coast should be adequately represented on this science coordination team. Both the IPC and SAC have membership or staff with expertise to contribute to such a Team, and it is critical that both the IPC and SAC be represented.

3. **Action 7.3.2**: Conduct laboratory studies to assess the direct effects of ocean acidification, alone and in combination with other stressors, on local species and ecosystems.

-AND-

Action 7.3.3: Conduct field studies to characterize the effects of ocean acidification, alone and in combination with other stressors, on local species.

Recommendation: Laboratory and field studies need to be conducted for the outer coast. There is capacity (Tribal/Coastal labs) along the coast to help implement these studies.

4. **Action 8.1.2**: Increase understanding of ocean acidification among key stakeholders, target audiences, and local communities to help implement the Panel's recommendations.

Tier Two

1. **Action 7.1.3**: Support development of new technologies for monitoring ocean acidification.

2. **Action 7.4.3**: Enhance the ability to model the response of organisms and populations to ocean acidification to improve our understanding of biological responses.

3. **Action 7.1.2**: Develop predictive relationships for indicators of ocean acidification (pH and aragonite saturation state).

Provide advice on potential responses and actions.

In an attempt to develop advice on potential responses and actions, the Working Group identified specific needs as they relate to the implementation of the Actions identified above. The Working Group utilized relevant sections of the Scientific Summary of Ocean Acidification in Washington State Marine Waters[5]. This document not only details what is currently known about ocean acidification, but also identifies areas where "the knowledge base is thin, and notes areas where more research could improve our understanding of ocean acidification in Washington marine waters". Relevant sections of this document[5] regarding "what we need to know" were utilized by the Working Group as a starting point for this exercise. Specifically:

1.0.2 - What we need to know about ocean acidification (p.3)

- What is the status of pH, dissolved inorganic carbon (DIC), and total alkalinity (TA) in Washington marine waters including Puget Sound and the outer coast? What are the long- term trends?
- What are the temporal and spatial scales of variability of the corrosive waters in Washington marine waters?
- What is the relative importance of local drivers to the acidification process, including those affected by human activities?
- How do marine organisms at different life stages respond to changes in pH, DIC, and TA?
- How do marine ecosystems respond to changes in pH, DIC, and TA?

2.0.2 - What we need to know about ocean acidification on Washington's outer coast (p.19)

- What are the carbon sources and sinks?
- What mechanisms drive the observed spatial and temporal variation in pCO2 and pH, and what is the relative magnitude of these drivers?
- What is the effect of the Columbia River plume on pCO2 and pH?

5.0.2 - What we need to know about responses of species and assemblages to ocean acidification (p.59)

- How will acidification affect species of importance in Washington State?
- Which local species are most vulnerable to the effects of acidification?
- How will co-occurring stressors influence species' responses to acidification?

6.0.2 - What we need to know about ecosystem response to ocean acidification (p.83)

- Do system-level responses differ from those of individual organisms? If so, how?
- How might marine food webs be altered?
- How might marine diseases respond?
- What is the scope for genetic adaptation to ocean acidification?
- Which habitats or systems are at greatest risk of change due to ocean acidification?

Based upon the eight Blue Ribbon Panel Actions identified by the OA Working Group and the relevant "what we need to know" sections of the Scientific Summary of Ocean Acidification in Washington State Marine Waters, **the OA Working Group has identified the following specific needs as they relate to the implementation of the prioritized Actions identified for the outer coast of Washington:**

Action 7.1.1: Establish an expanded and sustained ocean acidification monitoring network to measure trends in local acidification conditions and related biological responses

- Moorings equipped with CO_2 sensors to measure carbon/pH patterns on outer coast over time. This should help develop understanding of patterns in time and space and possibly provide evidence of sources and sinks.
- Continue, and where possible increase, cruises to get high-resolution hydrography. We need to trace carbon sources (to determine sources and sinks) and the dynamics of carbon in the water column (to increase predictive modeling capability). Survey cruises should collect biological samples including plankton and important fisheries species across life history stages to begin to measure biological response to OA.
- Nearshore monitoring of carbon could be added to existing water quality/HAB monitoring or with smaller vessels (i.e. in addition to NOAA big-ship surveys). This could also include sampling intertidal organisms to gauge the biological response.
- Outline what data is currently being collected on the coast so that we can identify the data gaps that need to be filled to better understand what is driving the variation in pCO_2 and pH.

