SCCWRP FACT SHEET

Modeling as a tool to support coastal water-quality decisions

A primer on how computer modeling is used to understand the effects of discharging nutrients to Southern California's ocean

When coastal communities face water-quality problems, they often struggle to understand the extent of the problem across space and time. Environmental monitoring programs can provide some insights, but only for a limited number of sites at discrete time points.

Moreover, as communities identify possible solutions over time to solve water-quality problems, they need assurances they'll get tangible environmental benefits – before investing millions or even billions of dollars in a particular solution. Monitoring programs can quantify the success of these solutions once implemented, but do not provide insights about the likelihood of success for solutions that have yet to be implemented.

Human activities on land can adversely affect the health of aquatic resources, including Southern California's coastal ocean, above. Coastal communities rely on computer modeling to better understand these problems and evaluate if proposed interventions will be effective.

Modeling helps communities make informed choices

For decades, managers have relied on computer modeling to generate a more comprehensive picture of coastal ecosystem health and to evaluate if proposed interventions to protect water quality will be effective. Through modeling, stakeholders can:

- Weigh the benefits vs. costs of different possible interventions
- Consider the risk of taking no action vs. taking action that turns out to be wrong or inadequate
- Use a common set of facts and data to reach consensus on the best course of action

Examples: Modeling informing decisions

Managers routinely use proven computer models as a basis for taking action:

» During hurricanes, weather forecasting models help public officials determine when and where to issue evacuation orders to move millions out of harm's way.

» When a body of water needs to go on a "pollution diet," water-quality models help predict how much pollution levels need to be reduced to restore healthy conditions for plant and animal communities.

» Policymakers rely on global climate models to understand how Earth's climate will change in the future and how reducing carbon emissions could slow these changes.

Should a model's predictions be trusted?

"All models are wrong; some are useful."
–British statistician George Box

All models generate predictions with some degree of error, which can lead to questions about how much their predictions can be trusted. The key to developing confidence in a model's predictions is to scrutinize how a model is performing – a critical step known as quantifying modeling uncertainty. When managers understand modeling uncertainty, they have context for deciding how much confidence to place in what the model is predicting.

» Uncertainty is not unique to modeling
All types of scientific measurements have uncertainty. Field and satellite measurements – often held up as the gold standard for assessing coastal water quality – have uncertainty too. The main difference is scientists have an easier time quantifying uncertainty in monitoring data than in models.

» How modeling uncertainty is quantified
Scientists commonly quantify modeling uncertainty in multiple ways, including:

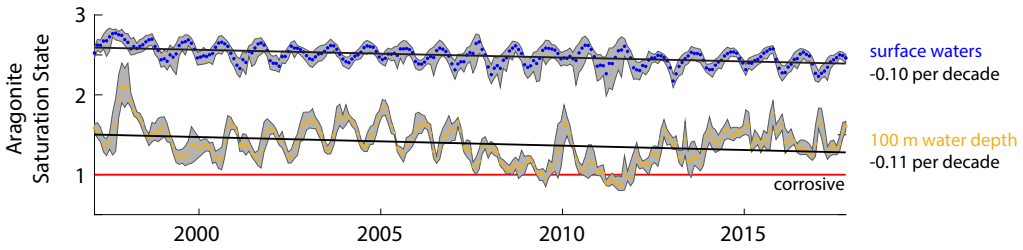
- Comparing the model's predictions to field data; any difference represents the model "uncertainty," which is a combination of error in the model's predictions and error in field measurements
- Conducting a sensitivity analysis, where the data that are fed into the model are intentionally tweaked to determine how vulnerable the model's outputs are to various modeling assumptions
- Running a model comparison analysis, where the model is compared to other models that predict similar variables to identify differences in their predictions

The more ways that modeling uncertainty gets quantified, the more confidence that managers can have in the model's predictions – and thus the more likely managers are to make informed decisions based on modeling insights.

