Consensus Findings and Recommendations for the ROMS-BEC Model

Independent Peer Review Panel Report

Prepared for

California Association of Sanitation Agencies

Prepared by

National Water Research Institute

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Disclaimer

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About NWRI

An IRS nonprofit organization and California Joint Powers Authority, the National Water Research Institute (NWRI) was founded in 1991 by leading Southern California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection and restoration of water supplies, protect public health, and improve the environment.

We assemble teams of scientific and technical experts that provide credible independent review of water projects, present consensus findings and recommendations that support investment in water infrastructure and public health and enable water resource management decisions grounded in science and best practices.

NWRI's Joint Powers member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Metropolitan Water District of Southern California, Orange County Sanitation District, and Orange County Water District.

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Executive Summary

The National Water Research Institute (NWRI) is pleased to present the final report of an Independent Peer Review Panel (Panel) that was engaged to review a coupled numeric ocean modeling system developed under the direction of the Southern California Coastal Water Research Project (SCCWRP). The ROMS-BEC Model (the Model) aims to help regulators, water resources managers, and scientists understand the influence of treated wastewater discharges on ocean processes in the Southern California Bight, an approximately 430-mile-long stretch of Pacific Ocean coastline between Point Conception, California, and Baja, Mexico.

Guided by a Project Steering Committee and a trio of science advisors, NWRI planned and facilitated three teleconferences and a two-day live meeting of the Panel to review the Model and prepare Panel members to write this report. As detailed in the **Consensus Findings and Recommendations** section, the Panel was charged with assessing the Model's readiness to answer ocean discharge management questions, advising on the Model's level of uncertainty to address management questions, and recommending next steps for improving the Model.

The Panel members agree that, in its current form, the coupled modeling system is capturing fundamental physical and biogeochemical processes in the Southern California Bight that are associated with ocean acidification and hypoxia. The coupled modeling system has been validated and gone through a rigorous scientific peer review process. It can be used to address basic management questions about whether nutrient loads from treated wastewater discharges in the region have impacted the marine environment and ecosystem in the Southern California Bight and what the large-scale and first-order impacts are.

As is the case with all modeling systems, the ROMS-BEC modeling system has limitations and does not capture all details of the physical and biogeochemical

processes related to treated wastewater discharges. The Panel recommends exercising caution when using the Model to pinpoint exactly how and where such discharges have affected the marine ecosystem. The Panel also provides recommendations for additional model analyses to address more detailed regulatory questions.

The Panel recognizes that all model analyses contain uncertainty. To quantify this uncertainty and increase confidence in the Model results, the Panel recommends approaches to understanding and improving processes that may hinder the ROMS-BEC Model from accurately predicting the effects of treated wastewater outfalls on the marine ecosystem. The Panel also recommends several avenues for advancing the modeling system and the program of experiments and analysis that are conducted with it, including quantifying the impact of historical and projected trends to more rigorously separate human-caused impacts from large-scale uncontrollable or natural variability of the marine environment.

NWRI and the Panel acknowledge the many comments received from interested stakeholders in response to the draft report. The Panel considered each of these comments, and the final report reflects improvements where the Panel felt that a response to a comment was warranted.

Further, the Panel recommends several specific investments that would improve communication among regulators, the modeling team, and the regulated community about issues such as transparent and effective use of the modeling results and how to prioritize future improvements to the modeling system.

Summary of Recommendations for Future System Improvement

In response to the questions that were presented to the Panel, the review process produced over 40 recommendations for future system improvement. A summary of these recommendations, organized around key themes, is provided below. For a more detailed and comprehensive discussion, please refer to the main body of the report.

1. Collaboration and Stakeholder Engagement

    1.1. Establish an Advisory Board. Create an advisory board with members from regulatory bodies, the modeling team, other stakeholders, and external communities to ensure ongoing collaboration and alignment between scientific developments and policy needs.

    1.2. Increase Communication with Stakeholders. Regularly update stakeholders on model advancements and encourage their input on how the Model can best serve environmental management objectives in the Southern California Bight.

2. Model Enhancements for Accuracy and Detail

    2.1. Near-Field Observations. Increase evaluation with near-field observations around outfalls to improve the Model's depiction of shallow water processes, which is important for future regulatory decisions related to specific wastewater discharges.

    2.2. Tests of Specific Biogeochemical Processes. Expand evaluation to make full use of observational datasets that pinpoint specific rates and processes, such as Apparent Oxygen Utilization (AOU), biomass-normalized rate data, subsurface nutrient concentration, and sediment trap data.

3. Addressing Uncertainty and Conducting Sensitivity Analyses

    3.1. Simulations with Varying Inputs. Conduct paired simulations with altered model inputs and boundary conditions to isolate the influence of anthropogenic nutrient inputs from other regional variability and to quantify the impact of treated wastewater discharges on hypoxia and ocean acidification in different possible scenarios.

    3.2. Quantify Parameter Sensitivity. Identify which parameters significantly impact model results through sensitivity analyses, specifically concerning light penetration, phytoplankton nutrient preferences, and zooplankton mortality rates. These analyses should be directly tied to specific management questions.

4. Model Transparency and Data Sharing

    4.1. Enhanced Data Output. Provide more comprehensive model output through public channels, including daily averages of key variables. The goal of such transparency is to enable stakeholders to perform independent evaluations of the Model's predictions.

    4.2. Version Control. Establish a clear system for tracking changes in the Model's source code, associated datasets, and observations. This will facilitate better collaboration among regulators, scientists, and other stakeholders.

5. Investments in Long-Term Improvements

    5.1. Climate Change Context. Future model updates should consider separating the impacts of large-scale nutrient load regulations and climate-induced regional changes, allowing regulators to assess how interventions align with broader environmental trends.

    5.2. Targeted Spatial Ecological Assessments. Focus on places of ecological significance, such as breeding grounds or specific habitats, to evaluate localized water quality impacts more precisely.

    5.3. Expanding Beyond Sentinel Species. While the Model currently uses pteropods and Northern Anchovy as indicator species, the Panel recommends long-term investments to expand to other ecosystem components to better understand broader ecosystem impacts.

Introduction

National Water Research Institute (NWRI) is pleased to present the consensus findings and recommendations of an Independent Peer Review Panel of experts formed to review a novel oceanographic modeling tool (the Project) developed by SCCWRP in collaboration with leading ocean scientists. The modeling tool seeks to integrate two recognized numeric models, the Regional Ocean Monitoring System (ROMS) and the Biogeochemical Elemental Cycling Model (BEC), into a coupled model (the ROMS-BEC Model) capable of helping regulators, water resources managers, and scientists understand the influence of land-based inputs, including treated wastewater discharges, on ocean processes in the Southern California Bight.

Guided by a Project Steering Committee (PSC) and science advisors, NWRI convened and facilitated a two-day, in-person meeting of the Panel plus three online webinars to familiarize Panel members with the ROMS-BEC Model and give them, the modeling team, and representatives from stakeholder communities (i.e., regulators and regulated communities) a forum to exchange perspectives, learn about water resources management in Southern California, and seek clarity. The goals of the Panel's independent review were to: (1) assess the Coupled Model's readiness to answer management questions; (2) advise on the Coupled Model's uncertainty associated with addressing management questions; and (3) recommend next steps for improving the Coupled Model's readiness.

Organization of the Report

This report presents an overview of the Project background, profiles of Peer Review Panel members, the Panel charge, meeting objectives, and a summary of the Panel's consensus findings and recommendations.

The **Consensus Findings and Recommendations** section is the Panel's opinion, formulated after it reviewed written and oral presentations and deliberated in closed sessions online and in person.

Appendices include information about the NWRI Peer Review Panel process (Appendix A), the meeting agenda (Appendix B), the webinar agendas (Appendix C) and a list of meeting attendees (Appendix D). Links for more information about the Southern California Bight, this project, NWRI, and SCCWRP are in Appendix E. A list of acronyms and terms are in Appendix F.

