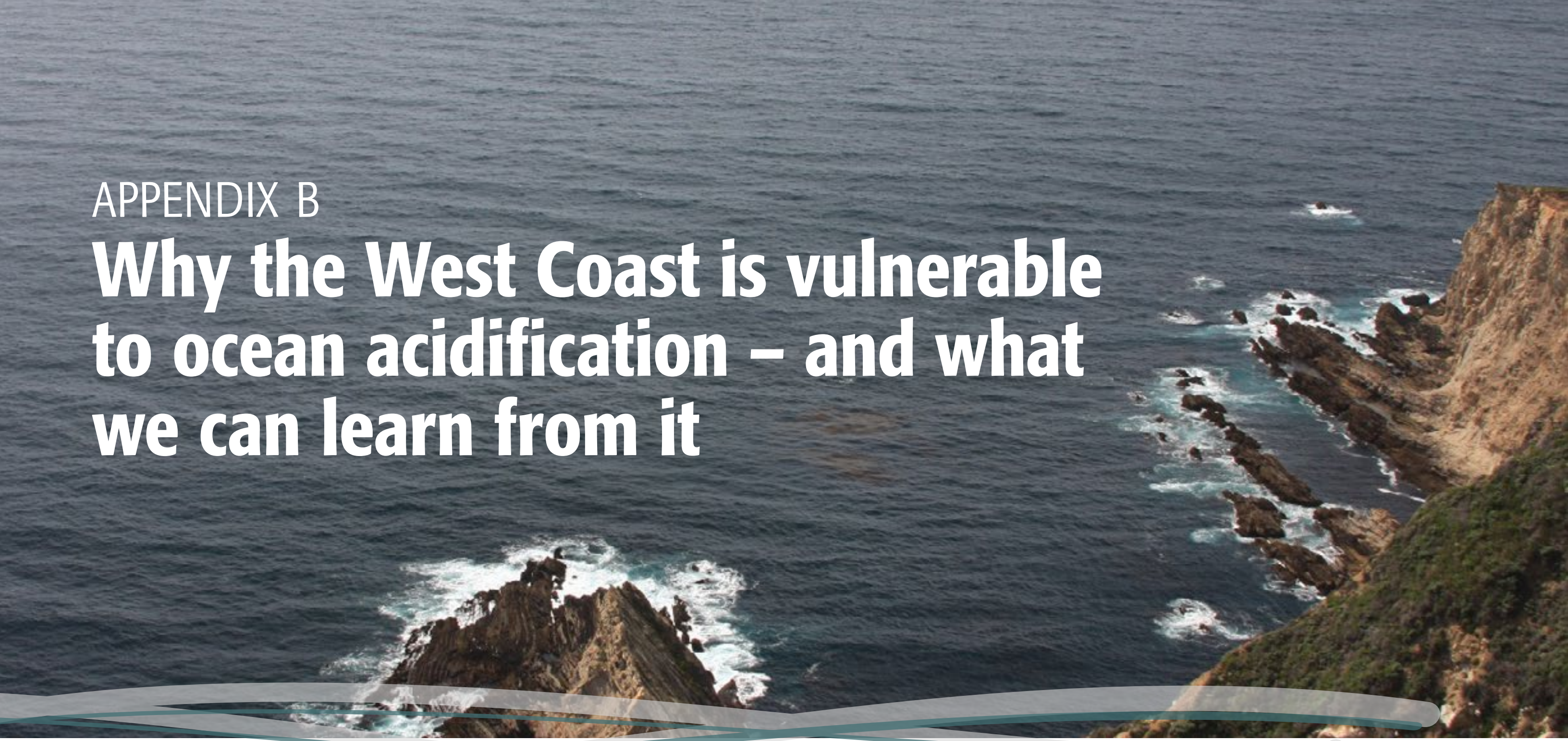

APPENDIX B

Why the West Coast is vulnerable to ocean acidification – and what we can learn from it

Ocean acidification (OA) is a global problem triggered by the world's oceans absorbing society's CO_2 emissions from the atmosphere, but the effects of OA will manifest unevenly in different regions of the world. The West Coast of North America – among the first and most prominent regions being impacted by OA – is especially vulnerable because of a confluence of factors affecting this ecologically and economically significant region. However, as OA's global impacts intensify, other regions of North America – from the fisheries-dependent Gulf Coast to the slow-flowing embayments of New England – also will be altered by OA. Thus, the West Coast can and should serve both as a harbinger of OA's impacts worldwide and as a case study on how to develop a highly effective, region-specific science strategy for reducing the threat of OA on the West Coast and other regions of North America.

A confluence of factors makes the West Coast particularly vulnerable to ocean acidification; a regional, coordinated science approach is the best strategy to mitigate impacts.

