Ocean Acidification and Hypoxia: Today's Need for a Coast-Wide Approach

The West Coast Ocean Acidification and Hypoxia Science Panel

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Building From Early Action

Since ocean acidification first became recognized as a potentially significant issue for marine ecosystems, a worldwide effort has ramped up to understand where and how deleterious effects might manifest. The production failures at commercial shellfish operations in both Oregon and Washington between 2005 and 2009 were a striking reminder of the potential consequences of ocean acidification to ecologically and commercially important resources, and of the limits to our knowledge about these impacts.

A series of high level bodies have sought to summarize the state of the science and lay out potential strategies for policy and management action. Along the west coast, one of the most notable of these efforts was the state of Washington's Blue Ribbon Panel, launched in 2012. This multi-disciplinary effort brought together academic and agency scientists with state, federal, and tribal government representatives, along with industry partners. The panel produced a comprehensive report that outlined the science underlying ocean acidification, limits to that knowledge, and potential impacts to the resources of the state of Washington.

The challenges ocean acidification poses to marine ecosystems extend beyond shellfish, are larger than any one state, and will require concerted efforts across jurisdictional boundaries. The West Coast Ocean Acidification and Hypoxia Panel represents an opportunity to consider complete west coast ecosystems, drawing together knowledge and resources across typical jurisdictional and management boundaries.

This report was produced by the California Ocean Science Trust, working in partnership with the West Coast Ocean Acidification and Hypoxia Science Panel.

A West Coast Panel to Address a Regional Challenge

The California Ocean Protection Council, a cabinet level body chaired by Secretary for Natural Resources John Laird, formally charged Skyli McAfee, Ocean Protection Council Science Advisor and Executive Director of the California Ocean Science Trust, with convening an Ocean Acidification and Hypoxia Science Panel at its September 13, 2012 public meeting. Subsequently, the governments of Oregon, Washington and British Columbia joined California, in recognition of the value of a coast-wide effort. The timing for this effort is particularly opportune – the Washington State Blue Ribbon Panel on Ocean Acidification final report in 2012 documented the current state of scientific knowledge and recommended actions to respond to increasing ocean acidification in Washington's local waters. The foundation of knowledge established in Washington provides a robust starting point for the work of the West Coast Panel to address these issues at a coast-wide scale. Washington's participation in the West Coast Panel brings a wealth of institutional knowledge (all of the Washington panelists were also members of the Blue Ribbon Panel); it also brings the opportunity to link advances across the coast to their ongoing efforts to implement the Washington panel's recommendations. This reflects the reality that decision makers along the Pacific coast must work together to ensure that the most relevant data are collected, the most relevant experiments are conducted, and that proposed management strategies will range across the California Current ecosystem.

Multiple Problems, One Panel

The state of Washington's Blue Ribbon Panel was convened to explicitly address the challenges of ocean acidification. Nevertheless, the Washington Panel clearly noted the importance of considering multiple, co-occurring stressors, as changes to marine environments do not happen in isolation. Among the other environmental shifts that have happened along the west coast in recent years is the increased frequency and intensity of hypoxia events, such as those that caused losses to Oregon fisheries beginning in 2002. The West Coast Panel has taken an integrative approach, noting that ocean acidification and increased occurrence of hypoxia are often linked in time and space. The addition of hypoxia considerations to the West Coast Panel provides opportunities to tap into ongoing efforts, such as regular monitoring occurring in Oregon to understand seasonal hypoxia dynamics, as well as modeling work occurring in the Southern California Bight to understand effects of nutrient loading. A similar body of work considers shifts in seawater temperatures, which affects the concentrations of gases, such as oxygen in the water. Each of these circumstances occurs in the context of simultaneous connections between lower pH and reduced dissolved oxygen (DO). As a result of these connections, any management action taken to address one of these issues may well have synergistic impacts on the other.

