Making progress on Washington State Blue Ribbon Panel Recommendations for Ocean Acidification

Monitoring and Investigations

January 2016 (Draft)

Chapter 7 of the Washington State Blue Ribbon Panel on Ocean Acidification (OA) identifies recommendations to increase awareness and understanding of OA. It calls for eleven actions within four strategies:

- **Strategy 7.1** Understand the status and trends of ocean acidification in Washington's marine waters.
- **Strategy 7.2** Identify factors that contribute to ocean acidification in Washington's marine waters, and estimate the relative contribution of each.
- **Strategy 7.3** Characterize biological responses of local species to ocean acidification and associated stressors.
- **Strategy 7.4** Build capabilities for short-term forecasting and long-term prediction of ocean acidification.

The following table highlights accomplishments towards implementing these actions.

Note: KEA stands for Key Early Actions.

Action	Action Title	Accomplishments	Partners	Funding
Action 7.1.1	Establish an expanded and sustained ocean acidification monitoring network to measure trends in local acidification conditions and related biological responses. *[KEA]*	With funding from the State Legislature, WOAC is establishing an ocean acidification monitoring network that measures trends in local water quality conditions and impacts to marine life. WOAC has brought together diverse partners to develop this network and supported deployment of three monitoring buoys, monitoring cruises, and the deployment of high-quality pH sensors within the existing monitoring array. The network monitoring strategy focuses on high-priority plankton species as well as chemical and physical conditions such as pH, pCO_2, total alkalinity, dissolved inorganic carbon, oxygen, nutrients, chlorophyll, salinity, and temperature. Additional funds were provided in the 2015-16 biennium to continue enhancing this monitoring network.	Washington Ocean Acidification Center (WOAC), NOAA, US IOOS-NANOOS	$625K (2015-16 biennium) $475K (2013-14 biennium) Leveraged $800k from NOAA/US IOOS

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		NWFSC scientists are working on a project with the University of Washington funded by WA Sea Grant to characterize 1) the chemistry of the water masses in which krill and copepods live and develop and 2) how variability in seawater chemistry affects development. For this project, the research team conducted two research cruises in Hood Canal, where they paired sampling of carbon chemistry and zooplankton. They will use data from these cruises to design experiments in the lab that test the success and timing of krill and copepod development in ecologically relevant conditions for today and those predicted for the future.	NOAA, UW and others	Washington Sea Grant funding
		NWFSC and PMEL scientists plan to install carbon chemistry monitoring instruments at the NWFSC Mukilteo Field Station, where some animals are reared prior to ocean acidification experiments (e.g., rockfish, Dungeness crab) and a pinto abalone hatchery is housed. These data will help scientists better understand near-shore carbon chemistry conditions and will be used to parameterize laboratory experiments on near-shore species.	NWFSC, PMEL	
		The Marine Waters Group, Ecology is piloting integrating alkalinity and dissolved inorganic carbon measurements in their long-term monitoring program to address seasonal variation at selected stations in Puget Sound.	Ecology	
		Purchasing equipment for use by Bainbridge Island HS Environmental Science students to monitor nearshore water chemistry. Equipment will be owned by Puget Sound Restoration Fund, and housed/deployed at the NOAA Manchester hatchery, when not being used by Bainbridge students. Deployed spring of 2014. Fieldwork will be conducted in conjunction with OA coursework (see OA Curricular Framework described in Action 8.1.2)	Puget Sound Restoration Fund WA Sea Grant, Suquamish Tribe, Bainbridge Island School District, PMEL, NWFSC, DNR, & UW Applied Physics Lab	~$25K of $40K award from 3M EcoGrant to purchase OA monitoring equipment