A confluence of factors makes the West Coast especially vulnerable to OA

OA along the West Coast is being driven by a confluence of conditions that will create increasingly severe impacts over the foreseeable future. There are two primary natural phenomena that work in concert to heighten the region's vulnerability to global CO_2 emissions:

1. **Ocean currents:** Acidification of West Coast waters originates with oceanic currents that transport waters across the northern Pacific Ocean from Asia to the West Coast. The journey for these waters – which takes about 30 years but can be as long as 50 years – begins off the coast of Japan, where surface waters absorb atmospheric CO_2 produced through global human activity and then sink hundreds of feet beneath the ocean's surface. As these subsurface waters move toward the West Coast, CO_2 levels rise even more as natural respiration processes break down sinking organic matter (and deplete dissolved oxygen). Because these deep waters are naturally enriched in CO_2, the added CO_2 from atmospheric emissions has a disproportionately large impact on ocean chemistry.
2. **Coastal upwelling:** Along the West Coast, winds that blow southward push surface waters away from the coastline. As surface waters are displaced, the deep waters rich in CO_2 and poor in dissolved oxygen (DO) are pulled to the surface in a process known as upwelling. Upwelling spreads CO_2–enriched waters across the entire continental shelf, pushing chemical conditions past biological thresholds for harm in many coastal zones.

Because these physical and biogeochemical processes play out over a multi-decade timeframe, the effects of West Coast OA are projected to become increasingly severe over time. Three decades ago, atmospheric CO_2 levels were about 16% lower than they are today. Thus, the waters already in transit to the West Coast will carry an increasingly heavy anthropogenic CO_2 burden as they arrive on West Coast shores. In fact, even if atmospheric CO_2 emissions could immediately be stabilized, the West Coast would still be grappling with increasingly CO_2-rich waters for at least the next three decades.

Compounding these challenges is global climate change, which is also triggered by rising CO_2 emissions. As the world's oceans warm, seawater will become less able to hold DO, and the difference in temperatures between surface waters and deeper waters will grow bigger, reducing the oxygen resupply to deeper waters. Both trends will result in larger and more severe low oxygen, or hypoxic zones. Meanwhile, West Coast upwelling is projected to intensify as the winds that drive upwelling strengthen in response to global warming. Because upwelled waters are also depleted in DO, the progression of OA in many parts of the West Coast will take place against a backdrop of increasing risk of hypoxia events. This co-occurrence of hypoxia poses further challenges for organisms already subject to OA stress, increasing the vulnerability of the West Coast region to the effects of rising CO_2 emissions.

The most effective way to reduce West Coast vulnerability is through coordinated science

Because OA is a regional problem for the West Coast, the best way to mitigate OA's impacts is a regionally coordinated scientific research and monitoring strategy. Scientists and managers from across the West Coast can work together toward reducing OA's impacts on coastal ecosystems. A coordinated approach can take advantage of scientific commonalities that link the geographically and ecologically disparate areas that make up the West Coast region. For example, while Southern California's highly urbanized coastline may bear little resemblance to the minimally developed outer coast of Washington, they share many species of marine life in common. In fact, many important fishery species such as hake, tuna, and sardines move readily across state and national borders. Even for bottom-dwelling invertebrates such as Dungeness crabs, clams, and mussels, local populations can be genetically connected over large distances by the dispersal of planktonic young on ocean currents. Insights into biological vulnerability gained from one region can thus quickly inform information needs in another. Likewise, projections of ocean chemistry changes in any local ecosystem will require input from coast-wide models that set the stage for broader-scale patterns and trends in exposure. The development of such crucial coast-wide models is already underway and offers another avenue to accelerate access to knowledge needed across the region.

While local modeling and monitoring efforts are critical, they can have tremendous added value when they are linked together in a region-wide context that matches the regional scope of West Coast OA. By forming collaborative partnerships that leverage regional expertise and resources, and reduce redundancies, the West Coast can take advantage of economies of scale to mount a strong defense against this intensifying region-wide problem. OA knows no political boundaries and cannot be managed within defined jurisdictional borders, underscoring the value of highly coordinated, leveraged science.

The West Coast can serve as a proving grounds for strategic OA management

The West Coast will be a harbinger for the types of OA impacts that will be widely felt across coastal North America in the coming decades. By working in a coordinated fashion, scientists can provide managers with useable knowledge and information that informs and supports their OA management decisions. Just as importantly, the West Coast can serve as a proving ground for strategic OA management in other regions of North America and the world. Even within the West Coast region, "one size fits all" approaches are unlikely to be successful, as local factors that amplify or dampen OA vulnerability will differ with geography. Consequently, the vast and varied West Coast region offers the opportunity to test and compare diverse strategies, models and guides that can be transferred to other regions of North America.

This report was produced by the West Coast Ocean Acidification and Hypoxia Science Panel (the Panel), working in partnership with the California Ocean Science Trust. The Panel was convened by the Ocean Science Trust at the request of the California Ocean Protection Council in 2013, working in collaboration with ocean management counterparts in Oregon, Washington, and British Columbia. Ocean Science Trust and the Oregon Institute for Natural Resources served as the link between the Panel and government decision-makers. The information provided reflects the best scientific thinking of the Panel. More information on the Panel can be found at www.westcoastOAH.org. Cover image: Steve Lonhart / NOAA MBNMS.