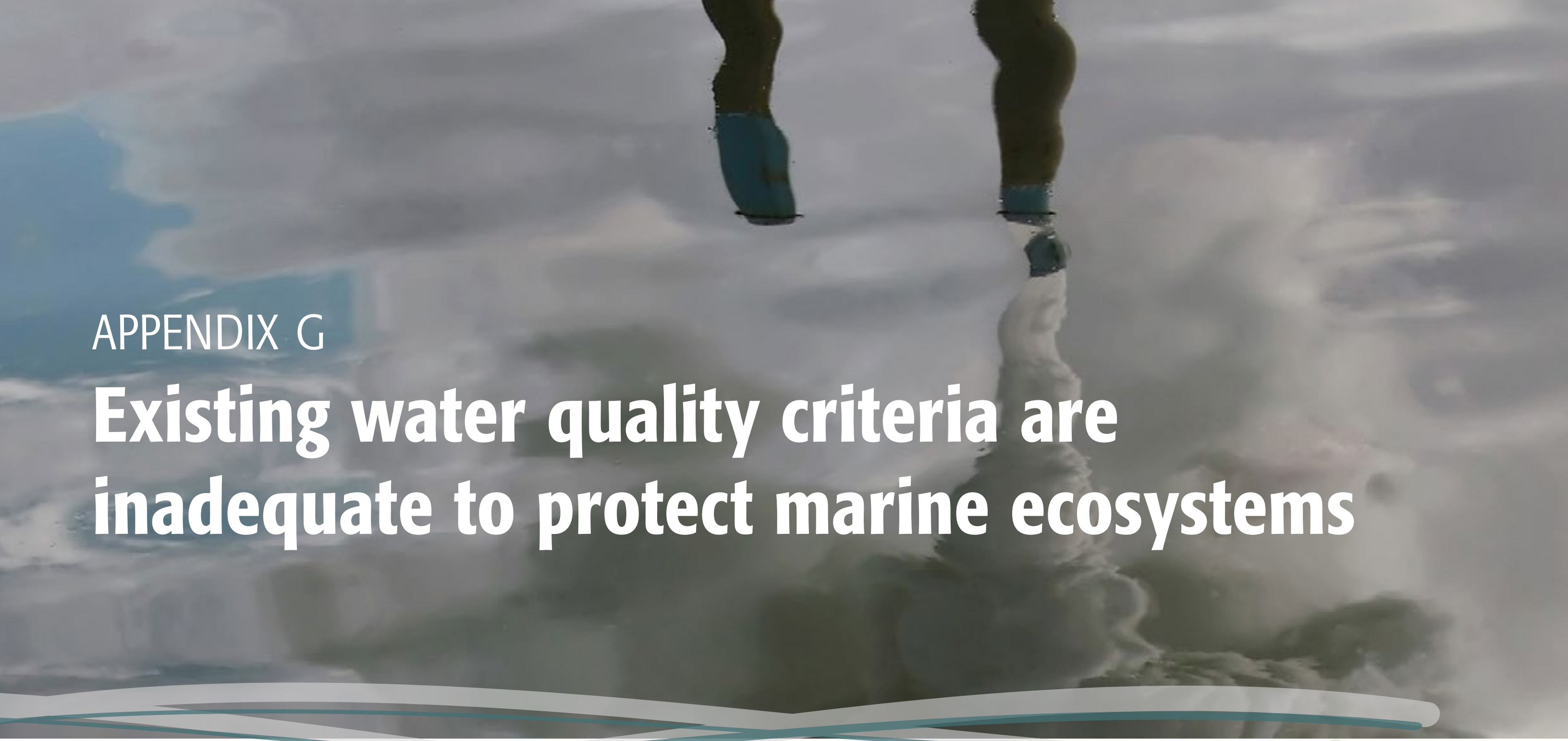

APPENDIX G

Existing water quality criteria are inadequate to protect marine ecosystems

Water quality criteria are the management foundation of the Clean Water Act. They provide a basis for assessing water body condition, determining the level of discharge that will maintain a water body in an ecologically acceptable condition, and objectively determining when a water body is impaired. Most importantly, water quality criteria serve as targets for water body planning and mitigation projects, even outside of the regulatory framework.

Unfortunately, the existing water quality criteria for pH are not scientifically valid for application to ocean acidification (OA). They were developed 40 years ago, and the Panel has determined that they are neither based on current science nor are they ecologically relevant. Damage to ocean biological communities has been documented at thresholds that are well within the criteria's legally permissible range.

> ...the existing water quality criteria for pH are not scientifically valid for application to ocean acidification.