Case study: Modeling the effects of nutrient discharges on Southern California coastal waters

Southern California communities face a conundrum

Increased greenhouse gas emissions are warming Earth and causing ocean pH and oxygen levels to fall along the West Coast, leading to widespread problems for marine life. Although greenhouse gas emissions are viewed as the primary driver of these changes, scientists are studying the extent to which nutrients discharged from heavily populated Southern California coastal communities could be exacerbating these problems. Computer models are foundational to these investigations; the outcomes could have significant cost implications for communities.



Modeling is used to simulate multiple aspects of coastal ocean health, including changes in a property of seawater chemistry known as aragonite saturation state, above, at two different depths over time.

Key management questions

As scientific understanding of the effects of coastal nutrient discharges improves, Southern California will be faced with tough questions about whether to act – and the costs of action vs. inaction:

» Will investing in reducing nutrient discharges make a measurable difference for coastal ocean health?

» How could nutrient reductions result in measurable changes in coastal water quality?

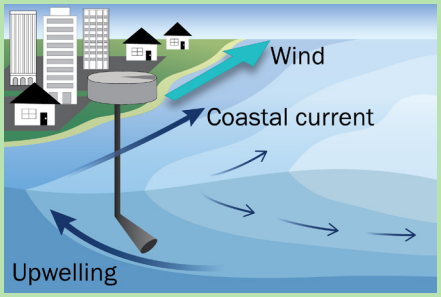
» Are there nutrient management alternatives – such as offshore kelp farming – that could measurably improve coastal water quality?

How the coastal water-quality model works

Southern California's coastal water-quality model is made up of two component models – collectively known as **ROMS-BEC** – that work in tandem to predict the influence that local nutrient discharges are having on coastal ocean health.

Southern California's ROMS-BEC coastal water-quality model

ROMS
Regional Ocean Modeling System



A circulation model that predicts how ocean water circulates – a key predictor of how nutrient discharges disperse in coastal waters

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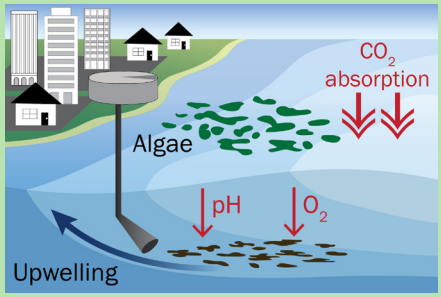
BEC
Biogeochemical Elemental Cycling



An ocean water-quality model that predicts how nutrient discharges combine with natural ocean nutrients to fuel growth of algal blooms that, upon their death, are decomposed by bacteria that consume oxygen and lower pH

» Assessing influence of local human discharges

Scientists are using the model to predict how coastal ocean health is affected by local nutrient discharges, then repeating the modeling simulation – except this time, reducing local nutrient discharges. The difference between the two simulations represents how much nutrient discharges have the potential to alter coastal ocean pH and oxygen levels.

» Evaluating effectiveness of possible interventions

Just as scientists are working to model what is happening now, models also have the potential to help understand the effectiveness of possible future nutrient management decisions. Scientists are using ROMS-BEC to simulate the combined effects of these potential management scenarios and projected future local and regional changes to ocean pH and oxygen levels driven by climate change.

Building management confidence in modeling

To build confidence in the ROMS-BEC model's predictive abilities, scientists are quantifying uncertainty in multiple ways, including:

» Comparing hindcast modeling of algal blooms, pH and oxygen levels in coastal waters to more than 20 years of corresponding field monitoring data (see "More reading" links below), focusing on areas where nutrient reductions have already occurred to assess model performance

» Partnering with stakeholders to invite outside experts to independently review the ROMS-BEC modeling work and evaluate modeling uncertainty

These and other model validation activities are ongoing.

More reading

Findings of ROMS-BEC water quality application

Findings of model skill assessment