Background

NWRI is a 501(c)(3) nonprofit corporation formed in 1991 to promote the protection, maintenance, and restoration of drinking water supplies and freshwater and marine environments through applied and project-oriented research including complex expert peer review, such as this engagement. This report presents science-based insights on the questions presented, which will—it is hoped—contribute substantially to an appropriate investment in resources that enhance water quality for people and the planet.

SCCWRP works to develop and apply next-generation science to improve management of aquatic systems in Southern California and beyond, and to build scientific consensus around best-practice approaches for improving aquatic systems management. The SCCWRP modeling group was led by Martha Sutula, PhD, and Fayçal Kessouri, PhD. Key SCCWRP ROMS-BEC development collaborators included Jim McWilliams, PhD, of the University of California, Los Angeles, and Curtis Deutsch, PhD, who is on the faculty at Princeton University.

The Southern California Bight includes 1,500 square miles of the Northeastern Pacific Ocean stretching from Point Conception in southwest Santa Barbara County, California, to Punta Colonet in the Ensenada Municipality of Baja, California Norte, which is 71 miles south of the international border between the United States and Mexico. (See

Appendix E for links to online maps of the region.) The Southern California Bight encompasses a nearly 430-mile (792 km) stretch of coastline defined by the North American continent and the Eastern Pacific Ocean. This dynamic coastline is characterized by sand dunes, beaches, wetlands, headlands, lagoons, bays, estuaries, creeks, and rivers. The coastal lands also host virtually every imaginable aspect of the built environment. In many respects, the Southern California Bight defines the region's history, identity, and future. Its resources and commercial traffic support the Southern California economy. Its waters teem with marine life and its environmental dynamics impact millions of people's quality of life.

Modeling the Southern California Bight

Computer models simulate complex environmental systems or phenomena—weather, for example—and allow people to analyze, understand, and predict behavior of the system. While no model can perfectly simulate every aspect of a complex system, useful models provide insights, guide decision making, and help solve problems by highlighting important relationships and patterns.

Unsurprisingly, regulators who rely on computer model simulations for decision making are deeply invested in their predictive performance. Issues ranging from data inputs, computational constraints, and parameter uncertainty are of great interest to institutions that set and implement public policy and to people whose livelihood depends on a model's predictions.

Millions of people, the Southern California regional economy, and a unique oceanographic environment rely on the health of the Southern California Bight. A variety of public and private computer models already monitor conditions in this important aquatic region. Developing a state-of-the-art computer model that informs environmental water resource managers and other stakeholders will help decision makers support and optimize the health and sustainability of the Southern California Bight in the face of increasing human impacts and climate change.

The ROMS-BEC Model, as currently composed, integrates two established numerical models to help regulators, water resources managers, and scientists investigate and accurately understand the influence of land-based inputs, including treated wastewater discharges, on biogeochemical and biological ocean processes that affect ocean acidification and hypoxia (decreased oxygen) in the Southern California Bight. Figure 1 illustrates how a regional ocean modeling system and a biogeochemical elemental cycling model were combined to develop the ROMS-BEC Model.

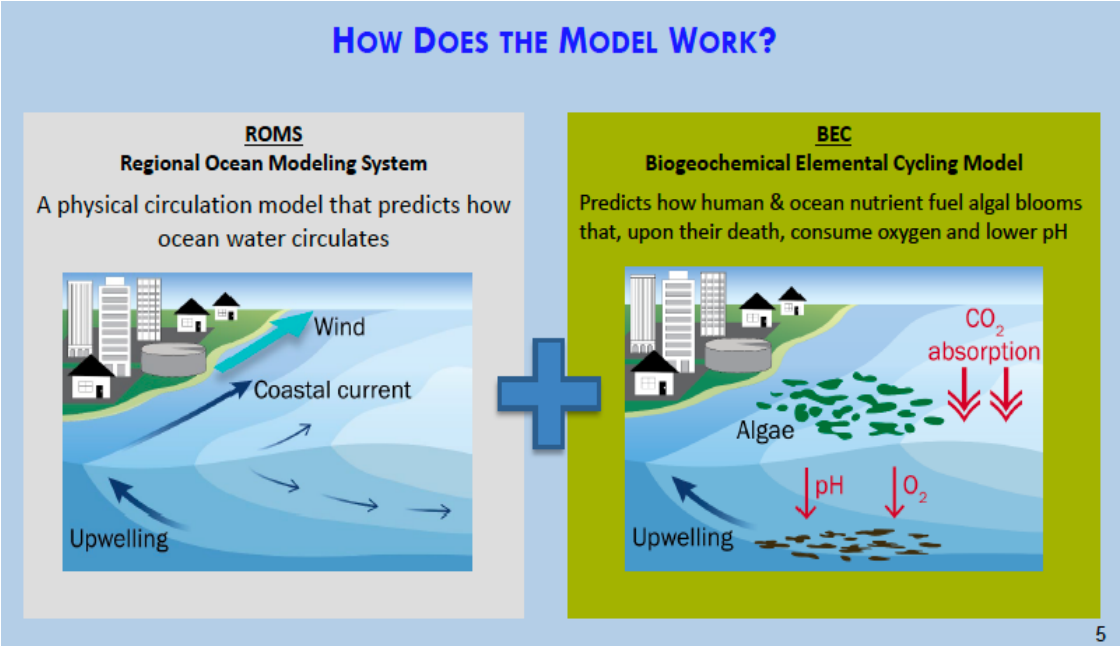

Figure 1. An illustration that depicts the two established numerical modeling tools that have been combined to analyze and predict biogeochemical, biological, and regional ocean processes that affect ocean acidification and hypoxia. (PowerPoint slide courtesy of SCCWRP.)

Peer Reviewing the ROMS-BEC Model

California Association of Sanitation Agencies (CASA) provided funding for NWRI to administer and facilitate this independent peer review of the ROMS-BEC Model. The peer review process was designed to assess the Model's readiness, quantify uncertainty, and provide suggestions to improve the Model's performance.

To ensure a thorough and independent peer review process, NWRI and the SCCWRP Commission Technical Advisory Group (CTAG) worked together to form a Steering Committee with four functions:

1. Advise NWRI on nomination of the expert Panel.
2. Approve the expert Panel members that are nominated by NWRI.
3. Refine charge questions from CTAG to the Panel.
4. Oversee recruitment of speakers for the Panel meeting and workshops to ensure a diversity of perspectives and sufficient information on which to base their deliberations.

The Panel Charge

This collaboration resulted in the formation of an Independent Peer Review Panel of internationally recognized experts with a clearly defined charge. NWRI, the Project Steering Committee, and Science Advisors organized a program of workshops and public meetings to offer a transparent environment for the Panel to engage with model developers and stakeholders, to hear different viewpoints, and to fulfill the Panel Charge, which is the basis of this report. The Panel Charge included three specific inquiries:

1. Do the ROMS, BEC, and coupled model's fundamental modeling choices enable the coupled model to predict the physical and biogeochemical processes impacting ocean acidification and hypoxia in the Southern California Bight?
2. Inventory and characterize sources of uncertainty and bias in the ROMS, BEC, and coupled model's inputs, parameters, and outputs.
3. What portfolio of investments would best promote long-term, continuous improvement of the Model's predictive accuracy and potential scope of use?

NWRI Independent Peer Review Panel Members

NWRI Panel members are internationally recognized experts in oceanography, marine science, and numerical modeling of ocean systems. Each is uniquely qualified to participate in this peer review of the ROMS-BEC Model and its application to the Southern California Bight. NWRI thanks these dedicated scientists for their time, expertise, and commitment to the goals of this independent review.

- W. Gordon Zhang, PhD, (Panel Chair), Associate Scientist with Tenure, Applied Ocean Physics & Engineering, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, United States.
- Neil Banas, PhD, Reader in the Department of Mathematics and Statistics at the University of Strathclyde, Glasgow, United Kingdom.
- Fei Chai, PhD, Chair, Professor in Marine Science at Xiamen University, Fujian, China, and Professor Emeritus at University of Maine, Orono, Maine, United States.
- Alexander Kurapov, PhD, Physical Scientist at National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland, United States.
- Marjorie A. M. Friedrichs, PhD, Research Professor at the Virginia Institute of Marine Science at William & Mary, Gloucester Point, Virginia, United States.
- Mike Stukel, PhD, Associate Professor of Oceanography at Florida State University, Tallahassee, Florida, United States.

