SCCWRP

2022 ANNUAL REPORT

Managing in the face of climate change

Scientists offer insights, solutions to help protect aquatic ecosystems from changing environmental conditions

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Applying next-generation science to aquatic ecosystems management

Welcome to the interactive version of SCCWRP's 2022 Annual Report! Click on the links below to jump directly to specific areas of the report. To request a printed copy of this report, contact pubrequest@sccwrp.org.

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SCCWRP 2022 ANNUAL REPORT

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Feature Articles

A SCCWRP field crew measures flow rates and other parameters in the Los Angeles River for a study evaluating the environmental flows needed to sustain the river's diverse freshwater ecosystems, plus the recreational benefits provided by these flows. **Page 7**

Southern California Coastal Water Research Project 2022 Annual Report

Editor
Stephen B. Weisberg, Ph.D.

Managing Editor
Scott Martindale

Cover photo
Courtesy of Pacific Marine Mammal Center
A sea lion that was poisoned by an algal toxin known as domoic acid is released after being treated by a local rehabilitation center.* Researchers are working to understand how toxin-producing blooms – which are becoming more frequent and severe with climate change – are spreading in coastal waters and affecting vulnerable marine life.

*Pacific Marine Mammal Center activities conducted under a stranding agreement with the National Oceanic and Atmospheric Administration

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Accomplishments with journal abstracts

People

Snapshot of Success

Steps taken by SCCWRP to improve aquatic science research and water-quality management in 2022

1 Scientific credibility

Goal: Establish and maintain credibility with colleagues in the aquatic science community

SCCWRP can more effectively transition science into application when the agency engenders credibility with scientific peers. SCCWRP uses two primary metrics to quantify success in this area:

» Publication rate

Publishing prolifically in scientific journals is an important measure of scientific success, as these articles go through a rigorous peer review process. A robust publication rate engenders credibility for SCCWRP in the broader scientific community.

Accomplishment

SCCWRP scientific staff published an average of **4.1** journal articles each per year over the past three years. This compares favorably with the **2** publications per year minimum that SCCWRP's partners at academic research institutions generally seek to achieve when being considered for promotion. **Page 29**

» Citation rate

Whereas the number of publications quantifies productivity, citation rate provides a measure of how widely read SCCWRP's work is and the degree to which it is influencing other researchers. SCCWRP's goal is for other scientists to reference SCCWRP's work when publishing their own.

Accomplishment

SCCWRP publications were cited **2,292** times in 2022, according to Web of Science statistics.

2 Scientific consensus-building

Goal: Promote consensus-building through scientific collaboration and leadership

The most expeditious path for the water-quality management community to incorporate scientific findings into decision-making is for researchers to achieve consensus. SCCWRP facilitates consensus-building through:

» Leadership

Attaining leadership roles with professional scientific organizations enhances SCCWRP's opportunities for interactions and consensus-building in the aquatic sciences.

Accomplishment

SCCWRP scientific staff held **151** leadership roles with professional societies, advisory committees and scientific journals in 2022. **Page 71**

» Collaboration

External interactions, especially in leadership capacities, often translate to collaborative scientific publications. The number of external organizations with which SCCWRP coauthors scientific publications is a reflection of SCCWRP's success building consensus.

Accomplishment

SCCWRP published scientific articles and reports with **188** different institutions in 2022. **Page 29**

What SCCWRP seeks to achieve

- Translate aquatic science research into management applications
- Optimally position the water-quality management community to benefit from scientific research
- Positively influence how aquatic systems are managed in Southern California and beyond

3 Management influence

Goal: Positively influence decision-making and actions by the end-user water-quality management community

Scientific credibility and consensus-building are important waypoints along SCCWRP's journey to produce science that positively influences management. The feature articles in this report illustrate SCCWRP's efforts to help the region's water-quality management community respond to the ecological effects of climate change.

» Characterizing issues

SCCWRP helps managers design robust environmental monitoring studies that illuminate potential threats to coastal ecosystems, as well as document improvements over time.

» Developing methods and tools

SCCWRP develops and test-drives new approaches for getting more insightful data faster and more cost-effectively.

» Assessing effectiveness of actions

SCCWRP helps evaluate the effectiveness of management interventions taken to better protect aquatic ecosystems.

Accomplishment

SCCWRP has co-developed a standardized scientific approach to help managers determine how to balance the human and ecosystem needs of California's increasingly limited flow resources. **Page 7**

Accomplishment

SCCWRP has helped lay a scientific foundation for tracking harmful algal blooms across California – including the harmful toxins they can produce – and identifying factors that are driving their proliferation. **Page 14**

Accomplishment

SCCWRP has conducted key field monitoring, laboratory experiments and computer modeling to help managers understand the ecological consequences of West Coast ocean acidification. **Page 21**

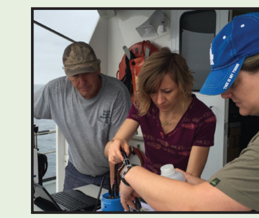
4 Long-term support

Goal: Provide technical support and expertise to SCCWRP's 14 member agencies to maximize their adoption and use of science

While influencing management decision-making is a signature SCCWRP accomplishment, SCCWRP maximizes the effectiveness of its influence by providing long-term guidance and assistance to its 14 member agencies.

» Training

SCCWRP develops user-friendly instruction materials and conducts hands-on training to ensure managers are properly educated about new tools and technologies.



» Intercalibration

SCCWRP facilitates intercalibration and quality-assurance exercises to ensure managers can demonstrate proficiency using new tools and technologies.

» Vetting

SCCWRP facilitates case studies and expert advisory committees to fully vet new tools and technologies.