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		Suquamish Tribal biologist is working with Chief Kitsap Academy in Suquamish to create carbon chemistry monitoring capacity for nearshore areas. Will replicate DNR pH sensors and purchase Seabird CTD and DO sensors. Will collect discrete samples for carbon chemistry to be analyzed at NWFSC.	Suquamish Tribe, PMEL, DNR, NWFSC	$30K (US Fish and Wildlife) for Chief Kitsap Academy in Suquamish
		The DNR Aquatic Assessment and Monitoring Team has established a nearshore monitoring network, to collect and compare data on carbonate chemistry dynamics in shallow waters with mid-channel measurements. Five sites were established across the DNR Aquatic Reserve system in September 2015, with four additional sites planned for April 2016. Sensor arrays measure pH, temperature, conductivity, dissolved oxygen, and chlorophyll, in and outside of eelgrass habitat. Eelgrass parameters are taken quarterly at each site, with further biological monitoring planned.	DNR	DNR agency management account
Action 7.1.2	Develop predictive relationships for indicators of ocean acidification (pH and aragonite saturation state).	Building pH sensors and carbonate analysis laboratory to deploy logging sensors and collect water samples over time and in different habitat types. Analyze water samples for carbonate chemistry and apply CO_2 sys model to predict values of aragonite saturation and pH from representative samples. A targeted field experiment in 2014 measured the rate of change in aragonite saturation state of water passing through eelgrass habitat.	DNR(AAMT) and UW (Ruesink Lab)	$63K – Sensor parts $2K – DNR staff $7K – UW IAA Funded by DNR agency management account
Action 7.1.3	Support development of new technologies for monitoring ocean acidification.	NWFSC scientist Dr. Paul McElhany is working with biologists from the Suquamish Tribe and the UW to develop a technology that could automate the biological monitoring of plankton. This technology utilizes computer image recognition systems already developed for facial recognition and medical research.	NOAA	
		Developing zooplankton imaging system for lab and field data collection using line scan camera.	Suquamish Tribe	~$30K (EPA)

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		Wendy Schmidt Ocean Health X Prize competition for marine monitoring technology was awarded in July 2015. Sunburst Sensors wan first prize for both affordability and accuracy of their deep-water acidity monitor and shallow-water monitor.	X Prize Foundation, Seattle Aquarium	$2M (X Prize Foundation)
Action 7.2.1	Quantify key natural and human-influenced processes that contribute to acidification based on estimates of sources, sinks, and transfer rates for carbon and nitrogen. ***[KEA]***	Model developed in 7.4.1 will be used to some extent for this task awarded to Dr. Parker MacCready's UW Coastal Modeling Group. The modeling team proposed to use their model to assess the contributions of various drivers of ocean acidification in Washington waters, and to assess the relative contribution of various anthropogenic and natural forcings.	WOAC	Partial funding through 7.4.1
		Washington Department of Ecology and the Pacific Northwest National Laboratory developed a detailed approach for how to assess the relative impacts of natural, Pacific Ocean, and local nutrient sources on acidification. The report, reviewed by representatives of NOAA, UW, EPA, Scripps and others, was finalized in December 2013. ECY, PNNL, and the UW Climate Impacts Group previously partnered to develop a model of the relative impacts of the Pacific Ocean, climate, and local human sources on dissolved oxygen in the Salish Sea through 2070. Adding acidification-related parameters to the oxygen model has not yet been funded. EPA provided funding ($350,00) to the Washington State Department of Ecology and the Pacific Northwest National Laboratory for the development and application of the acidification model that will address the relative influence of natural, Pacific Ocean, and local nutrient sources on acidification. They completed a Quality Assurance Project Plan in 2015 and completed the model set up and testing phase in January 2016. The team is currently calibrating the model to current conditions.	Ecology	Full proposal not funded by Legislature Partially funded by EPA grant through National Estuary Program ($40,000 + in kind contributions from Ecology) $350k (EPA)

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		U.S. EPA Region 10 and ORD, in partnership with Oregon State University and the Tulalip Tribes, are working on a project funded through the EPA RARE program ($84,500) to characterize high-resolution carbonate chemistry dynamics in two shallow subtidal seagrass beds in the Snohomish Estuary, WA. Continuous monitoring of pH and pCO2, along with a series of research cruises through 2015/16, are being used to characterize the variability of carbonate chemistry and identify the primary drivers of this observed variability (e.g. biological processes, tidal pumping, and river discharge) at both sites. Additionally, isotopic analyses are being used to identify natural and anthropogenic sources of nutrients to the study sites to estimate the contribution of nutrient-enhanced acidification processes to the observed carbonate chemistry records. The project is designed to investigate these processes at time (15-min sampling intervals) and space (above-bottom moorings in seagrass beds) scales relevant to organisms.	EPA, Oregon State University, Tulalip Tribes	$84.5K (EPA)
Action 7.2.2	Develop new models or refine existing models to include biogeochemical processes of importance to ocean acidification.	*Will be done as part of 7.4.1.*	WOAC	

