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**Increase Our
Ability to
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*Kelp demonstration site at Hood Head. Kelp may act as a buffer to acidifying conditions, and could be an important adaptation tool.
Photo credit: John Mickett*

Chapter 6 of the original 2012 Blue Ribbon Panel report outlined the importance of learning how to adapt and remediate the impacts of ocean acidification. Washington state needs to use a wide range of approaches to limit future losses of shellfish and other key marine resources. The Panel recommended preserving and enhancing the resilience of native shellfish and the ecosystems upon which they depend, and implementing a mix of innovative approaches and technologies to maintain and enhance cultivated shellfish production. These recommendations require collaboration across the private sector, nongovernmental organizations, academia, and federal, state and tribal governments.

This chapter describes accomplishments related to adaptation and remediation since 2012, revised and new actions, and key next steps to continue progress in this area. Refer to Chapter 6 in the original 2012 Panel report for a full summary of why adaptation and remediation measures are critical and for descriptions of each original action in this area.

6.1 Accomplishments since 2012

Ocean acidification conservation hatchery: The conservation hatchery at the Kenneth K. Chew Center for Shellfish Research and Restoration, located in Manchester, Washington

A public-private partnership for shellfish conservation

The Kenneth K. Chew Center for Shellfish Research and Restoration was established through a cooperative agreement between NOAA and Puget Sound Restoration Fund to collaborate and conduct research and restoration activities. Using federal and state funds as well as a \$1.5 million grant from the Paul G. Allen Family Foundation, this research facility is an example of successfully leveraging public and private partnerships to jointly work towards tackling ocean acidification.

on the Puget Sound, is a hub for native species propagation and restoration and ocean acidification research. Its size and location provide a unique opportunity for researchers and managers to learn more about ocean acidification and test strategies that local industry and managers could eventually use to mitigate impacts of ocean acidification on species of economic significance. No other facility in Washington exists that can serve researchers and managers in the manner necessary to make progress against increasingly acidifying conditions in Puget Sound and Washington's coast. Since it opened, the conservation hatchery has:

- Operated a kelp propagation lab to provide a steady and reliable source of native kelp to use in research and remediation efforts to determine if native kelp can improve pH conditions for calcifying species, which play important roles in food webs and healthy ecosystems
- Completed several adaptation and remediation actions recommended by the Panel that require hatchery propagation and research, including producing native kelp species (bull kelp and sugar kelp) and Olympia oysters suitable for different basins
- Produced Olympia oyster seed to help rebuild breeding populations in the state's 19 priority locations
- Cultured native species such as Olympia oysters, Pinto abalone, rock scallops, sea cucumbers, and geoducks to improve ecosystem resiliency and test resistance to ocean acidification
- Maintained the genetic diversity of native shellfish species
- Conducted research to identify and produce ocean acidification-resistant strains of several commercially-important shellfish species, such as Pacific oysters and Manila clams

Shellfish hatchery treatment methods: Water quality monitoring is ongoing at six existing shellfish hatcheries and rearing areas. Updated equipment and new pH sensors have been installed and funding received to expand to new sites. Managers have developed new hatchery methods to mitigate corrosive conditions and tests are ongoing for new monitoring and treatment methods.

Bioindicators: Researchers funded through WOAC developed oyster bioassays and are working to use pteropods as a biological indicator for ocean acidification. Additional research looks at

developing a species sensitivity index to assess the impacts of ocean acidification across several local species.

Species restoration: Several Panel recommendations focus on supporting species restoration. Efforts to achieve this are underway, including:

- Updating the Puget Sound Action Agenda and Washington Shellfish Initiative, among other efforts, to include maintaining and expanding shellfish production
- Evaluating the feasibility of a local commercial shell recycling pilot program
- Developing a strategy to increase eelgrass by 20% in Puget Sound by 2020; work is underway on restoration practices, techniques, and necessary information to restore populations
- Developing a kelp recovery plan and investigation to optimize kelp restoration techniques
- Monitoring potential sites to act as oyster refuges and forming a workgroup to identify criteria and select locations to apply remediation strategies
- Restoring 60 acres of native oyster habitat in Puget Sound

Vegetation strategies: Multi-year experiments and modeling are being conducted to test use of vegetation-based systems for remediation.