» Outreach

SCCWRP conducts outreach activities to ensure managers and stakeholders buy into and fully embrace new approaches and technologies.

SCCWRP prides itself on the long-term support it provides to member agencies.

Accomplishment

SCCWRP staff have spent more than **8,600** person-hours in 2022 providing implementation support to member agencies.

Director's Message

Quantifying the extent of our knowledge

I interviewed for the SCCWRP Director position 28 years ago, and I still remember one of the questions asked of me: "How will you respond to our science questions when you don't know the answer?" My reply was that scientists rarely *know* the answers and therefore every response I give should have two parts: (a) the best answer we have, and (b) the confidence level we have in that answer.

Most of SCCWRP's focus during my tenure has been developing environmental monitoring programs, where confidence levels are relatively easy to quantify. In the laboratory, we do intercalibration exercises to quantify measurement error, and take steps to lessen error based on those findings. In the field, we take replicate samples to determine error associated with small-scale spatial and temporal variability, and use the data to calibrate the number of replicates we should take to achieve acceptable error.

This year's Annual Report highlights an expansion of our toolkit at SCCWRP from monitoring to modeling. While monitoring tells us where we have been and whether past actions have been effective, modeling has the potential to tell us about the future, and to explore alternative futures that could result from different potential management actions. The feature articles in this Annual Report highlight some of our key ongoing modeling activities, including our ecohydrology modeling (Page 7), modeling of marine algal blooms (Page 14) and ocean acidification modeling (Page 21).

While modeling offers important advantages over monitoring, it brings challenges – especially how to quantify confidence in model predictions. There are a number of tools we use to measure modeling uncertainty, such as validating against empirical data and running sensitivity analyses to ascertain which data inputs are the most important ones to get right. In general, however, quantifying confidence in modeling data is not as straightforward or as easy as quantifying confidence in monitoring data. For instance, the field data against which we validate models are often collected at much more limited spatial and temporal scales than our model outputs, making comparisons inexact. Moreover, the field data we have for validation are most often only for static responses (i.e., physical oceanography or seawater chemistry), rather than for rate processes that drive the model (i.e., nutrient adsorption or plankton growth).

As a result, when it comes to quantifying the extent of our knowledge about modeling, we're still on a learning curve. Our modelers are learning how to engage environmental managers in helping us to define what our modeling products should look like, and helping them to recognize that modeling is a long-term investment that will incrementally improve over time as the supporting data sets – and the management questions we're trying to answer through modeling – become more sophisticated.

Our modelers also are learning the kinds of confidence information that SCCWRP member agencies and other environmental managers want before incorporating modeling predictions into their decision-making processes. One key is understanding the interplay between the magnitude of a management decision and the uncertainty associated with the modeling work we do to help inform this decision. Managers will likely accept a larger amount of uncertainty when the decision is relatively small in scale or cost, or is easily reversible. By contrast, other potential management actions we are presently modeling – such as the level of improvement to coastal water quality from reducing nutrient discharges – could involve billions of dollars in investments that are not practical to reverse once constructed. At the same time, we're using the same modeling tools to simultaneously examine how planting more kelp beds might help lessen hypoxia and ocean acidification – a solution that would be scalable as well as reversible, if necessary, after initial investment.

We look forward to working with our member agencies and other involved stakeholders to ensure the models we develop provide not only the information you need, but also the uncertainty estimates that allow for informed decisions.

Stephen B. Weisberg, Ph.D.
Executive Director

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MANAGING IN THE FACE OF CLIMATE CHANGE

Science offers insights and solutions to help environmental managers better protect aquatic ecosystems from the effects of climate change

For much of the time that climate change has been part of the public consciousness, it's been viewed as a distant eventuality – an abstract concept whose worst effects might still be decades away.

Today, as ordinary people experience the effects of climate change on a daily basis, it's no longer a future state. It's already happening.

Atmospheric rivers, bomb cyclones, hurricanes, wildfires and droughts are all becoming more common and more intense in lockstep with climate change. Communities are grappling with increased risks of flooding and erosion, property destruction and – in a worst-case scenario – loss of human life.

The disruptions caused by climate change aren't limited to adverse effects on humans and the built environment; these same challenges also are playing out in aquatic ecosystems.

In freshwater settings, changes in snow and rainfall patterns are affecting how and when water flows through rivers, creeks and other waterways – changes that can adversely affect vulnerable plant and animal communities.

Global atmospheric temperature increases, meanwhile, are raising the temperature of water bodies, creating more favorable conditions for nuisance species like harmful algal blooms and pathogens to flourish.

And as atmospheric carbon dioxide emissions

Courtesy of Occidental College Vantuna Research Group

North Lake at the Whittier Narrows Recreation Area in Los Angeles County is tainted murky green by a harmful algal bloom, forcing the closure of the popular spot for pedal boating over a recent Labor Day holiday weekend. SCCWRP is working to connect the physical manifestations of climate change with the ecological consequences for aquatic ecosystems.

are being absorbed by the ocean, seawater is undergoing fundamental chemical changes that are making it less habitable for coastal marine life.

To effectively manage aquatic ecosystems in the face of climate change, California's water-quality management community must be able to monitor and identify biological communities that are being most affected – and to understand when, where and why these adverse effects are occurring.

