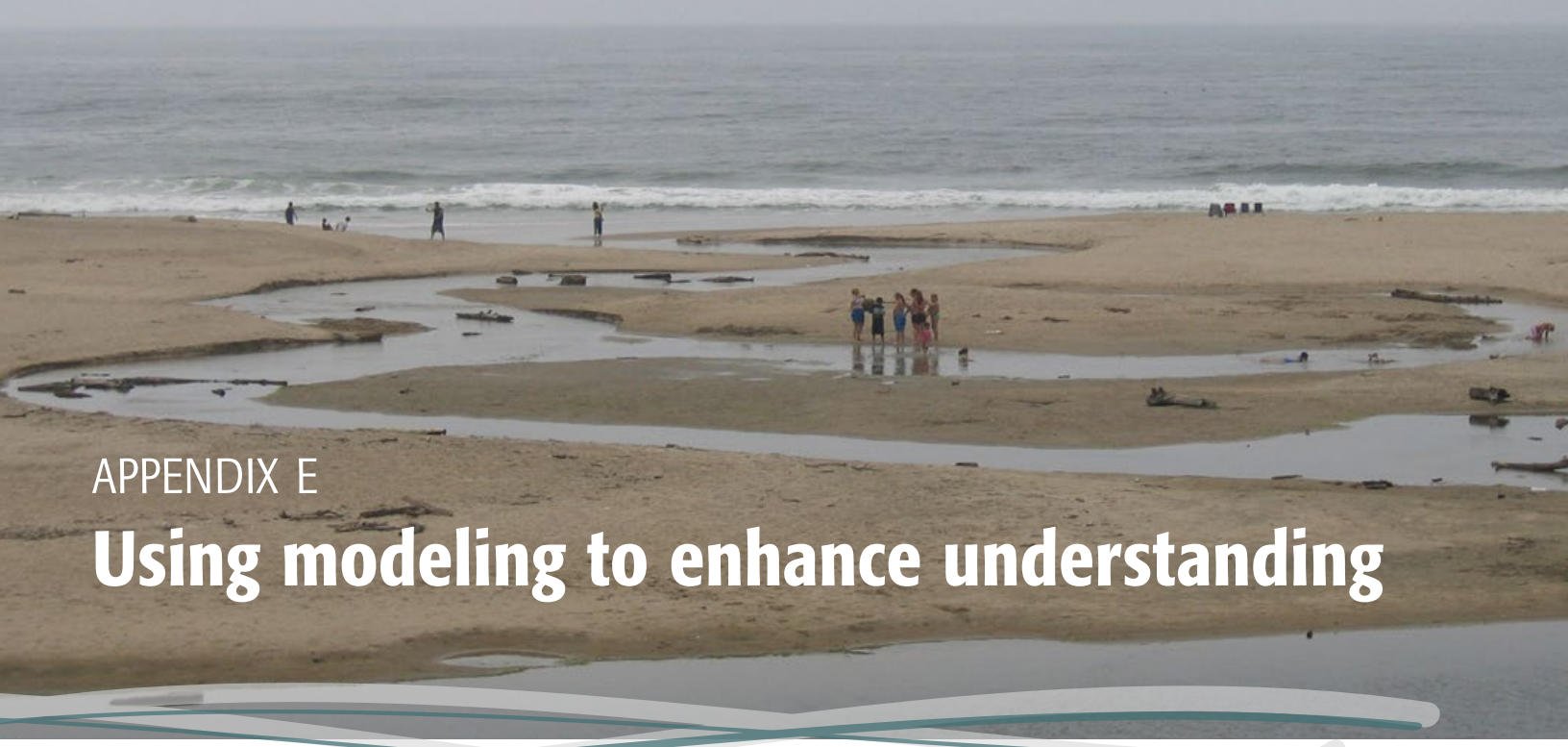

APPENDIX E

Using modeling to enhance understanding

Predictive mathematical models that provide insight into the potential ramifications of ocean acidification and hypoxia (OAH) play an instrumental role in scientists' ability to offer a suite of management options that address OAH in an informed, scientifically defensible fashion. Modeling tools allow scientists to forecast what future conditions will look like, to interpolate limited data sets to build a comprehensive picture of conditions, to evaluate likely success of potential management actions, to prioritize data gaps, and to evaluate monitoring plans.