- Critically important to establish/maintain a monitoring network to measure local trends - especially following any determination of current/potential impacts on local species (e.g., hypoxia). This focused, localized monitoring may help determine placement of additional monitoring stations and what instrumentation is necessary.
- Seek funding, perhaps specifically for the OCNMS, to update current coastal monitoring tools to get the additional data needed to understand more about OA on WA outer coast (priority #1).
- Build upon and validate emerging science that indicates relationship between upwell-driven coastal hypoxia events and low pH. Monitoring dissolved oxygen levels where possible may act as surrogate for CO_2 measurements, filling spatial gaps along a broad coastline.

Action 9.1.2: Create an ocean acidification science coordination team to promote scientific collaboration across agencies and organizations and connect ocean acidification science to policy and program needs.

- Ensure the science coordination team includes strong coastal representation
- Ensure the science team uses scarce funds to full advantage and that policy makers understand what is happening, and assure quality community-based science is a central component of a comprehensive coastal monitoring system.

Action 7.3.2: Conduct laboratory studies to assess the direct effects of ocean acidification, alone and in combination with other stressors, on local species and ecosystems.

- Use controlled lab experiments to predict biological responses to OA. Understanding larval response, reproductive system response, etc. to increasing acidity will be important to understand what types of physiological responses we can expect in important species. These might include economically and culturally important species as well as any that show promise as ecosystem indicators.
- Need studies of important tribal cultural resources (e.g., Pacific razor clams, Dungeness crab, California mussels, gooseneck barnacles, salmon etc.) throughout their life history to determine any current impacts and anticipate if/when impacts might occur. Life history studies are important as salmon, for example, depend on many organisms vulnerable to OA. Ecosystem level studies are crucial as well.

Action 7.3.3: Conduct field studies to characterize the effects of ocean acidification, alone and in combination with other stressors, on local species.

- Need to find specific biological responses to OA. Look beyond California Current Large Marine Ecosystem and compare recruitment for important fishery species throughout their range (e.g. AK, B.C., and West Coast) under different acidic conditions. Look for evidence of biological response in nearshore spp. (e.g. shell size/condition).
- Engage local communities through programs such as Marine Resource Committees (MRCs) and local commercial and recreational fishermen in the process of conducting field studies to characterize the effects of OA on local species like Dungeness crab, razor clams, oysters, etc. through citizen science projects. Intertidal and subtidal monitoring sites need to be established with regular inspections and constant sampling/monitoring.

Action 8.1.2: Increase understanding of ocean acidification among key stakeholders, target audiences, and local communities to help implement the Panel's recommendations.

- Focus outreach efforts to highlight importance of OA to coastal resources. Link outreach to the importance of healthy ocean resources to coastal communities.
- Printed outreach materials - a variety of booklets, pamphlets, posters
- Interpretive signage along coast
- Funding to assist with outreach along coast (booths, programs etc.)
- Networking opportunities with other organizations to help form partnerships to increase knowledge of Ocean Acidification along the coast
- Educational materials for school districts, colleges and universities
- Important to educate people but in order to do so the public the Panel and the Coast need information; i.e. real data that can illustrate trends, impacts and threats. We have some of that for shellfish hatcheries but little or none for coastal ecosystems.

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[1] NOAA Ocean Acidification Steering Committee (2010): NOAA Ocean and Great Lakes Acidification Research Plan, NOAA Special Report, 143 pp.

[2] Miller, I.M., Shishido, C., Antrim, L, and Bowlby, C.E. 2013. Climate Change and the Olympic Coast National Marine Sanctuary: Interpreting Potential Futures. Marine Sanctuaries Conservation Series ONMS-13-01. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of National Marine Sanctuaries, Silver Spring, MD. 238 pp.

[3] University of Washington Environmental management Certificate Program Keystone Project (2013): Washington's Working Coast – An Analysis of the Washington Pacific Coast Marine Resource-Based Economy. 94pp.

[4] Brooks, Rebekah, Miranda Wecker, and Keven Bennett. 2012. Washington's Working Coast: Phase 1 Compilation of Information. University of Washington Olympic Natural Resources Center. 67pp.

[5] Feely, R.A., T. Klinger, J.A. Newton, and M. Chadsey (2012): Scientific Summary of Ocean Acidification in Washington State Marine Waters. NOAA OAR Special Report. 175pp.