The Panel's responses to its charge are included in the **Consensus Findings and Recommendations** section of this report.

Meeting Objectives

NWRI staff, working collaboratively with the Project Steering Committee and Science Advisors, the Panel Chair, and the SCCWRP modeling team, planned webinars in December 2023 and January 2024 to orient the Panel to the Project and the ROMS-BEC Model and to prepare for the two-day meeting in January 2024. These

orientation webinars were designed to enable the Panel to successfully meet the following objectives:

1. Review the ROMS-BEC Model's local inputs, applications, and outcomes plus efforts to characterize and resolve model uncertainty.
2. Provide a public forum for stakeholders to present their views on the challenges and opportunities presented by the coupled model.
3. Allow time for participants to engage in both facilitated and impromptu technical and scientific dialog.
4. Begin drafting the Panel's consensus findings and recommendations and plan an approach for writing the Draft Report.

NWRI facilitated a third webinar in May 2024 to provide information about California's water quality regulatory framework. SCCWRP provided pre-meeting review materials for Panel members to prepare them for the webinars and in-person presentations. All Panel review materials, slide presentations, and meeting videos are available to download from the project page on the NWRI web site (the link is provided in Appendix E).

Consensus Findings and Recommendations

The consensus findings and recommendations presented here are the Panel's conclusions from a review of the materials provided by SCCWRP, the meeting presentations, and interactive discussions about the Project.

1. Do the ROMS, BEC, and coupled model's fundamental modeling choices enable the coupled model to predict the physical and biogeochemical processes impacting ocean acidification and hypoxia in the Southern California Bight?

The Panel members unanimously agree that the ROMS-BEC coupled modeling system is built on fundamental principles of physical and biogeochemical oceanography and has been evaluated using available observations. The modeling team has done a series of calibration and validation exercises with the model system. Their analyses on the first-order impact[1] of the treated wastewater discharge in the coastal environment have also been rigorously evaluated by the scientific community through the peer review process. In its current form, the coupled modeling system can capture many fundamental physical and biogeochemical processes associated with ocean acidification and hypoxia in the Southern California Bight. The coupled modeling system, even as a scientific tool that is still actively being improved for research purposes, can be used to address basic management questions related to the environmental and ecological impacts of treated wastewater discharges in the region. In particular, the Panel concurs that the ROMS-BEC coupled model can be used to investigate the question of whether nutrient

[1] First-order impact refers to ecosystem-level effects of discharging treated wastewater across the large South California Bight region rather than impacts on a specific marine species or parameter at a particular site.

loads from treated wastewater discharges may have affected the ecosystem of the Southern California Bight by modifying ocean acidification and hypoxia.

As is the case with all modeling systems, ROMS-BEC has limitations and, specifically, does not capture all details of the physical and biogeochemical processes relevant to the discharge of treated wastewater. The Panel believes that there are a series of model improvements and/or validation exercises that could be undertaken to further increase the confidence with which a specific management decision (e.g., nutrient release targets for a specific plant) is tied to specific predicted impacts. For example, to support experiments intended to provide detailed quantification of the specific impact of individual treated wastewater discharges, the Model would benefit from more evaluation with observations in the near field of outfalls and nearshore coastal region to ensure an adequate depiction of highly variable shallow water processes. Additionally, a greater focus on the deviation of oxygen from saturation (often referred to as apparent oxygen utilization) rather than on absolute oxygen concentration, will illustrate how well the Model is able to reproduce biogeochemical processes such as productivity and remineralization.

Other recommended model analyses include:

- **When possible, incorporate observations of biomass-normalized rates into the Model** validation, because biomass-normalized rates support tests of model processes that are independent of large-scale changes in biomass.
- **Conduct additional sensitivity analyses with the latest version of the BEC model,** especially related to light through the water column (light attenuation) and zooplankton grazing effects. Sensitivity analyses can serve many purposes and be designed in many ways; here, the goal is to verify that parameter uncertainty and intentional simplifications of complex processes do not lead to unacceptable levels of uncertainty in high-level conclusions regarding hypoxia and acidification. (More on this point below.)

- **More thorough analysis of the ecological impacts.** Currently, the framework developed to translate seawater chemistry changes into ecological effects focused on two sentinel organisms: pteropods and the Northern Anchovy. Focusing on two indicator taxa is an understandable simplification in the initial stages of model development, and these two taxa are well-chosen as sentinels; pteropods because they are widespread and particularly sensitive to ocean acidification, and Northern Anchovy because it is a central node in the larger food web. However, many fundamental ecological questions remain. For example, are pteropods replaceable in the diet of their predators by other zooplankton that are less sensitive to ocean acidification, or do they play a unique and irreplaceable role? To what extent can anchovy or their predators adapt to compression of habitat in a particular ocean region, and are some offshore regions more crucial as habitat than others?

The Panel feels that, for further improvement, long-term investment in the observations and modeling required to answer these ecosystem-level questions should be considered, alongside investment in more precision and transparency in quantifying hypoxia and acidification impacts. At the same time, an effort to trace food-web consequences comprehensively risks becoming an infinite regression and a barrier to responsible regulatory action. The Panel feels that the current focus on two sentinel species is a reasonable pragmatic choice in this stage of the analysis, and it is in keeping with water-quality impact assessment in other regulatory contexts.

Overall, the robust building blocks and careful configuration of the ROMS-BEC coupled modeling system enable it to successfully capture fundamental physical and biogeochemical impacts induced by treated wastewater discharges in the Southern California Bight; however, there are uncertainties associated with the Model's parameters and their impact that should be considered when using modeling scenarios for management-related decisions related to specific subregions or specific components of the ecosystem. These sources of uncertainty are described in more detail below.

2. Inventory and characterize sources of uncertainty and bias in the ROMS, BEC, and coupled model's inputs, parameters, and outputs.

The Panel recognizes that all models contain uncertainty. To quantify this uncertainty and increase confidence in the Model's results and potential future uses for addressing management questions related to detailed impacts, such as impacts on specific ecosystem components in particular regions, the Panel recommends two approaches:

- First, conduct additional evaluation analyses with key observational variables that relate to important modeled physical and biogeochemical processes.
- Second, conduct sensitivity analyses that are directly tied to specific management questions.

In both cases, these analyses should be tailored toward building an understanding of the key underlying processes or identifying parameters with the greatest uncertainties that could lead to model-reality disconnects related to the effects of outfalls on nutrient addition and phytoplankton bloom dynamics, ocean acidification, and deoxygenation.

Specifically, these targeted areas include:

1. Detailed nutrient budgets computed within a range of defined areas and volumes, including sources of ammonium and nitrate,
2. The relative preference of phytoplankton groups for nitrate and ammonium, and
3. The relative rate of sinking carbon and nitrogen export into the "twilight zone" versus the rate of flushing of this depth zone.

With respect to model-observation evaluation, the Panel recommends several avenues for further comparisons:

- **Subsurface nutrient concentrations** to ensure that modeled upwelled waters have accurate nitrate concentrations. A specific focus on evaluation in the region of the California Undercurrent is warranted (especially near the southern open boundary) as these waters are particularly important to upwelling in the system. This data is

readily available from the California Cooperative Oceanic Fisheries Investigations (CalCOFI) time series, among other sources.