Photo credit: Bill Dewey

Researching how eelgrass could be used to combat ocean acidification

The Washington State Department of Natural Resources (WDNR) has developed a robust research program to test practical management options to combat ocean acidification. Eelgrass – a marine plant – covers 22,000 hectares in greater Puget Sound, and provides numerous ecosystem services. Following Key Early Action 6.1.1, WDNR set out to determine whether eelgrass can absorb enough CO₂ to mitigate ocean acidification and provide refuge to species sensitive to ocean acidification.

Can eelgrass photosynthesis counteract ocean acidification?

In 2014, WDNR partnered with the University of Washington to test whether eelgrass affects local pH. Through a field experiment spanning five sites, WDNR scientists showed that eelgrass can significantly increase pH in nearshore environments, where crucial natural resources are concentrated.

Are shellfish larvae more abundant in eelgrass?

In 2015, WDNR designed an experiment to test whether shellfish larvae move towards eelgrass to take advantage of improved pH. By measuring shellfish DNA, WDNR and University of Washington scientists found that shellfish larvae do not appear to congregate in eelgrass when it is photosynthesizing.

Can eelgrass enhance shellfish growth and reduce environmental stress?

In 2016, WDNR worked with commercial shellfish growers and the University of Washington to test whether eelgrass can protect juvenile shellfish from ocean acidification. WDNR scientists transplanted juvenile Pacific oysters, Olympia oysters, and geoducks from a hatchery setting into the wild. At five sites, these juveniles were left for a one-month exposure period, inside and outside of eelgrass. Results show that eelgrass can enhance shellfish growth: Pacific and Olympia oysters grew 20 to 25% faster in eelgrass than outside of it.

Can eelgrass improve shellfish growth and pH in a halo around the meadow?

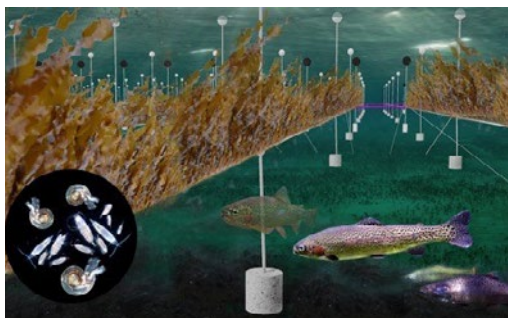
In 2017, WDNR led a field experiment to explore whether eelgrass can provide benefits to nearby juvenile shellfish. At five sites, WDNR scientists transplanted hatchery Pacific oysters and geoducks at set distances from eelgrass meadows. Pacific oysters once again grew most quickly in eelgrass, and oysters near the meadow grew faster than oysters farther away.



*Benoit Eudeline of Taylor Shellfish Farms tests water quality.
Photo credit: Taylor Shellfish Farms*



*Brian Allen with Puget Sound Restoration Fund pictured
with sugar kelp on a grow-line at Hood Head, March 20,
2017. Photo credit: Stephen Schreck*



*A graphic showing how kelp lines provide underwater habitat
during the growing period. Photo credit: Hannah Davis*

Cultivating seaweeds to mitigate ocean acidification and generate habitat, fertilizer, food, and fuel

A collaborative team led by Puget Sound Restoration Fund is investigating the power of kelp to improve seawater conditions locally as a strategy for protecting species and resources amid increasingly corrosive conditions. The five year project, launched in 2015, implements one of the Key Early Actions recommended by the Panel with funding from The Paul G. Allen Family Foundation.