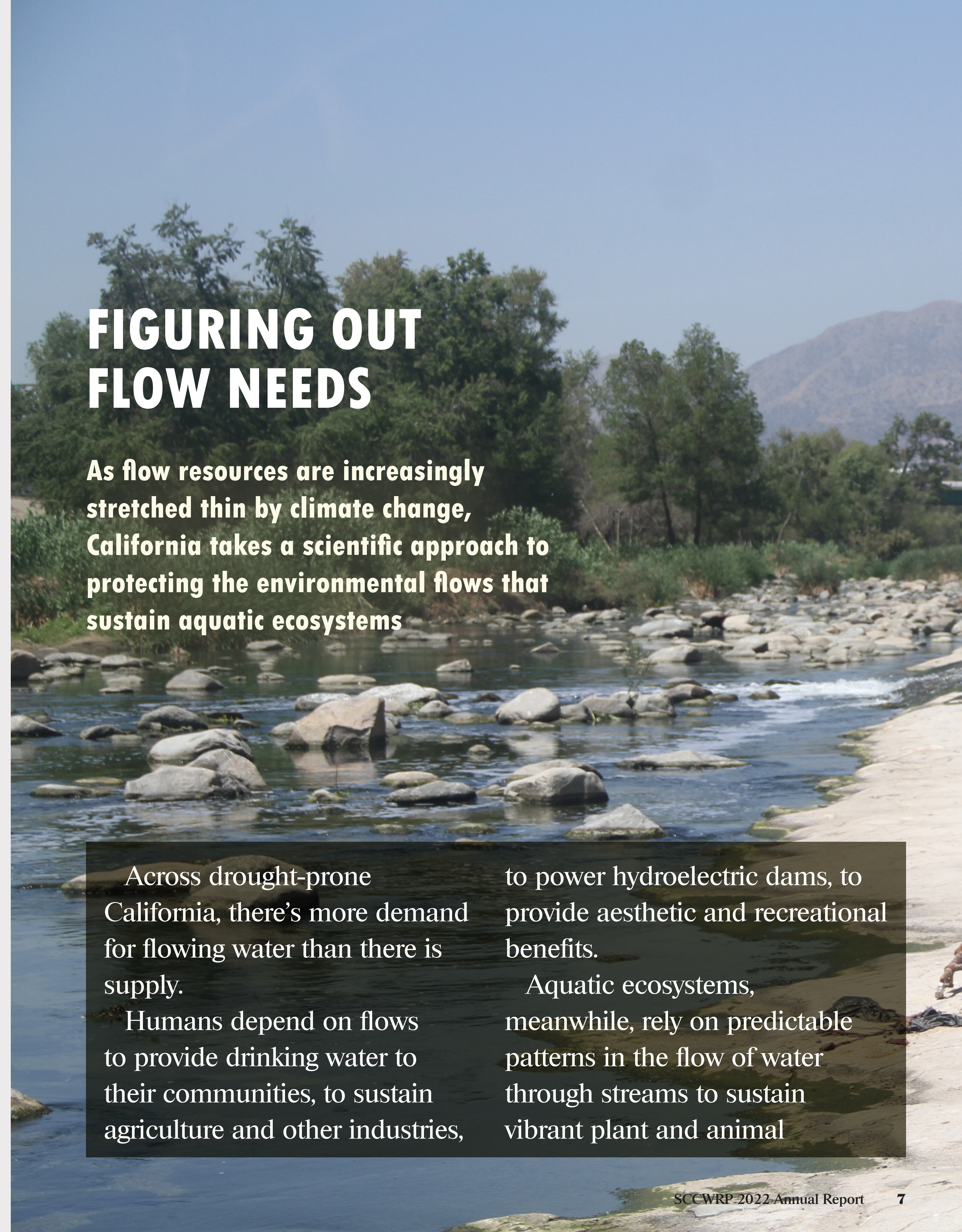
SCCWRP and its many scientific partners are working to fill these knowledge gaps, generating data and insights that can help managers prioritize, plan and decide how best to intervene to guard against climate change's most disruptive effects.

SCCWRP's climate change research is focused on connecting rapidly growing knowledge about the physical manifestations of climate change – changes in weather patterns, increases in water temperatures, and alterations to water chemistry – with assessments and predictions about how aquatic ecosystems are responding to these changes.

SCCWRP's goal is to build a scientific foundation for environmental managers to move with confidence and conviction as they make tough decisions about how to optimally protect and restore aquatic ecosystems affected by climate change.

"As people see the effects of climate change playing out in our daily lives, it's creating momentum for scientists to really focus and prioritize getting answers to the management community's biggest questions," said Dr. Stephen Weisberg, SCCWRP's Executive Director. "We have an opportunity right now to meaningfully inform the actions that managers are taking to protect the health and resiliency of our most vulnerable aquatic ecosystems."

The three articles that follow in this Annual Report chronicle SCCWRP's efforts to help build a scientific foundation for managing aquatic ecosystems in the face of climate change. The articles describe efforts to proactively strengthen and expand environmental monitoring programs, probe the causes and modes of action through which ecological change is occurring, and build capacity to reliably predict the trajectory of future change.



FIGURING OUT FLOW NEEDS

As flow resources are increasingly stretched thin by climate change, California takes a scientific approach to protecting the environmental flows that sustain aquatic ecosystems

Across drought-prone California, there's more demand for flowing water than there is supply.

Humans depend on flows to provide drinking water to their communities, to sustain agriculture and other industries, to power hydroelectric dams, to provide aesthetic and recreational benefits.

Aquatic ecosystems, meanwhile, rely on predictable patterns in the flow of water through streams to sustain vibrant plant and animal communities – ecosystems that humans also want to see protected.

The work of allocating limited flow resources is tough, and it's only growing more difficult as California's population grows and puts new demands on limited flow resources. For example, as a result of California's recent legalization of cannabis, growers are requesting to divert flows from local streams to provide irrigation water. Similarly, Southern California's efforts to recycle and retain its water resources has resulted in less water being released into waterways, reducing the flows that aquatic ecosystems depend on.