- **Sediment trap data** to ensure that the Model is accurately simulating downward fluxes into the mesopelagic zone and, hence, organic matter availability for remineralization and deoxygenation. This is, notably, an area in which the Model can be critiqued because diatoms are used to represent all large phytoplankton while other taxa that are less likely to sink, such as dinoflagellates, are absent or not well represented in the current model. Sediment trap data are available from floating traps from the California Current Ecosystem Long-Term Ecological Research program and moored traps from the Santa Barbara Basin time series. In both cases, the Panel recommends that, rather than trying to evaluate against point measurements, a focus on examining the relationship between Net Primary Production (NPP) and organic matter export is more valuable. If the Model is compared to the observational data and no major discrepancy is found, this potential line of critique would no longer be concerning.
- **Photosynthetically active radiation (PAR).** The Panel recommends evaluating the Model's percent surface irradiance against percent surface PAR measurements from CalCOFI. Percent surface PAR will likely be a more robust comparison between the Model and data, because it avoids stochasticity in absolute PAR introduced by clouds. This PAR exercise can directly address issues raised about how light is treated in the Model, especially if there is a focus on the nearshore domain. The depth of the 1 percent light level is a useful metric given its relationship to the base of the euphotic zone.
- **Primary productivity and apparent oxygen utilization.** The Panel recommends that the Model should be evaluated with publicly available oxygen and net primary production datasets, while giving special attention to vertical profiles of AOU and productivity and to biomass-specific productivity rates (i.e., NPP divided by phytoplankton biomass, or based on absorption). AOU can be calculated across the

domain from the CalCOFI time series and at higher temporal resolution from moorings. The focus here is on ensuring that the Model is accurately simulating the processes that constrain photosynthesis, something that is more difficult to discern by focusing on vertically integrated net primary production.

With respect to sensitivity analyses, the Panel recommends that paired simulations be conducted (with and without anthropogenic inputs) at the same time as parameters are varied to test whether the core management questions addressed by the Model are sensitive to uncertainties in the parameterization. These simulations could then be filtered based on agreement with observational data, with simulations that give reasonable fits to the observational data used to form a single-model ensemble for assessing uncertainty in management decisions. In particular, the Panel recommends:

- **Assessing the consequences of uncertainty in natural nutrient inputs.** This can be done by modifying the nutrient concentrations of the boundary conditions, particularly in the California Undercurrent waters. The boundary conditions could be compared to climatological means from CalCOFI data and adjusted to test the sensitivity to boundary conditions that are at the mean of the climatology and at the mean plus one standard deviation of the climatology. Sensitivity to terrestrial inputs from extreme events (100-year storms) could be tested in a similar manner.
- **Assessing the consequences of uncertainty in phytoplankton nutrient preferences, i.e., the half saturation constants for nitrate and ammonium uptake**. Specifically, the Panel recommends an experiment in which the nitrate uptake half saturation constant is decreased while keeping the ammonium uptake half saturation constant at current levels. This would increase phytoplankton relative uptake of nitrate with respect to ammonium, thereby directly addressing the potential concern that incorrect nutrient utilization leads to greater use of anthropogenic rather than natural nutrients.
- **Assessing the consequences of uncertainty in zooplankton grazing and mortality.** These terms (especially the mortality formulation) are poorly constrained from

laboratory and observational data. Hence, the parameters chosen (and the formulations, e.g., quadratic versus linear mortality expression) should be considered quite uncertain. Sensitivity analyses will determine whether management outcomes are sensitive to this aspect of the ecosystem modeling.

- **Particle sinking and remineralization rates can be modified** to alter where and to what extent sinking particle remineralization in the water column or on the bottom of the shallow shelf drives deoxygenation.
- **Assessing the influence of light attenuation parameterization.** The Panel recommends quantifying the sensitivity of modeled primary productivity and biogeochemistry to the prescribed light attenuation coefficient, especially in the nearshore coastal region with potential influence from river-injected fine sediments.

The Panel offers these recommendations to highlight possible areas to improve the Model, rather than as a recipe to follow, because the Model developers have a better understanding of which parameterizations are associated with the greatest uncertainties. The Panel also notes that these recommendations are not made as a critique of the Model design decisions, but rather as ways to increase confidence in these decisions through further investment in observations to constrain the Model's parameters or to conduct parameter sensitivity experiments to demonstrate that the missing details would not change the conclusions.

3. What portfolio of investments would best promote long-term, continuous improvement of the Model's predictive accuracy and potential scope of use?

3.1 General investments in transparency and communication

The modeling team has done an excellent job of publishing the Model description and model experiments, along with key model-observation comparisons and summary results in the peer-reviewed scientific literature. As a supplement to this, the Panel recommends several additional investments that would improve communication with regulators and regulated communities:

- **A more exhaustive set of comparisons with observations that follow norms in the engineering community as opposed to the conventions of scientific publishing.** This is time-consuming work and should be resourced accordingly. An effort to semi-automate the production of graphical comparisons and summary statistics between many model variables and many observational datasets—although it would require a non-trivial investment of scientific programming time up front—would likely have long-term payoffs, by making it feasible to keep ground-truthing of the Model up to date in future versions/iterations.
- **Openly provide model output, as opposed to highly condensed summaries**. The Model output should be shared with the public through commonly used channels, such as THREDDS servers. At a minimum, provide daily averages of key variables at key depths, across the full model domain. This would enable regulators and regulated community to conduct their own multi-scale explorations of model behavior, not only for the sake of evaluating model performance, but also for better understanding natural variability in this system and the persistence and consistency of the anthropogenic impacts that the Model diagnoses.
- **A simple system for associating output datasets, model-observation comparisons, and scientific publications with versions of the Model's source code**. This would prevent ambiguities in interpreting modeling results, such as those related to the numerical scheme used to parameterize the nearfield dynamics. Having a clear version control of the Model's source code would also help facilitate collaborations within the modeling team and enable regulators and regulated communities to track the improvement of the modeling system.
- **Finally, regulators should provide a strategic plan for management and regulatory applications**. Both critical evaluation of the Model and further investments in development should be considered against management and regulatory applications at specific spatial scales, since requirements will

fundamentally vary. The following recommendations are organized around these distinctions.

3.2 Investments aimed at large-scale nutrient load regulation (e.g., far-field impacts of total Southern California Bight anthropogenic nutrient load)

Modeled impacts should be better placed in the context of California Current-scale patterns and long-term historical and projected trends, including those associated with climate change. Most crucially, it should be possible for the modeling team to compare the impact of a potential intervention to projected future changes in the region, such as climate-induced acidification and ecosystem transformation. The result would help regulators to measure the intervention in terms of how many years it would buy against climate-driven trends. Furthermore, it would be useful to see whether areas of seasonal habitat compression linked to anthropogenic nutrients are new spatial features that are solely a result of coastal nutrient inputs, as opposed to an expansion or rearrangement of hypoxic features that are already characteristic of the California Current.

In the long term, it would be highly valuable to better understand and quantify the population- and ecosystem-level impacts of localized changes in water chemistry: the goal should be a comprehensive description of the biological influence of released treated wastewater over multiple trophic levels, beyond pteropods and anchovy. This is a grand challenge scientifically, because of spatial connectivity in plankton, fish, and predator populations between the Southern California Bight and the larger California Current and North Pacific, and because of the flexibility and diversity of the organisms involved in terms of diet and behavior. A practical short-term step with potentially high impact would be to identify places of particular ecological concern (either to anchovy or the food web they support; for example, spawning grounds, breeding colonies) and present results on water-quality impacts on those places specifically, not only impacts on the Southern California Bight as a whole.

The Panel understands that multi-model ensembles like the Intergovernmental Panel on Climate Change (IPCC) Coupled Model Intercomparison Project are well beyond the

reasonable scope of the project. However, targeted investment in a single-model ensemble based on sensitivity analyses of key parameters (e.g., modified sinking rates, remineralization rates, zooplankton mortality, and other parameters noted above under Question 2) would allow for some quantification of uncertainty in model results. This quantification will be especially useful if detailed management impacts are assessed for each model run. The Panel notes that this goes beyond typical practice for model evaluation in scientific literature, but is warranted in this case, given the Model's potential regulatory use.

3.3 Investments aimed at finer-scale regulatory applications (on the scale of individual outfalls) and regulatory modeling in the coastal zone

In addition to the domain-averaged statistics, which is mostly dominated by the deep ocean, the Panel recommends focusing on shelf areas, including assessment of the benthic processes and on scenarios that simulate the fate of outputs from individual outfalls. These scenarios should consider different conditions, such as strong upwelling versus downwelling conditions and internal tide contribution to dispersion.