Sugar kelp is being cultivated at a 2.5-acre site north of the Hood Canal Bridge leased by Hood Canal Mariculture. During the growing season, kelp soaks up CO₂ and nitrogen from the surrounding seawater, potentially creating a refuge for sensitive species. At harvest, carbon and nitrogen within the kelp are removed from the marine environment, improving conditions locally and providing an organic biomass that can be transformed into food, fertilizer, feed, and other products. Scientists at University of Washington (Applied Physics Laboratory), NOAA (Pacific Marine Environmental Laboratory, National Marine Fisheries Service, and Manchester Research Station), and Washington Department of Natural Resources are assessing the effects of kelp cultivation on pH, carbonate chemistry, biology, and fish utilization.

Modelers at System Science Applications are creating a computer model that analyzes carbon and nitrogen sequestration, kelp biomass, and net production in order to illustrate the potential for kelp cultivation to remediate ocean acidification conditions. Washington Sea Grant is conducting outreach and communication. An Advisory Team of kelp experts is providing guidance on propagation, phytoremediation strategies, and ocean acidification.

2017 is the first year of full-scale cultivation and assessment, with kelp harvested in July and transported to SkyRoot Farm on Whidbey Island for direct soil enrichment and compost trials. A second year of full-scale cultivation and assessment will occur in 2018.

6.2 Updated Actions

Specific revisions to the Panel’s 2012 action language are underlined for easy reference.

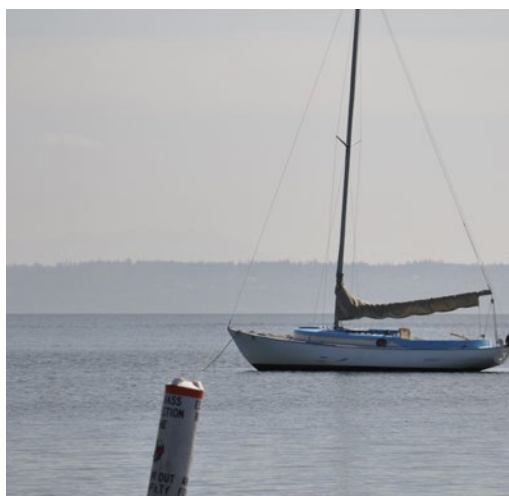
Action	Original Language	Updated Language	Rationale
6.1.1	Develop vegetation-based systems of remediation for use in upland habitats and in shellfish areas	Develop <u>land and aquatic</u> vegetation-based systems of remediation for use in upland habitats and in shellfish areas	<ul style="list-style-type: none"> Clarify language so action applies to both land and aquatic vegetation-based systems

6.3 New Actions

Action	Language	Rationale
6.1.4	Identify and support research and implementation of activities to increase the marine ecosystem’s ability to preserve carbon stored in sediments and capture and store additional carbon from atmospheric sources	<ul style="list-style-type: none"> Emerging opportunity to act on research and implementation related to capturing and storing atmospheric carbon in the marine ecosystem
6.1.5	In watersheds where models show land-based pollution contributes to local acidification, implement macroalgae recycling programs between local shellfish farms and terrestrial farms	<ul style="list-style-type: none"> Local seaweed recycling could be used to buffer corrosive conditions in ocean acidification hotspots created by local land-based pollution sources Developing a macroalgae recycling program could create financial incentives for local shellfish and terrestrial farms
6.2.5	Investigate the relationship between ocean acidification resistance in shellfish and feed quantity and quality to assess potential to strengthen shellfish through adjusted feeding regimes	<ul style="list-style-type: none"> Research suggests feed quantity and quality may influence capacity of shellfish larvae and calcifying zooplankton to survive and grow under stress from ocean acidification and other adverse environmental conditions (e.g., at low or high temperatures and low oxygen levels) Careful study of the effects of feed regimes on growth, survival, and physiological responses to these stresses may lead to adaptation strategies that are practical and useful in shellfish culture
6.3.6	Identify and protect intertidal and nearshore habitats that currently support, or will support in the future due to sea level rise, organisms vulnerable to ocean acidification and those that mitigate ocean acidification impacts	<ul style="list-style-type: none"> As climate change impacts our region through sea-level rise, protecting key habitat through restoration and/or preservation of what could become key habitat is an important adaptation strategy Initial focus should be on priority species, including kelp, eelgrass, and native oysters