Further compounding the challenge of flow management in California is climate change. Not only are Western states becoming drier, but storm events are becoming flashier and simultaneously less frequent. Meanwhile, warming atmospheric temperatures are triggering snow to melt faster and earlier in the year.

Against this backdrop, California's water resources management community is being called upon to develop balanced, science-informed solutions for allocating limited, increasingly scarce flow resources.

SCCWRP and other researchers are rising to meet this challenge, developing next-generation strategies, tools and methods to help managers take more consistent, standardized, and scientifically defensible approaches to allocating flows. These solutions are helping managers more effectively sustain and protect California's aquatic ecosystems over the long term, even in the face of climate change.


Courtesy of Ventura River Watershed Council

Californians have made numerous alterations to the way water flows across landscapes. Above, the Foster Park Subsurface Dam and Diversion in Ventura County is designed to slow the flow of water in Coyote Creek, enabling water to be extracted more readily and improving the efficiency of groundwater recharge.

"Over the past few years, we've made a concerted effort to develop information on ecological flow needs that water resources managers can use to better inform flow allocation decisions," said Alyssa Obester, Senior Environmental Scientist for the California Department of Fish and Wildlife. "There are many competing demands that are considered in water resource management including protecting and preserving the health of our aquatic ecosystems in the process."

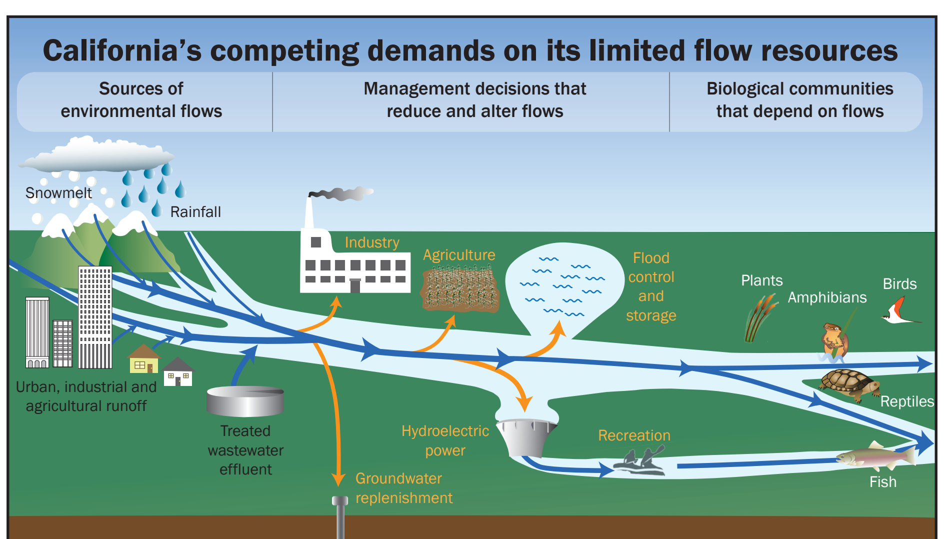
Recognizing flow alteration as a major stressor

Human-made alterations to how water flows across California have become a major source of stress affecting the ecological health of waterways.

In Southern California, foundational work by the Southern California Stormwater Monitoring Coalition has determined that altered flows are the greatest cause of degradation to biological communities in the region's streams – a bigger stressor than heavy metals, pesticides, excess nutrients and other pollutants.

These findings, which are based on analyses of regional stream bioassessment data from 2009 to 2013, have helped bring into focus the importance of protecting and restoring optimal flow patterns for Southern California's diverse rivers, creeks and other waterways.

The flow patterns needed to sustain aquatic ecosystems – and the societal benefits these flows provide to humans – are known as environmental flows. Environmental flows explain the timing, duration and intensity of the flows necessary to sustain these many beneficial uses – across seasons and across years.



Instead of trying to automatically mimic historical flow patterns, the goal of focusing on environmental flows is to create flow patterns that protect key aspects of flow that are functionally necessary to maintain the health of vulnerable plant and animal communities.

For example, the survival of the endangered arroyo toad, which lives at the edge of Southern California stream environments, is dependent on predictable flow patterns over the course of the year. Similarly, the Santa Ana sucker fish depends on streambed gravel to lay its eggs – gravel that can be washed away if flows become too fast and too flashy.

"With stresses from population growth and climate change, it's easy to see a future where every stream in Southern California looks like the barren concrete channels in iconic Hollywood race scenes," said Jeremy Haas, Environmental Program Manager for the San Diego Regional Water Quality Control Board. "However, environmental flow tools help provide us a feasible path toward stream protection and restoration that support sustainable development goals and a more resilient future for wildlife, recreation and water supply in our communities."

Developing a framework for determining flow needs

Historically, California has not been consistent about determining environmental flow needs for waterways.

