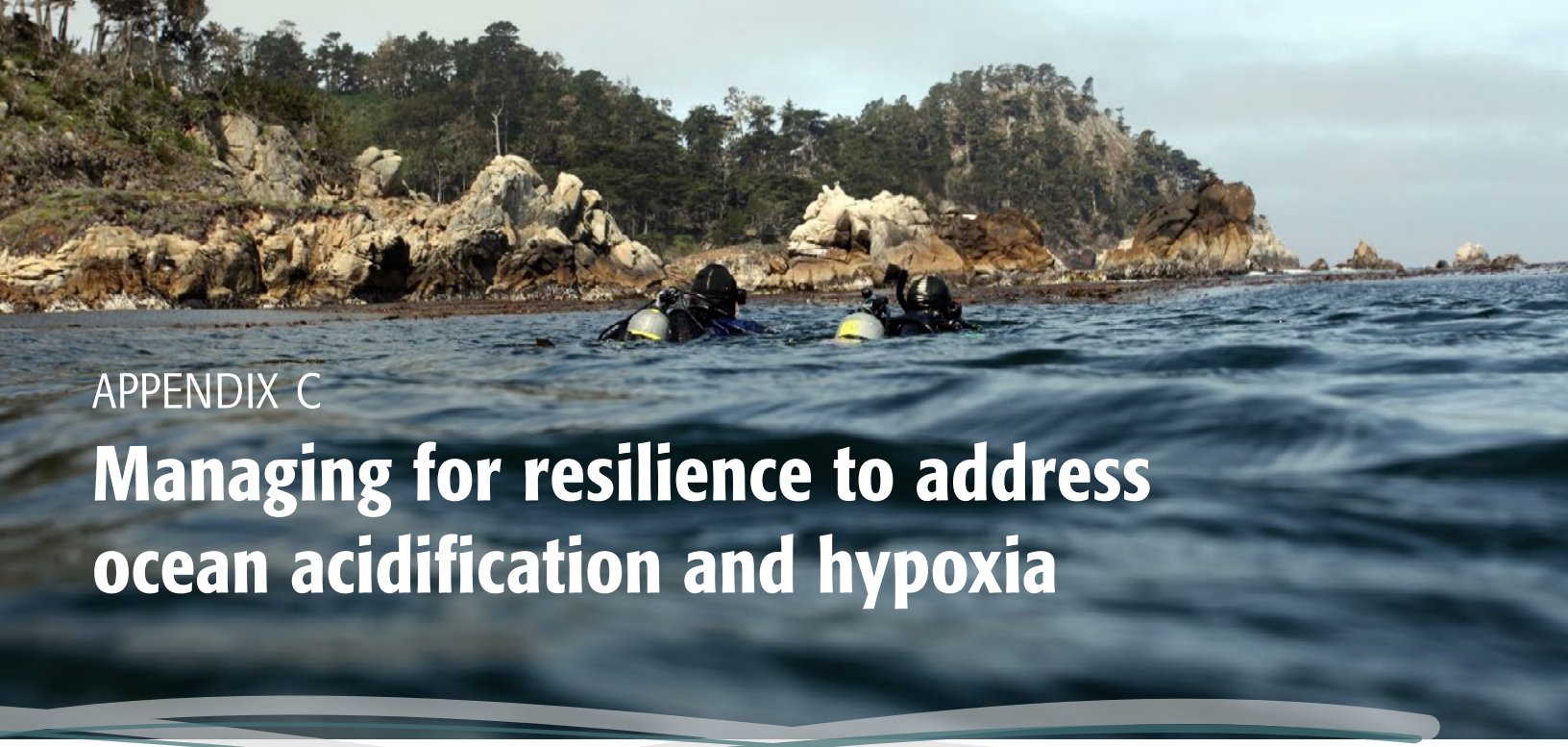

APPENDIX C

Managing for resilience to address ocean acidification and hypoxia

The term "resilience," as applied here, refers to the adaptive capacity of ecological systems to cope with and recover from the impacts of ocean acidification and hypoxia (OAH) and other stressors. Here we provide the Panel's suggestions for how the management community can support ecological resilience under conditions of intensifying OAH by undertaking targeted actions that preserve or enhance the capacity for ecological systems to cope with and recover from OAH. Managing for resilience includes adaptation measures that seek to proactively lessen the impacts of OAH, and mitigation approaches that reduce exposure to co-occurring stressors. Such actions can be applied now to address impending changes in ocean chemistry. While intensifying OAH conditions may eventually cause some ecosystems to change substantially or irreversibly, over the near-term, managing for resilience represents an important strategy for "buying time" to slow the onset and reduce the scope of harmful ecosystem changes.

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Ecological concepts that underlie managing for resilience

Resilience spans many scales of biological organization, ranging from short-term physiological adjustments that take place within individual organisms, expression of adaptive capacity through evolutionary changes in populations, to the maintenance of ecological function by species turnover at the scale of ecosystems. Despite the number and complexity of biological and ecological processes that contribute to ecological resilience, scientists have been able to identify a specific set of desired attributes of resilient systems that are well-suited for protection or enhancement via management intervention. These general attributes include diversity, redundancy, modularity, connectivity, and adaptive capacity. For example, diversity in the form of a species-rich and functionally-redundant community of aquatic vegetation can be fostered by habitat protection measures. The resilience of fish populations can be promoted through harvest regulations that maintain broad distributions in age class structure and the contribution of sub-populations to a fishery. Population connectivity and, to a lesser extent, modularity, are already central elements in the design of coastal protected area networks.

Managers can also develop solutions that foster resilience by focusing on stressors that co-occur with OAH, such as physical disturbances to nearshore habitats, warming temperatures, toxic contaminants, biological invasion, and harvest. Co-occurring stressors can diminish the ability of ecological systems to cope with OAH, but may be amenable to control through management action.

Maximizing benefits from managing for resilience

Although managing for resilience is a useful near-term management strategy for coping with OAH, the adaptive capacity of West Coast ecosystems is not limitless. Managing for resilience is likely to become less and less effective as OAH intensifies and degrades precisely the biological and ecological attributes that confer resilience to populations, communities, and ecosystems. Where and when managing for resilience is likely to be most successful is also likely to vary greatly among systems and from place to place, but understanding of this variation is poorly developed for OAH. Identifying priority candidate fisheries or systems where the development and implementation of resilience-focused management plans are most likely to be beneficial would be an important first step in managing for resilience across the region.

Resilience management can involve actions to prevent the loss of resilience from status quo conditions, or interventions that enhance the resilience of a system in the face of intensifying OAH stress. The effectiveness of either approach will depend on establishing metrics of resilience, defining targets and goals, and developing the ability to track changes in resilience and intervene adaptively if goals are not met. Because preserving and enhancing resilience to OAH are not currently explicit goals of natural resource management, metrics to quantify resilience, targets for those metrics and approaches to monitor changes in resilience have yet to be fully developed.

Increasing the capacity to hone such tools is an important opportunity to advance managing for resilience from conceptual strategy to concrete implementation. For now, managers will need to work with scientists to develop, test, and refine such approaches in real world applications.

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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: Chad King / NOAA MBNMS; circle inset: David Berry / Creative Commons License.