The Panel recommends a comparison of simulations at 300-meter and 1-kilometer resolution. This comparison would determine the importance of submesoscale processes to outflow dispersion and mixing. Since running the Model at 300-meter resolution is very computationally expensive, justification should be made about why the 300-meter resolution matters. Does the increased resolution change any of the statistics or biogeochemical budgets? Furthermore, is the 1-kilometer model sufficiently accurate for use in sensitivity analyses and ensemble model construction? If yes, this would dramatically reduce the computational investment required to implement the approach to uncertainty quantification recommended under Question 2.

The Panel notes that the Project will benefit from a more systematic approach to model assessment in the nearshore zone, by comparing the Model to high-temporal resolution time series observations. These comparisons should include observational data from the

Integrated Ocean Observing System, University of California, San Diego, local municipalities' ocean monitoring programs, and other assets in the region. Examples of the available observations include shelf and offshore profiles of near-surface and near-bottom temperature, salinity, and velocities measured using the Acoustic Doppler Current Profiler, partial pressure of carbon dioxide (pCO_2), pH, and nitrate.

Another type of observation that appears to have been neglected but should be used for model assessment is High-Frequency (HF) radar[2] data which is useful for verifying modeled alongshore currents at temporal scales from several days to seasonal and interannual. In addition, the HF radar observations should be useful for assessing energetics of the inertial and internal tides/internal waves. The Panel recommends that this part of the model assessment should target specific temporal and spatial scales that are relevant to the regulatory questions. Tidal, inertial, weather-band, seasonal, and interannual processes should be assessed separately to demonstrate that the Model has the correct kinetic energy levels when used as a mixer of the contaminant tracer. The newly available SWOT (Surface Water and Ocean Topography) altimetry data sets may provide additional means of model verification, with regards to both phenomenology and energy levels.

[2] HF radars on the Southern California coast measure surface currents as part of the Southern California Coastal Ocean Observing System (https://sccoos.org/high-frequency-radar/). The data are publicly available. Surface currents measured by HF radars in other coastal regions are widely used in the scientific community to calibrate or validate circulation models. The Panel agrees that the ROMS-BEC modeling team should consult the existing HF radar current data in the region to validate modeled currents and their variations, including those associated with internal waves, which are waves below the ocean surface. For additional resources, see https://doi.org/10.1016/j.dsr2.2017.04.013

Other Comments

The Panel commends the modeling team and stakeholder representatives for candid discussions during the webinars and the in-person Panel meetings. The discussions helped the Panel achieve a comprehensive understanding of the strengths and weaknesses of the ROMS-BEC Model system. The issues raised by representatives from the regulated communities were fully considered in the Panel discussion, and some of those issues were incorporated into this report. The Panel suggests that the regulators, regulated communities, and model developers continue this type of dialog and work together to further improve the modeling system for more effective use in resource management and decision-making. To facilitate the dialog in the future, the panel recommends establishing an advisory board with representations from all parties, including the modeling team, regulators, and regulated communities, as well as independent external members with experience in bridging scientific research and policymaking processes.

Appendix A · About NWRI Panels

NWRI Independent Peer Review Panels are distinguished teams of internationally recognized experts who tackle some of the most complex challenges in water resources management and policy. Through rigorous, science-driven analysis and the application of best practices, these panels enable informed decision-making that shapes the future of water in communities across the country.

Serving a diverse range of clients, from municipalities and counties to special districts, government agencies, NGOs, and private sector partners, NWRI Panels bring unmatched expertise to the table. Over hundreds of engagements nationwide, they've addressed critical issues, from designing and optimizing water treatment and reuse infrastructure to managing groundwater recharge, enhancing surface water quality, and pioneering regional and state potable reuse policy.

NWRI Panels deliver:

- Objective, Third-Party Insight: Independent evaluations that cut through complexity, bringing credibility to every project.
- Industry-Leading Expertise: Scientific and technical guidance from top experts in relevant fields, ensuring the best solutions for every challenge.
- Support for Tough Decisions: Whether navigating regulatory hurdles or addressing complex scientific questions, NWRI Panels provide the clarity and support to move forward confidently.
- Thorough Reporting: Clear, actionable updates on progress, key findings, and recommendations tailored to meet the needs of every engagement.
- Public and Regulatory Engagement: Assistance in fostering productive interactions with the public, policymakers, and regulatory bodies, driving meaningful progress and collaboration.

Appendix B · Meeting Agenda

Independent Peer Review of SCCWRP's Coupled Regional Ocean Monitoring System and Biogeochemical Elemental Cycling Model

January 17–18, 2024
Atrium Hotel, Irvine, California

Online Meeting Location	NWRI Contacts
See the Calendar invitation for login information	Suzanne Sharkey: (949) 258-2093 Tianna Manzon (562) 708-0123 Kevin Hardy: (760) 801-9111

Goals of Independent Review

The goals of this Independent Peer Review Panel are to assess model readiness to answer management questions; advise on model uncertainty associated with addressing management questions; and recommend next steps for improving the model readiness.

Panel Charge Questions

1. Do the ROMS, BEC, and coupled model's fundamental modeling choices enable the coupled model to predict the physical and biogeochemical processes impacting ocean acidification and hypoxia in the Southern California Bight?
2. Inventory and characterize sources of uncertainty and bias in the ROMS, BEC and coupled model's inputs, parameters, and outputs.
3. What portfolio of investments would best promote long-term, continuous improvement of the model's predictive accuracy and potential scope of use?

Today's Meeting Objectives

- Review the coupled model's local inputs, applications, and outcomes plus efforts to characterize and resolve model uncertainty.
- Provide a public forum for stakeholders to present their views on the challenges and opportunities presented by the coupled model.
- Allow time for participants to engage in both facilitated and impromptu technical and scientific dialogue.
- Begin drafting the Panel's consensus findings and recommendations and plan an approach for writing the Draft Report.

Meeting Schedule for Wednesday, January 17

Time (Pacific)	Topic	Presenter
7:30 a.m.	Breakfast	NWRI
8:00 a.m.	Call to Order, Welcome, and Logistics	W. Gordon Zhang, Chair Kevin M. Hardy, NWRI
8:15 a.m.	Technical Session 1: Local Inputs	Modeling Team, SCCWRP
9:00 a.m.	Q&A for the Presenters	W. Gordon Zhang, Chair Kevin M. Hardy, NWRI
9:15 a.m.	Technical Session 2: Application of the Model and Related Outcomes	Modeling Team, SCCWRP
10:00 a.m.	Q&A for the Presenters	W. Gordon Zhang, Chair Kevin M. Hardy, NWRI
10:15 a.m.	Nutrition Break | Adjourn Teleconference	NWRI
10:30 a.m.	Travel to the Orange County Groundwater Replenishment System (GWRS)	NWRI
10:45 a.m.	Arrive GWRS	NWRI
11:00 a.m.	Stakeholder Exchange: Potable Reuse Source Water Production	Rob Thompson, General Manager, OC San
1:00 p.m.	Lunch	NWRI
1:30 p.m.	Stakeholder Exchange: Potable Reuse Advanced Water Treatment	Jason Dadakis, Executive Director, OCWD
3:30 p.m.	Depart GWRS	NWRI
3:45 p.m.	Arrive Atrium Hotel | Wellness & Nutrition Break	NWRI
4:00 p.m.	Adjourn	NWRI
6:00 p.m.	Private Panelist Dinner	NWRI