Some environmental flows have been allocated based on analyses aimed


Courtesy of U.S. Fish and Wildlife Service

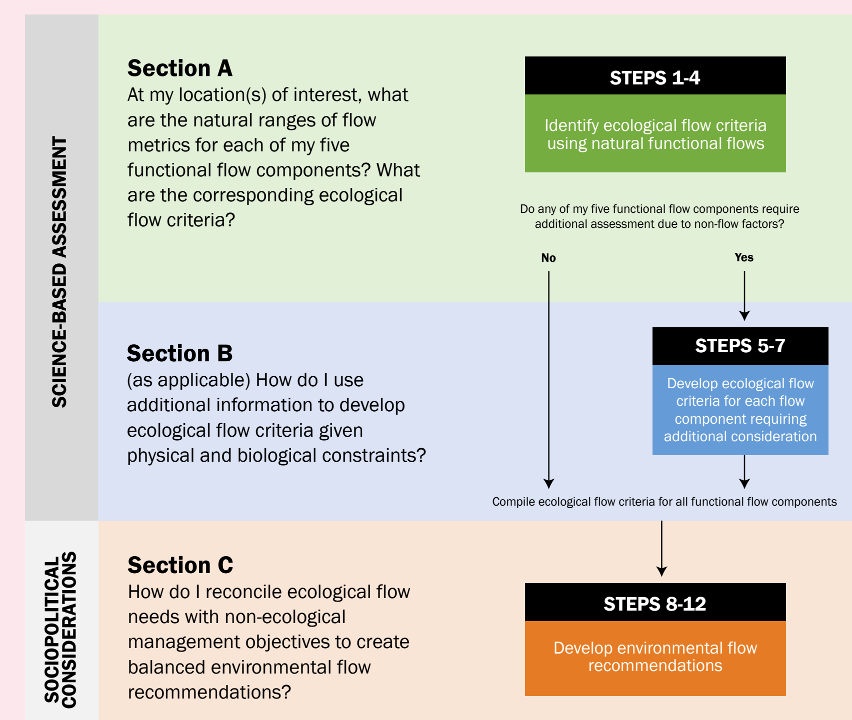
The endangered arroyo toad is vulnerable to even short-term changes in flow patterns, which can destroy its breeding pools at the edges of aquatic habitats.


Courtesy of U.S. Fish and Wildlife Service

The arroyo chub, left, and the endangered Santa Ana sucker, right, are among the freshwater species in California sensitive to changes in flow patterns. Stream flows, for example, help flush out the gravel-filled habitats where the Santa Ana sucker lays its eggs.

California Environmental Flows Framework (CEFF)

A team of researchers from across California, including SCCWRP, has developed a standardized scientific approach to help managers make decisions about how to allocate limited flow resources that balance both human and ecosystem needs for flowing water. The California Environmental Flows Framework is divided into three main sections that encompass multiple types of tools and methodologies for determining the environmental flow needs of streams. To arrive at a final set of flow recommendations, the framework reconciles science-based flow analyses with sociopolitical considerations.



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at protecting a single species, such as salmon during breeding season, or a single beneficial use, such as kayaking. Other types of flow management decisions in California have equated the natural, historical state of flows with environmental flows.

The potential problem with these approaches is that they lead to flow allocation decisions that may or may not protect or improve overall ecosystem functioning, nor do they promote a holistic, integrated approach to managing limited flow resources.

Courtesy of U.S. Geological Survey

The endangered Least Bell's vireo depends on specific flow patterns to support the riparian habitats where it builds its nests.

For example, Southern California's network of waterways has been so heavily altered from its natural state – including via concrete lining – that an effort to restore natural flow conditions at a site without restoring some aspects of its natural physical habitat may not result in any improvements to ecosystem health.

Similarly, some of the Southern California waterways that presently flow year-round are augmented by treated wastewater effluent and irrigation runoff that get discharged into waterways. While some of these augmented flows – especially unpermitted ones – can promote growth of non-native, invasive species like Arundo, tamarisk and bullfrogs, removing these augmented flows can, in some locations, actually jeopardize the health of aquatic ecosystems that have become dependent on these augmented flows.

About five years ago, a group of environmental flow researchers from across California, including at SCCWRP, came together to unify the water resources management community around a standardized scientific approach for balancing the many competing demands on California's limited flow resources, including human uses.

Unveiled in 2021 and known as the California Environmental Flows Framework (CEFF), the approach consists of a methodical, multi-step process for determining the magnitude, duration and frequency of stream flows needed to protect ecological integrity, recreational opportunities and other beneficial uses.

Instead of focusing narrowly on a single species at a specific life stage or a single beneficial use that may not be representative of overall ecosystem functioning, CEFF helps managers focus on protecting the most ecologically significant attributes of a water body's flow patterns over the course of a year, such as the annual recessional flow patterns generated by snow melt in the early spring.

The development of CEFF follows more than a decade of scientific research, deliberation and debate about how to appropriately determine environmental flow needs across drought-prone California. Significantly, the framework is consistent with approaches established under the international Brisbane Declarations, which call for use of a consensus scientific approach for establishing environmental flows.

CEFF integrates seamlessly with a wide range of management programs and goals for environmental flows in California, and is flexible, rapid and cost-effective enough to be implemented statewide. The framework's development was coordinated by the California Water Quality Monitoring Council, which is made up of the major California environmental management agencies that are responsible for protecting environmental flows.

CEFF also enables managers to incorporate climate change into long-term flow planning decisions. Through CEFF, managers can assess how flows could be altered by future climate change, enabling managers to develop adaptive flow management strategies that can be changed in lockstep with future changes in climate and water-use practices.

"CEFF provides managers a common set of flow modeling tools that helps us move in a standardized, consistent fashion to protect flow-dependent ecosystems over the long term," said Dr. Julie Zimmerman, Director of Science for The Nature Conservancy's California Water Program.

CEFF's flexibility for determining environmental flow needs

The underlying premise of the California Environmental Flows Framework (CEFF) is that natural flow patterns that pre-date human development are the most supportive of a stream's ecological health. But given the many ways that humans have altered these flow patterns and compromised ecosystem health, CEFF offers a path forward for revising the default flow needs of a stream – while simultaneously preserving the most important functional ecological benefits provided by these flows.

CEFF is designed so that each flow analysis can take into account site-specific physical and biological factors and priorities, when appropriate. For example, if a stream has become deeper and wider because of erosion, the natural flow patterns through the site may no longer be sufficient or appropriate for protecting ecosystem health. In this case, CEFF provides a pathway for evaluating if the default flow patterns need to be adjusted.