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Action 7.3.1	Determine the association between water and sediment chemistry and shellfish production in hatcheries and in the natural environment. ***[KEA]***	2010-2013 Research Project: "Effects of OA on declining Puget Sound calcifiers" 2013-2014 Research Project: "Effects of early exposure of Pacific oysters to OA on subsequent performance" NWFSC scientists, in collaboration with scientists from the University of Washington, Oregon State University, or Cal Poly and using materials from Taylor Shellfish or Penn Cove Shellfish, have conducted experiments on the impacts of ocean acidification on Pacific oyster, geoduck clam, and Manila clam larvae and bay and Mediterranean mussel juveniles. The experiments on larvae focus on survival, growth, and development and the mussel experiments on proteomics.	Washington Sea Grant and UW Fisheries (Friedman lab), NOAA	$426,797 (2010-2013) plus $165,933 (2013-2014) for two University of Washington studies. Contingent on receiving full NOAA grant award
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. ***[KEA]***	Washington State Legislature provided funds in the 2013-2015 biennium for laboratory studies to assess the effects of ocean acidification on Washington's species and ecosystems and to study their ability to adapt to ocean acidification. WOAC, working with partners, has started laboratory studies on Dungeness crab, geoducks, Olympia oysters, and krill. Initial results indicate these species are negatively impacted by higher levels of CO_2 and ocean acidification conditions. Experiments were completed in June 2015. WOAC received additional state funding to support continued experiments on other marine species of interest.	WOAC	$200k (2015-16 biennium) $170K (2013-14 biennium) Leveraged $200K from NSF
		Experiment tested the response of juvenile Pacific oysters settled on different substrates to three levels of aragonite saturation state. Laboratory results will be used in the interpretation of oyster outplanting studies, exposing juveniles to natural variation in water chemistry and measuring growth and survival.	UW (Ruesink Lab), WWU (Love Lab), DNR (AAMT)	$13,400 (DNR agency management account)

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Action 7.3.3	Conduct field studies to characterize the effects of ocean acidification, alone or in combination with other stressors, on local species.	Equip shallow draft boat with sensors to monitor pH, CO_2, salinity, temperature and DO. Using video and sonar equipment, survey distribution to map presence and assess signs of vigor of benthic communities (e.g., epiphyte loading).	DNR and UW	$32,000 (DNR staff) $26,700 (UW IAA) $8,500 (UW Faculty) Funding from DNR agency management account
		2013-2014 Research Project: "Impacts of OA on early life stages of crustacean zooplankton"	Washington Sea Grant and UW Oceanography (Keister lab)	$219,036 (2013-2014). Contingent on receiving full NOAA grant award
		Research on the impacts of ocean acidification on wild and farmed mussels in Puget Sound, WA.	Washington Sea Grant and UW Friday Harbor Labs (Carrington lab)	$257,752. Contingent on receiving full NOAA grant award
		Partnered with NOAA NWFSC to study effect of pH on Dungeness crab larvae. Lab work completed, report in preparation.	NWFSC Suquamish Tribe	$20K (US Fish and Wildlife, EPA)
		A targeted field experiment in 2015 explored whether bivalve shellfish larvae move into photosynthetic eelgrass to take advantage of improved water chemistry.	DNR, UW Tacoma (Becker Lab), UW (Ruesink Lab, Roberts Lab)	DNR agency management account
Action 7.4.1	Establish the ability to make short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern. ***[KEA]***	WOAC used initial State funds to develop a short-term forecasts of corrosive conditions for application to shellfish hatcheries, growing areas, and other areas of concern. Additional funding will support ongoing maintenance and keep it publically available. WOAC is working to update the Puget Sound portion of the model and add finer scale models for individual inlets.	WOAC	$150K (2015-16 biennium) $325,K (2013-14 biennium) Leveraged $300k from NOAA, NSF, & Microsoft Research

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		The Marine Waters Group, Ecology is implementing an empirical predictive model published by APL, using climatic and oceanic boundary conditions to inform on the probability of ocean intrusions delivering low-pH high-nutrient water through Admiralty Reach.	Ecology	
Action 7.4.2	Enhance ability to predict the long-term future status of carbon chemistry and pH in Washington waters and create models to project ecological responses to predicted ocean acidification conditions.			
Action 7.4.3	Enhance ability to model the response of organisms and populations to ocean acidification to improve our understanding of biological responses.	NWFSC scientists have collaborated with university researchers to explore how gene transcription and protein translation is affect by ocean acidification. This work has included studies on Manila clam and Dungeness crab gene expression with University of Washington graduate students and scientists and Mediterranean and bay mussel proteomics with Cal Poly scientists.	NOAA UW	
		In addition to the food web modeling described above, NWFSC scientists are exploring how ocean acidification may affect population dynamics of Dungeness crab. To do so, they are conducting experiments on how ocean acidification may affect the growth and survival of early life stages of Dungeness crab, using these data to develop scenarios of ocean acidification on Dungeness crab, and applying the scenarios to a life cycle model of Dungeness crab that is currently being developed for the project.		