Meeting Schedule for Thursday, January 18

Time (Pacific)	Topic	Presenter
7:30 a.m.	Breakfast	NWRI
8:00 a.m.	Call to Order, Welcome, and Logistics	W. Gordon Zhang, Chair Kevin M. Hardy, NWRI
8:15 a.m.	Technical Session 3: Steps to Quantify and Resolve Model Uncertainty	Modeling Team, SCCWRP
9:00 a.m.	Q&A for the Presenters	W. Gordon Zhang, Chair Kevin M. Hardy, NWRI
9:15 a.m.	Technical Session 4: Technical Input	Andy Leising, NOAA Scott Jenkins, Michael Baker International
10:00 a.m.	Q&A for the Presenters	W. Gordon Zhang, Chair Kevin M. Hardy, NWRI
10:15 a.m.	Nutrition Break | Stakeholder Exchange	NWRI
10:30 a.m.	Technical Session 5: Presenter Elucidation	Kevin M. Hardy, NWRI
11:30 a.m.	NWRI Hosted Luncheon | Stakeholder Exchange	NWRI
12:00 p.m.	Technical Session 6: Public Comments	Kevin M. Hardy, NWRI
12:45 p.m.	Technical Session 7: Panelist Questions and Perspectives	W. Gordon Zhang, Chair
1:30 p.m.	Closing Remarks | Teleconference Adjourned	Kevin M. Hardy, NWRI
1:30 p.m.	Private Panel Working Session	W. Gordon Zhang, Chair
6:00 p.m.	Private Panelist Dinner	NWRI

Independent Peer Review Panel Members

- Chair: W. Gordon Zhang, PhD, Woods Hole Oceanographic Institution
- Neil Banas, PhD, University of Strathclyde (UK)
- Fei Chai, PhD, University of Maine
- Marjy Friedrichs, PhD, Virginia Institute of Marine Science
- Michael Stukel, PhD, Florida State University
- Alexander Kurapov, PhD, NOAA

Steering Committee Members

- Lorien Fono, Bay Area Clean Water Agencies
- David Gibson, Regional Water Quality Control Board, San Diego Region
- Justine Kimball, Ocean Projection Council
- Karen Mogus, State Water Resources Control Board, Division of Water Quality
- Steve Wagner, Goleta Sanitary District
- Lan Wiborg, Orange County Sanitation District

Ex Officio Science Advisors

- Sean Bothwell, California Coastkeeper Alliance
- Kristin Davis, PhD, University of California, Irvine
- Steve Weisberg, Southern California Coastal Water Research Project

National Water Research Institute

- Kevin M. Hardy, Executive Director
- Mary Collins, Technical Editor/Communications
- Tianna Manzon, Research Project Coordinator
- Suzanne Sharkey, Water Resources Scientist/Project Manager

Appendix C · Webinar Agendas

AGENDA

Webinar 1: Independent Peer Review of SCCWRP's Coupled Remote Ocean Monitoring System and Biogeochemical Elemental Cycling Model

December 12, 2023
9:00 am Pacific / 12:00 pm Eastern

Online Meeting Location	NWRI Contacts
See the Calendar invitation for login information	Suzanne Sharkey: (949) 258-2093 Mary Collins: (206) 380-1930 Kevin Hardy: (760) 801-9111

Meeting Objectives

1. Familiarize Panelists with the State's perspectives on investment in OAH modeling.
2. Introduce the Coupled Model and facilitate Q&A among the modelers and Panel.
3. Present regulated community perspectives on the Model and facilitate related Panel Q&A.
4. Conduct a private, facilitated Panel discussion on the materials presented and to gain consensus on key elements of the Webinar 2 agenda.

Time (Pacific)	Topic	Presenter
9:00 a.m.	Welcome, Panelist Introductions, Review Agenda, Meeting Objectives, Panel Goals and Charge Questions	Kevin Hardy, NWRI
9:10 a.m.	State Water Board and California Ocean Protection Council Perspectives on OAH Modeling and facilitated Panel Q&A	Jon Bishop, Water Board Jenn Eckerle, OPC
9:30 a.m.	Overview of the Coupled Model and facilitated Panel Q&A	Martha Sutula, SCCWRP
10:30 a.m.	Regulated Community Perspectives on the Coupled Model and facilitated Panel Q&A	Jared Voskuhl, CASA Amber Baylor, SOCWA
11:30 a.m.	Closed Panel Working Session	W. Gordon Zhang, Chair
12:00 p.m.	Adjourn	

Goals of Independent Review

The goals of this Independent Peer Review Panel are to assess model readiness to answer management questions; advise on model uncertainty associated with addressing management questions; and recommend next steps for improving the model readiness.

Panel Charge Questions

1. Do the ROMS, BEC, and coupled model's fundamental modeling choices enable the coupled model to predict the physical and biogeochemical processes impacting ocean acidification and hypoxia in the Southern California Bight?
2. Inventory and characterize sources of uncertainty and bias in the ROMS, BEC and coupled model's inputs, parameters and outputs.
3. What portfolio of investments would best promote long-term, continuous improvement of the model's predictive accuracy and potential scope of use?

Independent Peer Review Panel Members

- Chair: W. Gordon Zhang, PhD, Woods Hole Oceanographic Institution
- Neil Banas, PhD, University of Strathclyde (UK)
- Fei Chai, PhD, University of Maine
- Marjy Friedrichs, PhD, Virginia Institute of Marine Science
- Michael Stukel, PhD, Florida State University
- Alexander Kurapov, PhD, NOAA

Steering Committee Members

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- David Gibson, Regional Water Quality Control Board, San Diego Region
- Justine Kimball, Ocean Projection Council
- Karen Mogus, State Water Resources Control Board, Division of Water Quality
- Steve Wagner, Goleta Sanitary District
- Lan Wiborg, OCSAN

Ex Officio Science Advisors

- Sean Bothwell, California Coastkeeper Alliance
- Kristin Davis, University of California, Irvine
- Steve Weisberg, SCCWRP

National Water Research Institute

- Kevin M. Hardy, JD, Executive Director
- Mary Collins, Technical Editor/Communications
- Tianna Manzon, Research Project Coordinator
- Suzanne Sharkey, Water Resources Scientist/Project Manager

AGENDA

Webinar 2: Independent Peer Review of SCCWRP's Coupled Remote Ocean Monitoring System and Biogeochemical Elemental Cycling Model

January 9, 2024
9:00 am Pacific / 12:00 pm Eastern

Online Meeting Location

See the Calendar invitation for login information

NWRI Contacts

Suzanne Sharkey: (949) 258-2093
Mary Collins: (206) 380-1930
Kevin Hardy: (760) 801-9111

Goals of Independent Review

The goals of this Independent Peer Review Panel are to assess model readiness to answer management questions; advise on model uncertainty associated with addressing management questions; and recommend next steps for improving the model readiness.

Panel Charge Questions

1. Do the ROMS, BEC, and coupled model's fundamental modeling choices enable the coupled model to predict the physical and biogeochemical processes impacting ocean acidification and hypoxia in the Southern California Bight?
2. Inventory and characterize sources of uncertainty and bias in the ROMS, BEC and coupled model's inputs, parameters, and outputs.
3. What portfolio of investments would best promote long-term, continuous improvement of the model's predictive accuracy and potential scope of use?

Today's Meeting Objectives

- Review development, setup, and validation of the individual ROMS and BEC elements of the Coupled Model.
- Review development, setup, and validation of the coupled model's biological conversions and interpretations of model outputs.
- Provide time for Panelists, Stakeholders and Modelers to engage in facilitated question and answer periods.