Broad Coast With Common Themes

The coasts of California, Oregon, Washington, and British Columbia span thousands of kilometers of varied topography, and include powerful upwelling regimes, massive estuaries, deep fjords, and protected bays. Ocean acidification and hypoxia events manifest in different ways depending on these physical factors, and any potential management actions must consider how the ocean regime will influence effectiveness. Nevertheless, there are common oceanographic themes that repeat along the range.

The Washington Panel classified the waters of Washington state into four major types; 1) the outer coast, 2) deep, stratified estuarine systems (e.g., Puget Sound and the Strait of Juan de Fuca), 3) shallow, mixed estuaries (e.g., Willapa Bay), and 4) the Columbia River. These distinctions are quite specific to the state, though they certainly have direct analogs along the coast. The entire west coast encompasses a broader range of oceanographic variability, freshwater inputs, and nutrient limitations.

A valuable organizing strategy may thus be a broad categorization with a number of subdistinctions. When these include the waters of Washington state, the descriptions from the Washington Panel will apply. Each of these regions differs in the relative contributions of atmospheric, oceanographic, and terrestrial drivers as well as in the species and ecosystems potentially affected:

1. **Coastal shelf systems:** make up the majority of the coastal waters. In these regions, several factors (e.g., distance to continental shelf break, local winds) determine the relative contributions of deep ocean water and land-based influences in driving nearshore chemistry. This category may include several subcategories based on current system (Alaska or California), shelf width, upwelling intensity, and freshwater inputs.
2. **Estuarine systems:** in these systems, local, land-influenced processes rather than the deep ocean waters often dominate chemical conditions. Within this category, there are distinctions based on depth and degree of mixing or stratification of the estuary system. Shallow seasonal rivers in California will have different influences than the deep fjords of Washington and British Columbia.
3. **Unique systems:** include major enclosed seas and river systems along the coast (Salish Sea / Puget Sound, Columbia River, San Francisco Bay) as well as the Southern California Bight. Puget Sound and Columbia River were called out for special consideration in the Washington Panel report, and this category should be expanded to incorporate other unique systems.

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Threats to economically important fisheries are among the primary drivers of stakeholder interest in acidification and hypoxia.

Improved sensor technology and availability is permitting new explorations of nearshore water chemistry.

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Beyond Oysters

The west coast is home to some of the most diverse and productive ecosystems on earth as well as economically important fisheries. The potential threats to these fisheries from ocean acidification and hypoxia are among the primary drivers of stakeholder interest in these issues.

The Washington Panel devoted considerable attention to the impacts to marine species and ecosystems critical to the state. Washington is the largest producer of aquaculture-grown shellfish on the coast, and these species occupied a central place in the panel's work. Bivalve moluscs, while less economically important elsewhere, are critical members of ecosystems throughout the west coast. Intensive research efforts on these taxonomic groups provides a wealth of knowledge about how they will respond at the molecular, genomic, and ecological levels. The information about these species is broadly applicable to the entire region. Local and regional differences in species and community composition and economically and culturally important uses of the ocean will affect the assessments of impacts and potential strategies for management.

In addition to its focus on bivalves, the Washington Panel report also considered a wide variety of taxa – including seagrasses, primary producers responsible for harmful algal blooms, and fish that are important members of ecosystems throughout the west coast. Most of the information on species responses contained within the Washington Panel report is relevant elsewhere. However, research on these physiological responses is advancing rapidly, and the West Coast Panel has an opportunity to incorporate recent developments.

Fresh Information

In a field advancing as rapidly as ocean acidification, any summary report is necessarily a snapshot of the state of knowledge at that time. Indeed, ocean acidification research is one of the most active and exciting areas in marine science, with thousands of new studies published each year since 2012. The Washington Panel conducted an in-depth literature review that summarized the scientific knowledge at the time, but great strides have been made in several areas since then. This document does not attempt to summarize the current state of the scientific literature; rather, it highlights several major target areas where rapid advances in the field have changed our understanding and provide a new foundation for the work of the West Coast Panel. This new knowledge will provide the nuanced understanding to inform management actions.