OAH models will allow coastal managers to make better-informed decisions about implementing controls on local pollution sources that are exacerbating OAH, and to engage in ecosystem-scale resource management planning. Multiple research groups are already in various stages of developing such models, but efforts to date are limited in several respects. First, OAH model development has primarily focused on large oceanic scales, leaving important knowledge gaps in scientists' ability to predict OAH dynamics in near-coastal waters, estuaries and bays that are the primary focus of potential management action. Second, physical models that describe the movement of ocean water across space and time have not yet been systematically coupled with biogeochemical models, which describe how various environmental elements together exert collective effects on OAH chemistry, or with ecosystem models that integrate physical, biogeochemical and ecological properties to predict effects on marine life populations and whole ecosystems.

Thus, additional investments in OAH modeling work are needed to enhance, coordinate and link existing modeling efforts to OAH-related management decisions. The Panel recommends that West Coast managers and the scientific community move forward by building and improving upon both coupled physical-biogeochemical models and fishery and ecosystem models. These models should be validated with management endpoints in mind and against various settings. The modeling community would also benefit from a modeling forum to promote collaboration and interaction with managers. These recommendations are outlined in greater detail here.

OAH models will allow coastal managers to make better-informed decisions about implementing controls on local pollution sources...

OAH Modeling Recommendations

1. Invest in a suite of coupled ocean-margin physical and biogeochemical models.

Although a nested set of physical and, to a lesser extent, biogeochemical models has already been developed for the West Coast, these models have coarse resolution that inhibits their application in areas that are the focus of management concern. West Coast managers should build capacity for downscaling these physical models, extending them closer to shore, and integrating them with biogeochemical models to create high-resolution, coupled models.

2. Improve fishery and ecosystem models.

Although a broad suite of models are currently employed to inform fishery management and predictions of ecosystem changes along the West Coast, the objectives of these efforts have generally fallen outside the scope of OAH management needs. Fishery and ecosystem models will be crucial for understanding and predicting the full extent of OAH impacts. The utility of these models, however, will depend on how biological and ecological responses of OAH are parameterized, and how outputs from coupled physical-biogeochemical models are utilized. To better support marine resource decisions, scientists should prioritize research that yields parameterize-able understanding of the biological and ecological impacts of OAH, and improvement in the capability of fishery and ecosystem models to be informed by advances in coupled physical-biogeochemical models.

3. Validate the models.

The management decisions that will be based on model outputs are likely to be costly. As such, models should be validated and improved with endpoint management decisions in mind, and with a focus on identifying knowledge gaps and quantifying uncertainty. Validation efforts should extend explicitly into near-coastal areas where temporal and spatial variability are the highest, and where a large number of management decisions are concentrated. Scientists should first seek to validate existing models using observational data for a broad range of climate and ecosystem states, with a focus on quantifying uncertainties and identifying key gaps in data and modeling infrastructure. Second, scientists should compare the outputs of multiple models to constrain uncertainty in their projections, which could ultimately pave the way for development of the next generation of models.

4. Collect data to support model development and refinement.

The ability of models to make accurate predictions of future ecosystem changes – be it aragonite saturation state, dissolved oxygen, biodiversity, or fish populations – is limited by the availability of data that can be used to parameterize those key attributes. In turn, confidence in model outputs will depend on a clear understanding of the ability of models to accurately reproduce features of the ecosystem that are of greatest management interests. This understanding will require diverse datasets that test model performance across different regions or habitats, and across different seasons and years as ocean and ecosystem conditions change. Investments in the sustained collection of integrated oceanographic and ecological data sets will be crucial for refining the performance of predictive models and their utility in informing decisions. There also should be effort to create a central repository for observational data and model output so that they are used effectively to inform further research, and ultimately management action.

5. Establish a forum to advance coastal ocean modeling.

The West Coast would benefit from creation of a forum that brings scientists and managers together to synthesize local and regional management needs, and to ensure that scientists are working in a coordinated, synergistic fashion to address those management needs. An organized community of modelers, observational researchers, and managers will serve to: (1) provide a vehicle for dialogue on management goals and scenarios, (2) encourage discussion on the use of model outputs to illustrate outcomes of management options to reach those goals, (3) facilitate discussion about the level of validation needed to use models to support management decisions, and (4) coordinate modeling products among different technical specialists. A first critical action is to convene a series of workshops to summarize key regional and local management needs, and identify the status of existing models to support those needs.

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: Becky Stamski / NOAA MBNMS.