Meeting Schedule

Time (Pacific)	Topic	Presenter
9:00 a.m.	Call to Order, Welcome, and Agenda	Kevin M. Hardy, NWRI
9:10 a.m.	ROMS Development, Set-Up, and Validation	Martha Sutula, SCCWRP Jim McWilliams, UCLA
9:40 a.m.	Facilitated Panelist Q&A	W. Gordon Zhang, Chair
9:50 a.m.	BEC Development, Set-Up, and Validation	Martha Sutula, SCCWRP Curtis Deutsch, Princeton
10:20 a.m.	Facilitated Panelist Q&A	W. Gordon Zhang, Chair
10:30 a.m.	Break	
10:45 a.m.	Biological Conversions and Interpretation of Model Outputs	Martha Sutula, SCCWRP Christina Frieder, SCCWRP
11:15 a.m.	Facilitated Panelist Q&A	W. Gordon Zhang, Chair
11:25 a.m.	Facilitated Stakeholder Q&A	Kevin M. Hardy, NWRI and Martha Sutula, SCCWRP
11:55 a.m.	Final Panel Member Questions	W. Gordon Zhang, Chair
12:00 p.m.	Adjourn	

Independent Peer Review Panel Members

- Chair: W. Gordon Zhang, PhD, Woods Hole Oceanographic Institution
- Neil Banas, PhD, University of Strathclyde (UK)
- Fei Chai, PhD, University of Maine
- Marjy Friedrichs, PhD, Virginia Institute of Marine Science
- Alexander Kurapov, PhD, NOAA
- Michael Stukel, PhD, Florida State University

Modeling Team Members

- Daniele Bianchi, UCLA
- Curtis Deutsch, Princeton University
- Christina Frieder, SCCWRP
- Fayçal Kessouri, SCCWRP
- Jim McWilliams, UCLA
- Martha Sutula, SCCWRP

Steering Committee Members

- Lorien Fono, Bay Area Clean Water Agencies
- David Gibson, Regional Water Quality Control Board, San Diego Region
- Justine Kimball, Ocean Projection Council
- Karen Mogus, State Water Resources Control Board, Division of Water Quality
- Steve Wagner, Goleta Sanitary District
- Lan Wiborg, Orange County Sanitation District

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- Sean Bothwell, California Coastkeeper Alliance
- Kristin Davis, PhD, University of California, Irvine
- Steve Weisberg, Southern California Coastal Water Research Project

National Water Research Institute

- Kevin M. Hardy, Executive Director
- Mary Collins, Technical Editor/Communications
- Tianna Manzon, Research Project Coordinator
- Suzanne Sharkey, Water Resources Scientist/Project Manager

NATIONAL WATER RESEARCH INSTITUTE

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Independent Peer Review of SCCWRP's Coupled Regional Ocean Monitoring System and Biogeochemical Elemental Cycling Model: Webinar 3

Date: Wednesday, May 15, 2024
Time: 11:00 AM Pacific / 2:00 PM Eastern

Online Meeting Location –

See Calendar Invitation for login information or
Contact tmanzon@nwri-usa.org

NWRI Mobile Contacts –

Kevin Hardy: 760.801.9111
Tianna Manzon: 562.708.0123
Suzanne Sharkey: 949.258.2093

Goals of Independent Peer Review

The goals of this Independent Peer Review Panel (Panel) are to: assess model readiness to answer management questions; advise on model uncertainty associated with addressing management questions; and recommend next steps for improving model readiness.

Panel Charge

1. Do the ROMS, BEC, and coupled model's fundamental modeling choices enable the coupled model to predict the physical and biogeochemical processes impacting ocean acidification and hypoxia in the Southern California Bight?
2. Inventory and characterize sources of uncertainty and bias in the ROMS, BEC, and coupled model's inputs, parameters, and outputs.
3. What portfolio of investments would best promote long-term, continuous improvement of the model's predictive accuracy and potential scope of use?

Today's Meeting Objectives

- Close the Panel's record of review having presented for its consideration:
  - a non-governmental organization's perspective on the coupled model's purpose, capabilities, and future development;
  - a summary of California's water quality regulatory framework presented from the perspective of State Water Resources Control and Regional Water Quality Board executives; and,
  - novel and relevant solutions arising from today's facilitated, topic-specific question and answer sessions.
- Work privately with the Panel to facilitate its continuing review and editing of the draft report.

NWRI Panel for SCCWRP's Coupled ROMS-BEC Model: **Webinar 3 Meeting Agenda**

Today's Agenda

Time (Pacific)	Topic	Presenter
11:00 a.m.	Call to Order, Welcome, and Agenda	Kevin M. Hardy, NWRI
11:10 a.m.	NGO Perspectives on the Coupled Model's Purpose, Capabilities, and Future Development	Mark Gold, Director of Water Scarcity Solutions, Natural Resources Defense Council
11:30 a.m.	Facilitated Q&A	Kevin M. Hardy, NWRI W. Gordon Zhang, Panel Chair
11:40 a.m.	California's Water Quality Regulatory Framework	Karen Mogus, Chief Deputy Director, State Water Board David Gibson, Executive Officer, San Diego Regional Water Quality Control Board
12:00 p.m.	Facilitated Q&A	Kevin M. Hardy, NWRI W. Gordon Zhang, Panel Chair
12:10 p.m.	Next Steps: Independent Peer Review Panel Process and Report	Kevin M. Hardy, NWRI W. Gordon Zhang, Panel Chair
12:20 p.m.	Facilitated Q&A	Kevin M. Hardy, NWRI W. Gordon Zhang, Panel Chair
12:30 p.m.	Adjourn to Private Panel Working Session	
2:00 p.m.	Adjourn Private Session	

Independent Peer Review Panel Members

- Chair: W. Gordon Zhang, PhD, Woods Hole Oceanographic Institution
- Neil Banas, PhD, University of Strathclyde (UK)
- Fei Chai, PhD, University of Maine
- Marjy Friedrichs, PhD, Virginia Institute of Marine Science
- Alexander Kurapov, PhD, National Oceanic and Atmospheric Association
- Michael Stukel, PhD, Florida State University

NWRI Panel for SCCWRP's Coupled ROMS-BEC Model: **Webinar 3 Meeting Agenda**

Modeling Team Members

- Daniele Bianchi, University of California, Los Angeles (UCLA)
- Curtis Deutsch, Princeton University
- Christina Frieder, Southern California Coastal Water Research Project (SCCWRP)
- Fayçal Kessouri, SCCWRP
- Jim McWilliams, UCLA
- Martha Sutula, SCCWRP

Steering Committee Members

- Lorien Fono, Bay Area Clean Water Agencies
- David Gibson, Regional Water Quality Control Board, San Diego Region
- Justine Kimball, Ocean Protection Council
- Karen Mogus, State Water Resources Control Board, Division of Water Quality
- Steve Wagner, Goleta Sanitary District
- Lan Wiborg, Orange County Sanitation District

Ex Officio Science Advisors

- Sean Bothwell, California Coastkeeper Alliance
- Kristin Davis, PhD, University of California, Irvine
- Steve Weisberg, SCCWRP

National Water Research Institute

- Kevin M. Hardy, Executive Director
- Mary Collins, Technical Editor/Communications
- Tianna Manzon, Research Project Coordinator
- Suzanne Sharkey, Water Resources Scientist/Project Manager