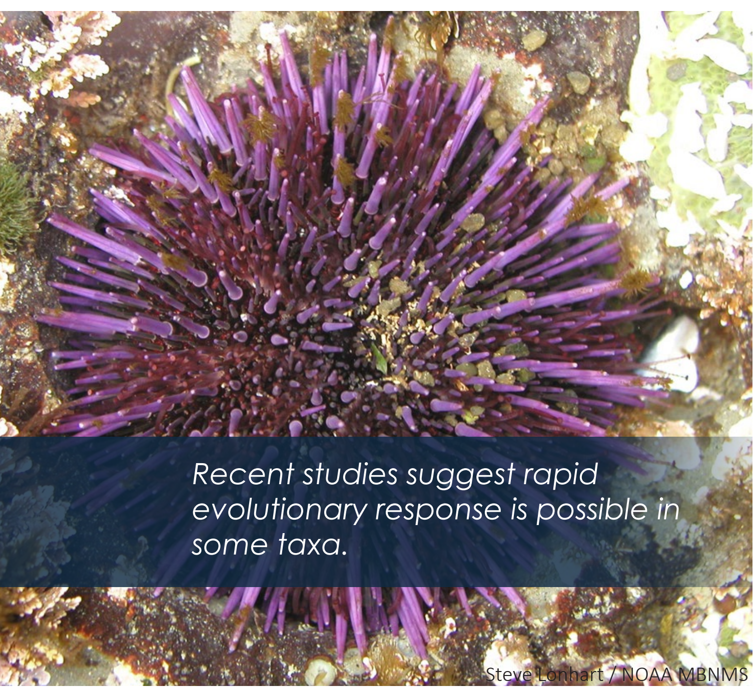
a. Near shore oceanography from the continental shelf to the beach

Very recent data are helping us appreciate the degree to which chemical conditions in the nearshore vary in time and space. As decision-makers consider potential strategies to address ocean acidification and hypoxia, they are often hampered by a lack of information on the variation in water chemistry through time and space. Since the Washington Panel report was developed, sensor availability has improved as field pH sensing technology has moved from specialized laboratories to commercial products that are more broadly available. This is permitting new explorations of water chemistry in the very nearshore with multiple new sampling sites instrumented in California, Oregon, and Washington. The few sampling programs that were in place in 2012, such as the Ocean Margin Ecosystems Group for Acidification Studies (OMEGAS) and the Joint Effort to Monitor the Strait of Juan de Fuca (JEMS) have continued their work, providing longer data records that can reveal more details about oceanographic patterns. Some of these results are demonstrating regional differences in the pH and DO characteristics of water masses. These new data will enhance understanding of the relative contributions of local and offshore forcing of nearshore water chemistry. New data from Puget Sound and Southern California is providing additional insight into how pH and DO conditions vary within these unique coastal regions.

Scientific understanding remains limited for robustly predicting linkages between climate change, atmosphere, upwelling, and surface chemistry. Here, there has been some progress clarifying the projected shifts in upwelling with future climate change, but this is still an area of active research. Our understanding will continue to improve as longer data sets provide additional opportunity to quantify patterns through time.

b. Biological responses

A major focus of ocean acidification research highlighted in the Washington Panel report is the ways that organisms and ecosystems will respond to the lower pH of future oceans. Our understanding of biological responses to ocean acidification has improved on several fronts since the since Washington Panel report. For example, the Washington Panel incorporated many examples of reduced pH altering growth rates or physiological function of marine organisms. Since that time, our understanding has expanded in several directions, including additional details about biological processes besides calcification, and meta analyses revealing the generality of effects. Decision-makers across the west coast need to understand impacts on a broad of species, and need to understand those impacts in the context of real conditions in the environment. These levels of detail are beginning to emerge.