Similarly, if managers are trying to protect an endangered bird species during critical egg-laying periods, CEFF provides a pathway for evaluating the stream's flow needs in the context of whether the default flow patterns are sufficient to protect this bird species.

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"What we have is a tool and approach that can increase the effectiveness of our actions to restore stream flows that are beneficial for freshwater biodiversity."

Balancing flow needs with water recycling

In developing CEFF, researchers have created a pathway for environmental management agencies to take a shared, agreed-upon approach for determining the flow patterns needed to sustain the health of aquatic ecosystems.

Already, CEFF has helped managers work through some particularly contentious flow management decisions.

Perhaps the most high profile of these decisions – and one that was used as a case study during the development of CEFF – has been a debate over whether flows in the Los Angeles River can be diverted for water-recycling purposes without jeopardizing the ecological and recreational benefits that these flows provide.

The majority of the L.A. River's year-round flows come from wastewater agencies that discharge treated effluent into the river, plus stormwater management agencies that discharge wet-weather runoff into the river.

Using CEFF, a diverse coalition of L.A. River stakeholders came together to reach agreement on a common scientific approach for evaluating the environmental flow needs of multiple sensitive species and habitats along an urban, 45-mile stretch of the L.A. River. The approach also enabled stakeholders to consider the multiple recreational benefits provided by the river's flows, including fishing and kayaking.

In 2021, the City of Los Angeles used this agreed-upon approach to apply for

Treated wastewater effluent is discharged into the Los Angeles River from a nearby water reclamation plant. Researchers have developed a standardized approach to help L.A. River managers determine if some of the river's flows can be diverted for water-recycling purposes without jeopardizing the ecological and recreational benefits that these flows provide.

A SCCWRP field crew measures flow rates and other parameters in the Los Angeles River downstream from where wastewater effluent is discharged into the river. Researchers have developed a standardized approach for evaluating the environmental flow needs of multiple sensitive species and habitats, plus the multiple recreational benefits provided by these flows.

Development of flow criteria

Some flow criteria exist to regulate the release of water from dams in California, but unlike the prescriptive criteria that have been developed to reduce pollutant loading in waterways, there isn't nearly as robust and mature of a regulatory structure for managing flows.

Dramatic advances in the science behind flow management, however, could pave the way for development of regulatory criteria that define for California water resources managers the environmental flow needs of streams.

Already, California is moving forward with developing regional flow criteria to support ongoing efforts to determine how much water cannabis growers can divert from streams to support their crops, as well as developing watershed-wide flow criteria for priority streams to support critical habitat for salmon.

Because climate change is affecting both stream flows and water temperature, future flow criteria will need to be adaptive to account for changing environmental conditions over time.

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A storm drain discharges unnatural dry-weather flows into a tributary of Arroyo Trabuco Creek in southern Orange County. Researchers have used the California Environmental Flows Framework to help local watershed managers decide how they should reverse these unnatural flow patterns, which have degraded stream habitat.

regulatory approval, under State Water Code Section 1211, to begin recycling more wastewater effluent at a water reclamation plant in Van Nuys, which presently discharges to the L.A. River.

Meanwhile, the City's Department of Water and Power, in partnership with its Bureau of Engineering, Sanitation and Environment, and Department of Recreation and Parks, used the framework to apply for approval to capture more stormwater in the San Fernando Valley via specially designed underground structures – instead of allowing stormwater from these areas to run off into the L.A. River.

Both applications are under review by the California State Water Resources Control Board.

More agencies are expected to seek this regulatory approval in the coming years as more water gets recycled across drought-prone Southern California. Central to making decisions to approve diversion plans that reduce flows to streams will be a CEFF-based analysis.

"The L.A. River case study is a perfect demonstration of why we need CEFF as the scientific foundation for our decision-making," said Jonathan Bishop, Chief Deputy Director for the California State Water Resources Control Board. "CEFF has enabled us to move past debates over whether the science is sound, and onto policy decisions about whether the L.A. River should see its flows reduced to support California's goal of recycling more water."

Integrating flow considerations into watershed management

In recent years, researchers also have been working to help managers integrate CEFF-based environmental flow considerations into their broader watershed restoration and protection planning efforts.

In 2022, SCCWRP completed a study demonstrating how watershed managers can use CEFF to build a rigorous scientific foundation for integrating environmental flow considerations into an ongoing initiative to restore 23,000 linear feet of degraded stream habitat in southern Orange County.

Stream managers are using the study's insights to decide what specific, targeted actions they should take at which sites to reverse the area's unnatural flow patterns and work toward achieving the greatest improvements to ecological health. These actions are expected to include installation of flow-capture devices across multiple adjacent watersheds to reduce unnatural dry-weather flows.

Meanwhile, the State Water Resources Control Board's Division of Water Rights intends to use CEFF as the basis for deciding how to establish diversion limits for California cannabis growers that are requesting to use water from local waterways to support cannabis cultivation. Via a workflow that researchers developed based on CEFF, cannabis growers will be required to demonstrate that the water they are requesting to use can be diverted from nearby waterways without adversely affecting the ecological health of the waterway. Recreational marijuana was legalized in California in 2016.

The workflow, released in draft form in 2022, consists of a process to develop flow diversion limits using CEFF, as well as a suite of technical tools to assess potential ecological risks from diverting stream flows to support cannabis cultivation.

Courtesy of Ted Grantham, University of California, Berkeley

California cannabis growers, including this farm in Northern California, above, are requesting to divert water from nearby streams to support cannabis cultivation. The California Environmental Flows Framework is being used to evaluate whether these flow diversions would adversely affect aquatic life and ecosystem functioning.