Appendix D · Meeting Attendees

NWRI CASA IRP Panel Meeting Day 1 – January 17, 2024

Kyra Barboza, Irvine Ranch Water District

Amber Baylor, South Orange County Wastewater Authority

Daniele Bianchi, University of California, Los Angeles

Sean Bothwell, Ca Coastkeeper Alliance

Samuel Choi, OC Sanitation

Yiping Cao, OC Sanitation

Kristin Davis, University of California, Irvine

Lorien Fono, Bay Area Clean Water Agencies

Christina Frieder, Southern California Coastal Water Research Project

David Gibson, San Diego Regional Water Quality Control Board

Minna Ho, Southern California Coastal Water Research Project

Saundra Jacobs, Santa Margarita Water District

Stephanie Jaeger, City of San Diego

Scott Jenkins, South Orange County Wastewater Authority

Steve Jepsen, Clean Water So Cal

Faycal Kessouri, Southern California Coastal Water Research Project/UCLA

Justine Kimball, California Ocean Protection Council

Ami Latker, City of San Diego

Joe Manzella, OC Sanitation

Lisa McCann, State Water Resources Control Board

Karen McLaughlin, Southern California Coastal Water Research Project

Eckart Meiburg, University of California, Santa Barbara

Karen Mogus, State Water Resources Control Board

Thomas Parker, LA County Sanitation Districts

Jian Peng, OC Public Works

Violet Renick, City of San Diego

Martha Sutula, Southern California Coastal Water Research Project

Danny Tang, OC Sanitation

Laura Terriquez, OC Sanitation

Jared Voskuhl, CA Association of Sanitation Agencies

Steve Wagner, Goleta Sanitation District

Steve Weisberg, Southern California Coastal Water Research Project

Josh Westfall, LA County Sanitation Districts

Lan Wiborg, OC Sanitation

NWRI CASA IRP Panel Meeting Day 2 – January 18, 2024

Alicia Appel, Encina Wastewater Authority

Kyra Barboza, Irvine Ranch Water District

Amber Baylor, South Orange County Wastewater Authority

Daniele Bianchi, University of California, Los Angeles

Sam Choi, OC Sanitation

Lorien Fono, Bay Area Clean Water Agencies

Mike Gaskins, El Toro Water District

Mark Gold, Natural Resources Defense Council

Stephanie Jaeger, City of San Diego

Scott Jenkins, South Orange County Wastewater Authority

Steve Jepsen, Clean Water So Cal

Faycal Kessouri, Southern California Coastal Water Research Project/UCLA

Justine Kimball, California Ocean Protection Council

Ami Latker, City of San Diego

Joe Manzella, OC Sanitation

Lisa McCann, State Water Resources Control Board

Karen McLaughlin, Southern California Coastal Water Research Project

Jim McWilliams, University of California, Los Angeles

Eckart Meiburg, University of California, Santa Barbara

Karen Mogus, State Water Resources Control Board

Mitchell Mysliwiec, Larry Walker Associates

Thomas Parker, LA Sanitation Districts

Jian Peng, OC Public Works

Violet Renick, City of San Diego

Ken Schiff, Southern California Coastal Water Research Project

Stephanie Smith, City of San Diego

Martha Sutula, Southern California Coastal Water Research Project

Danny Tang, OC Sanitation

Laura Terriquez, OC Sanitation

Jared Voskuhl, CA Association of Sanitation Agencies

Steve Wagner, Goleta Sanitation District

Shelly Walther, LA County Sanitation Districts

Steve Weisberg, Southern California Coastal Water Research Project

Josh Westfall, LA Sanitation

Lan Wiborg, OC Sanitation

NWRI Staff (Both Days)

Kevin Hardy, Executive Director

Suzanne Sharkey, Project Manager

Tianna Manzon, Project Assistant

Mary Collins, Technical Editor

Appendix E · Additional Resources

NWRI Home Page

NWRI Web Page about the ROMS-BEC Modeling Peer Review

Cal State University, Long Beach, Southern California Bight Oceanography

SCCWRP Home Page

SCCWRP Southern California Bight Regional Monitoring Program

Southern California Bight regional monitoring

Seasonal nearshore ocean acidification and deoxygenation in the Southern California Bight

Phytoplankton dynamics in the Southern California Bight indicate a complex mixture of transport and biology

Modeling semidiurnal internal tide variability in the Southern California Bight

Development, implementation, and validation of a California coastal ocean modeling, data assimilation, and forecasting system

Seasonal and interannual variability in along-slope oceanic properties off the US West Coast: Inferences from a high-resolution regional model

Slope and Shelf Flow Anomalies Off Oregon Influenced by the El Niño Remote Oceanic Mechanism in 2014-2016

The M_2 Internal Tide Off Oregon: Inferences from Data Assimilation

Variational assimilation of HF radar surface currents in a coastal ocean model off Oregon

Influence of varying upper ocean stratification on coastal near-inertial currents

Appendix F · Acronyms and Terms

Anthropogenic – Related to or resulting from human influences.

AOU – Apparent Oxygen Utilization

BEC – Biogeochemical Elemental Cycling Model

Benthic processes – Biological, chemical, and physical processes occurring on or near the seabed, affecting marine ecosystems.

Biogeochemical processes – Natural cycles that transform chemicals and nutrients between the environment and living organisms.

CalCOFI – California Cooperative Oceanic Fisheries Investigations

CASA – California Association of Sanitation Agencies

Coupled model – A computational model that integrates two or more separate models to simulate interactions between different systems, such as the ROMS and BEC models.

CTAG – SCCWRP's Commission Technical Advisory Group

Ecosystem – A community of organisms, including plants, animals, and microbes, interacting with each other and with their physical environment.

Ecosystem-level – Relating to the entire system of organisms and their environment, considering interactions across multiple species and habitats.

Euphotic zone – The upper layer of a body of water where sunlight penetrates, supporting photosynthesis for plant life and primary producers.

Enhanced data output – Providing more comprehensive and detailed model outputs, often made accessible through public channels for transparency and stakeholder review.

Fluxes – Movements or flows of substances within a system, such as the transfer of nutrients or gases in an ecosystem.

HF – High Frequency

Hypoxia – Low oxygen levels caused by nutrients in ocean water that feed algal overgrowth; hypoxic zones contribute to reduced sea life in so-called "dead zones" according to the National Oceanic and Atmospheric Administration (NOAA).

Indicator species – Species whose presence, absence, or abundance reflects specific environmental conditions, acting as signals of ecosystem health.

Inputs – Data or information fed into a model to produce results, including environmental variables like temperature, salinity, or nutrient levels.

IPCC – Intergovernmental Panel on Climate Change

Light attenuation coefficient – The rate at which light reduces as it passes through ocean water.

Mesoscale processes – Oceanographic processes occurring on medium spatial scales, such as eddies or currents, larger than microscale events but smaller than basin-wide phenomena.

Near-field observations – Data collected close to the source of interest, such as wastewater discharges and other relevant point and non-point sources, to improve model accuracy in depicting local processes.

NPP – Net Primary Production

Numerical model – Computer models based on mathematical equations that are used to simulate complex scenarios and make predictions about natural processes.

Nutrient load management – Efforts to regulate and monitor the input of nutrients into a marine system to mitigate environmental impacts such as eutrophication or hypoxia.

Observational datasets – Collections of data obtained through observation, often used as reference points for validating models.

Ocean acidification – According to NOAA, the process of reduced pH of ocean water caused by the uptake of carbon dioxide (CO_2) from the atmosphere.

Outputs – The results or predictions generated by a model based on its inputs and parameters.

PAR – photosynthetically active radiation

Parameters – Adjustable variables in a model that define specific aspects of the system being studied, such as growth rates or reaction coefficients.

pCO_2 – partial pressure of carbon dioxide

Peer review – A process in which experts critically evaluate a study or model to ensure its scientific validity before publication or use.

Physical processes – Natural phenomena in the physical world, such as the movement of ocean currents, changes in temperature, and wave action.

Phytoplankton – Microscopic marine algae.

Plankton – Tiny, ocean-dwelling organisms that drift in tides and currents and are the basis of the marine food web.

PSC – Project Steering Committee

Predictive accuracy – The degree to which a model's outputs can reliably forecast real-world outcomes.

Pteropods – Small, free-swimming sea snails and sea slugs.

Quality control – Procedures that ensure data or model outputs meet established standards and are accurate and reliable.

ROMS – Regional Ocean Monitoring System

SCCWRP – Southern California Coastal Water Research Project

Sentinel species – Species used to detect potential environmental risks to human health by providing early warnings about harmful changes.

Sensitivity analysis – Assessment used to determine how changes in specific inputs or parameters affect a model's outputs, helping to identify the factors that most influence results.

Southern California Bight – The coastal region off Southern California, characterized by its curved coastline, extending from Point Conception to Punta Colonet, encompassing the waters off Los Angeles and San Diego.

Submesoscale processes – Dynamic ocean processes such as eddies and other interactions between currents and water bodies.

SWOT – Surface Water and Ocean Topography

Temporal resolution – The level of detail regarding time intervals in data or model outputs, affecting the granularity of temporal trends.

Treated wastewater – Wastewater that is processes at a treatment plant to remove contaminants before it is discharged into the environment.

Trophic levels – The hierarchical levels in a food chain, indicating an organism's position based on its diet and energy source.

Uncertainty – The degree to which a model's predictions are unknown or variable due to factors like data limitations or approximations in the model.

Zooplankton – Tiny floating animals that, combined with phytoplankton, constitute the ocean’s plankton community.