Recent studies suggest rapid evolutionary response is possible in some taxa.

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c. Responses to realistic environments

The majority of biological impacts experiments have been conducted using a narrow range of acidification treatments; this is beginning to change as researchers strive to more closely capture natural conditions.

One area of advance has been in consideration of multiple, simultaneous stressors. Many experiments are being conducted to investigate interactions between temperature and elevated CO_2. To a lesser extent (due to technological challenges), work is advancing on combining the effects of high CO_2 and low DO. The results of these experiments highlight the variety of possible biological responses; in some cases multiple stressors act synergistically, while in other cases, changing two conditions may actually ameliorate negative consequences seen in a single-stressor experiment. Such experiments are critical to understand the extent to which single stressor experiments will be relevant to a world where multiple environmental factors are shifting.

There has also been expansion of our knowledge about how organisms respond to chemical conditions that fluctuate through time in an environmentally-realistic manner. This has emerged from expanded knowledge of chemical conditions in nearshore habitats as well as refinements in experimental techniques since the Washington Panel report. New experiments with e.g., diurnally fluctuating exposure conditions, are contributing essential knowledge for defining exposure limits.

Finally, we are beginning to gain better understanding of how organisms are responding to the changes in ocean chemistry that have already occurred. Field studies of organisms in natural habitats provide evidence of currently occurring impacts of reduced seawater pH.

d. Evolutionary responses

The Washington Panel noted the need to understand evolutionary responses to ocean acidification conditions. At that time, there were only a very few studies, including modern experiments, analysis of contemporary systems, and examinations of the Paleontological record to provide any evidence for adaptive potential. It is still a nascent research field, but a few recent studies have made important advancements. There is now stronger evidence that rapid evolutionary response is possible in some taxa. Additional evidence is accumulating that local adaptation is possible, with small populations of a single species differentially adapted to one or more environmental factors. This has important implications, for instance, in deciding whether local management measures might be needed to protect populations from rapidly changing chemical conditions.

e. Ecological Interactions

Ultimately, concern about ocean acidification and increasing hypoxia is driven by worries about effects to marine ecosystems and consequent economic and societal impacts. We continue to find examples of biological thresholds: levels of elevated CO_2 above which individual performance measures such as calcification rates, growth, or reproductive success declines precipitously. These may have strong ecological ramifications if they result in dramatic population declines, shifts in species compositions, or altered ecosystem structure or function.

A Coast-Wide Opportunity

The progress since the Washington Panel demonstrates the active nature of this field, but also highlights the importance of a coast wide approach to address these environmental shifts. The water monitoring programs that Washington instituted as a result of the Washington Panel recommendations will be of great benefit to the state as they plan local efforts. As these data are combined with similar programs in Oregon and California, they will lead to a better understanding of the mechanisms driving chemical conditions throughout the region. These same benefits will accrue to Washington from its neighbors as well. Cruise data from Oregon chemistry monitoring programs helps parameterize models that span the west coast. Moving forward, monitoring throughout the region is expanding beyond the water quality parameters that are directly linked to ocean acidification and hypoxia. Marine protected area monitoring will detect ecosystem changes and species shifts that can inform ecosystem-based management decisions across multiple agencies. Though not initially envisioned as ocean acidification monitoring efforts, they provide some of the best opportunities to detect shifts in the structure and function of coastal ecosystems. Additional efforts are needed to monitor the impacts of shifting ocean chemistry on the socioeconomic structures of communities reliant on the ocean throughout the west coast.

Moving forward, there will be a need for innovative, cross-sector partnerships between scientists, managers, and community members to foster creative, long-range solutions to the challenges of ocean acidification and increased hypoxia along the west coast. With new research consortia and robust ocean observing programs, as well as industry, state, federal, tribal, and stakeholder partnerships in place, the west coast is responding to this challenge.

Convening Editors

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