Shortcomings of existing criteria

Existing OA criteria are based on two types of pH thresholds: a requirement that pH should not fall below 6.5, and a requirement that pH should deviate no more than 0.2 pH units from natural conditions. Both types of thresholds are flawed for the purposes of application to acidification.

The minimum pH of 6.5 is inadequate because numerous studies have shown diverse biological impacts routinely manifest at pH levels well above 7.5, at which acidity (hydrogen ion concentration) is an order of magnitude higher than pH 6.5 (pH is on a logarithmic scale). The Panel's publication, "*What changes in the carbonate system, oxygen, and temperature portend for the northeastern Pacific Ocean: a physiological perspective*," provides more detail about the range of biological responses that occurs even as existing pH criteria are met.

The second part of the criteria, which calls for a deviation of no more than 0.2 pH units from natural, is flawed because it is impractical to apply. "Natural" conditions cannot be established spatially because the entire West Coast region is undergoing change due to global atmospheric inputs, and it is difficult to establish temporally because there are few long-term data sets with enough precision and accuracy to capture this level of change. This is compounded because measurement imprecision of the technology used in discharge monitoring programs is greater than 0.2 pH units, creating a margin of error that can mask ecologically relevant pH changes. Criteria inadequacies regarding establishing "natural" conditions are further described in the Panel supporting document "*Water quality criteria for acidifying oceans: Challenges and opportunities.*"

Water quality criteria should be expanded to encompass other acidification parameters

Although developing an alternative pH criteria represents an important first step, revisions to water quality criteria should be expanded to include other biologically relevant acidification parameters. pH is only one of several possible parameters for describing effects of acidification, and it is unclear if pH is even the most biologically relevant variable for many species. Aragonite saturation state, another viable candidate indicator, has been found to be more biologically relevant than pH for shell-building in calcifying organisms. Considerable scientific evidence, particularly from studies of oysters and pteropods – a shelled zooplankton at the base of the food web – is already available for establishing both chronic and acute thresholds for aragonite saturation state. In addition, parameters such as pCO_2 have been found to be biologically relevant for fish, affecting their behavior and ability to navigate.

In developing ecologically relevant thresholds for OA parameters, managers should account for potential interactions of OA with co-occurring stressors such as hypoxia. There is a growing recognition that the most acidified regions of the ocean are also low in oxygen, with recent studies showing that dual effects of low pH and hypoxia are more severe than the predicted effects of either stressor alone. In the immediate future, a scientific workshop is needed to identify appropriate biologically relevant indicators and thresholds to assess OA, and to prioritize short-term research needs for informing criteria and threshold development.

> ...revisions to water quality criteria should be expanded to include other biologically relevant acidification parameters.

Development of biological criteria will improve assessment of acidification effects

The Clean Water Act provides an opportunity for assessing ocean health by examining condition of the biological communities that live within it, which has advantages over using pH or other chemical criteria alone. Traditional chemistry thresholds and associated monitoring are limited because they provide information about a relatively narrow portion of the environment at a discrete point in time. In contrast, bioassessment accounts for exposure to multiple stressors over extended time periods, and provides a more integrated reflection of aquatic ecosystem condition.

Incorporating biological criteria into a management context requires linking population and community effects with specific stressors. Effective biological criteria should provide early-warning management cues, before significant ecosystem alteration has already taken place. However, biological criteria also need to relate to effects on growth, survival, reproductive success or other metabolic functions that have repercussions at the population level, as opposed to simply quantifying exposure to a stressor. For example, pteropods might prove useful as a biologically relevant criterion for linking acidification stress to biological response, as they are an important food source for economically important fish and are among the first organisms to be affected by acidification in a marine ecosystem. Pteropods have thin aragonitic shells and narrow optimum windows for calcification, leading them to display rapid responses to corrosive waters. Acidification effects on their calcification have been studied under both field and laboratory circumstances and such indicators could offer a more integrated understanding of acidification effects.

Using ecologically relevant criteria to support OA management

Water quality criteria are typically used as regulatory tools, such as making decisions under the Clean Water Act Section 303(d) regarding whether a water body is impaired. The Panel recognizes that this is one application of water quality criteria, but the Panel also recognizes that credible water quality criteria can be effective in other decision-making contexts. For example, water quality criteria provide essential context for interpreting monitoring data or the output of model predictions about the likely effects of potential management actions. They also become part of a shared toolkit with managers from other sectors, providing a common framework for discussions about appropriate actions for fisheries and marine reserves. Additionally, scientifically-founded OA criteria can also be used to educate the public about OA and its effects on local waters.

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: Todd Walsh / MBARI 2008 / Marine Photobank; circle inset (Marin watershed monitoring) - Dan Best, SPAWN / Marine Photobank.