6.3. New Actions, continued

Action	Language	Rationale
6.3.7	Review and evaluate current regulations governing the culture and harvest of aquatic vegetation and develop recommendations for regulatory changes, if needed	<ul style="list-style-type: none"> Research has shown photosynthesizing marine vegetation may locally remediate acidified waters, potentially conferring some protection from ocean acidification to both wild and cultured shellfish and other calcifiers Existing regulations governing harvest and interaction with aquatic vegetation may impede development of adaptation practices that take advantage of this function to reduce ocean acidification impacts Conversely, existing regulations and enforcement practices allow recreational harvest that, in some instances, could impair efforts to conserve and restore eelgrass and kelp A thorough, multi-agency, multi-disciplinary review could generate proposed regulatory changes that better serve conservation and restoration goals as well as ocean acidification remediation goals
6.4.1	Identify and share key findings from adaptation and remediation actions with ocean acidification communicators to support outreach and communication efforts designed to raise public awareness of ocean acidification (<i>Related to New Action 8.1.6</i>)	<ul style="list-style-type: none"> As part of developing a strong ocean acidification outreach and communications strategy, each topic area is charged with sharing key findings, success stories, and relevant information to ensure communicators can successfully develop accurate key messages



Jefferson Marine Resource Committee's voluntary no anchor zones protect eelgrass that is a natural buffer to rising acidity.
Photo credit: Northwest Straits Commission

6.4 Continuing Progress

In reviewing accomplishments and updated and new actions, the following were identified as key steps to continue adaptation and remediation efforts over the next five years:

- Continue to maintain and expand shellfish production
- Continue expanding deployment of instruments and operations of current instruments
- Continue developing new monitoring and treatment methods to increase implementation of effective methods for mitigating corrosive conditions at hatcheries
- Continue developing other ocean acidification indicators such as pteropods and working to incorporate thresholds (i.e., species tolerance limits) to guide action

- Continue improving and refining restoration practices and monitoring protocols for marine vegetation, and transplant eelgrass and kelp to meet stated restoration goals and improve monitoring protocols to better identify vulnerable populations of eelgrass and kelp
- Continue progress of selecting refuge sites and ensure their protection and management
- Continue restoration efforts to achieve the goal of restoring 100 acres of Olympia oyster habitat in Puget Sound, and pursue restoration on the Washington coast
- Continue operations of the Kenneth K. Chew conservation hatchery and its work to promote genetic diversity
- Use findings from research to develop implementable projects that use vegetation-based systems for remediation
- Assess benefits and risks of seaweed harvest at shellfish farms, quantify value of organic material to farmers in the watershed, and develop potential cost structure for marketing biomass to farmers
- Identify local opportunities to retain and use shell in key marine areas rather than relying on commercial sources
- Identify activities that could increase the ability to capture and store atmospheric carbon
- Research the effects of feed regimes on growth, survival, and physiological responses to ocean acidification stresses that may lead to practical and useful adaptation strategies for shellfish and other cultured species. Initially focus on larval effects with future work to study later life stages
- Conduct a thorough, multi-agency, multi-disciplinary review of current regulations on the culture and harvest of aquatic vegetation, and propose changes, as needed, that better protect native vegetation, serve conservation and restoration goals, and contribute to ocean acidification remediation goals



Cultchless oyster seed in hand. As a result of actions taken by the Panel, Washington's oyster seed crisis has been alleviated. Photo credit: Taylor Shellfish Farms