The workflow will help the State Water Board determine whether the individual and cumulative effects of cannabis growers' proposed stream flow diversions will adversely affect the flow regimes necessary to support aquatic life and ecosystem functioning.

Finally, researchers have begun modeling how sensitive species like the endangered arroyo toad are expected to be affected by future alterations to flow patterns across Southern California – a response not only to climate change, but also to future anticipated changes in land use and water management practices. Hydrologic models are being coupled with species distribution models to assess the species' vulnerability to anticipated future stream flow alterations.

Researchers' goal is to build a risk decision framework that can help watershed managers across California prioritize which streams to protect and restore over the long term.

"The case studies illustrate how environmental flows can be protected and restored as part of integrated, long-term watershed planning efforts," said Grant Sharp, Manager of the South Orange County Watershed Management Area for Orange County Public Works. "A balanced approach to watershed management should include protection of environmental flows, and thanks to this effort, we now have a set of tools to help achieve that."

Understanding co-occurring stressors

Most environmental flows research to date has focused on patterns in the volume, timing and frequency of flows themselves.

But as climate change takes hold, it will become increasingly important to understand the interactive, co-occurring effects of flows, water temperature and water quality in influencing ecosystem health.

For example, in the near term, warming temperatures may present an even bigger risk to the ecological health of streams than alterations to flow patterns.

SCCWRP's Rachel Darling deploys a temperature logger at Bear Creek, a tributary of the San Gabriel River in Los Angeles County, for a study investigating the influence of wastewater discharges downstream of this site on ecosystem health. Wastewater effluent is commonly discharged above the stream's ambient temperature.

To that end, researchers in 2022 began investigating how increased water temperatures from treated wastewater effluent discharges have affected the health of sensitive aquatic life in Southern California streams. Wastewater effluent is commonly discharged into streams above the stream's ambient temperature.

Improved understanding of the relationship between water temperature and ecological health could have implications not only for the permissible temperature range for discharges, but also for how stream restoration projects are designed – as well as for how groundwater is managed. Groundwater commonly mixes with surface waters at certain times and places, which means it has the potential to lower surface water temperatures.

Researchers also have begun building tools for evaluating the synergistic roles that flow, temperature and water quality play in influencing ecosystem health. Researchers are working to integrate multiple physical and ecological models that will give managers the tools they need to identify and prioritize remediating the most significant risks to ecosystem health.

Meanwhile, as flow patterns continue to change over time – especially in lockstep with climate change – researchers have begun working to consider the long-term viability of entire populations of aquatic species. This work involves shifting from species occurrence models that predict the likelihood of observing a species at a site, to population viability models that predict the long-term sustainability of the entire population at the site.

"In everything we're doing, our goal is to help watershed managers optimize the long-term management strategies they're developing to address the most important stressors impacting aquatic life, whether that be flows, temperature or water quality," said Dr. Sarah Yarnell, Senior Research Hydrologist at the University of California, Davis. "Climate change has highlighted many of the big challenges ahead for the future of flow management – but also the incredible opportunities we have to offer solutions and support proactive efforts to promote resiliency."

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TACKLING TOXIC BLOOMS

Scientists are developing monitoring programs, tools and strategies to help managers more effectively manage the threat posed by toxin-producing bloom events

Single-celled organisms that produce toxins have been part of the makeup of aquatic environments for millennia. Under balanced conditions, these toxin producers live in a diverse community of other species of protists, bacteria and algae – and pose a minimal threat to human and ecosystem health.

But human activities have disrupted this delicate balance, triggering sudden proliferations of harmful algal blooms (HABs) that are becoming more intense, more geographically widespread and longer-lasting – trends that appear to be linked to climate change.

One of the biggest drivers of HABs is excess nutrients discharged in wastewater and washed off urban and agricultural landscapes and into waterways, fertilizing the water and fueling rapid growth, especially in settings where water stagnates.

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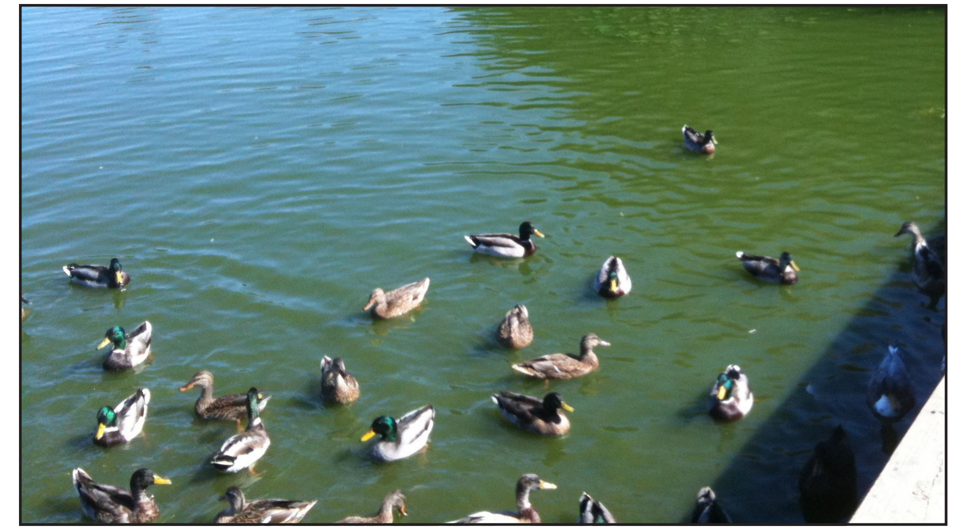

Ducks swim in a lake tainted green by a harmful algal bloom. When these blooms produce toxins, they can be lethal at all levels of aquatic and terrestrial food webs, from aquatic insects to birds and dogs.

But compounding the HABs challenge in California is climate change – specifically, changes in the timing, duration and intensity of how water flows through watersheds and circulates in coastal environments, as well as warming of water temperatures, which is enabling certain species to grow rapidly and dominate microbial communities.

While HABs themselves are disruptive to aquatic ecosystems, the most consequential and lasting effect of HABs is the toxins that some types of blooms produce. These toxins have polluted drinking water supplies, contaminated fish and shellfish, killed wild and domestic animals, and sickened humans who swim in contaminated waters.

In California, the proliferation of toxin-producing HABs has created newfound urgency among the water-quality management community to understand when, where and why blooms are occurring, as well as how to more accurately forecast when, where and why blooms release toxins into their environment.

Scientists and managers have responded by working collaboratively to build out and expand HABs monitoring programs, as well as investigate the specific environmental conditions that trigger proliferation of toxic blooms. Researchers also are developing sophisticated computer models that can predict when and where toxic blooms will occur.

Researchers' goal is to arm managers with the insights necessary to direct attention and resources to where they're needed most, so that water-quality managers can optimally reduce the ecological and human health threats posed by HABs.

"Climate change is intensifying the drivers of HABs in California, making it challenging to assess and manage at a statewide scale, but with this next generation of scientific advances guiding HABs management over the past few years, we're poised to really begin gaining the upper hand on this enormous management challenge," said Carly Nilson, a Senior Environmental Scientist and co-lead of the Freshwater HABs Program for the California State Water Resources Control Board.

Toxic long after blooms die

HABs refer to sudden proliferations of bacteria, protists and algae that often taint the color of water vibrant shades of blue-green and red.

The blooms are responsible for disruptions in freshwater and marine environments across multiple levels of aquatic and terrestrial food webs. At high densities, HABs can consume dissolved oxygen in water, block sunlight and smother habitats. Often, HABs pose a seasonal threat, forming in late spring or early summer and dying by fall – although in some watersheds in California, because of the warm Mediterranean climate, they can occur year-round.

Certain types of blooms are particularly problematic because they can produce toxins. When aquatic organisms inadvertently ingest toxin-filled HAB cells, the toxins can be transferred through food webs, poisoning humans, wildlife, dogs, and other domestic animals and wildlife. The cells also can release their toxins into the water column during or at the end of their life, or both. The release of these toxins can be triggered by a variety of stressful factors, including recreational activities that agitate water.

A SCCWRP field crew collects samples during an ecologically disruptive bloom in the Santa Margarita River that spans Riverside and San Diego Counties. Major bloom events can consume dissolved oxygen in water, block sunlight and smother habitats.

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Malibou Lake in the Santa Monica Mountains in Los Angeles County is tainted vibrant shades of green by a harmful algal bloom. These ecologically disruptive events can occur year-round in many parts of California.

Some HAB toxins have been linked to mass strandings of sea lions and other marine mammals that become sickened from consuming toxin-contaminated seafood. The toxins also have contaminated mussels and other shellfish consumed by humans. And when humans swim in or drink toxin-tainted water, they can develop acute poisoning symptoms, ranging from skin rashes and gastrointestinal illness to impaired neurological functioning and liver damage.

Some toxins can remain in surface waters or sediments for months and perhaps even years, making HAB toxins by far the most enduring and impactful consequence of bloom events.

During the 2018 cycle of the Southern California Bight Regional Monitoring Program, researchers examined for the first time how widespread HAB toxins are along Southern California's coastal seafloor. Researchers detected domoic acid – a toxin produced by a ubiquitous type of marine harmful algae known as *Pseudo-nitzschia* – across 54% of all seafloor sediment along Southern California's continental shelf.

The Bight '18 study also detected the toxin in the tissues of organisms living in and on seafloor sediment – even at times of the year when there weren't bloom events and even in places where the toxin could not be detected in the surrounding sediment. And although these organisms aren't consumed by humans, about 10% of the tissues contained toxin levels that were above safe-to-eat health thresholds established by the U.S. Food and Drug Administration.

The findings have laid bare the ubiquity and pervasiveness of HAB toxins in Southern California's coastal ocean, and underscore the need for follow-up investigations probing the long-term consequences of these toxins for both ecosystems and human health.

"It is especially concerning that we are finding HAB toxins can persist in the environment, extending potential impacts long after a bloom ends and complicating the process of identifying the sources of these compounds," said Dr. David Caron, a Professor of Biological Sciences at the University of Southern California and a close SCCWRP collaborator on HABs research. "There's still much more work to be done in both freshwater and marine ecosystems to establish the frequency, extent and persistence of toxins in the environment, and the ecological and/or human health risks they pose. Understanding the precise sources and causes of toxic events will aid in our ability to mitigate their impacts, and ultimately provide information for reducing or even preventing future events."

Monitoring to understand the scope of blooms

The first step to gaining the upper hand on the enormous and growing problem of toxin-producing HABs is to build more comprehensive snapshots of when and where these blooms are occurring.

In the coastal ocean, weekly monitoring of HABs is conducted via the California Harmful Algal Bloom Monitoring and Alert Program (HABMAP). Through this statewide monitoring program established in 2008, managers have been able to generate foundational, standardized data sets that have helped track bloom events in coastal waters statewide.

HABMAP data have helped protect humans from consuming toxin-contaminated shellfish and other locally caught seafood as well as provided important insights into the causes of blooms.

Courtesy of Institute for Applied Marine Ecology/Marine Applied Research and Exploration (IfAME/MARE)

Domoic acid, a toxin produced by a type of marine harmful algae known as *Pseudo-nitzschia*, is widespread in seafloor sediment off the coast of Southern California, including in the tissue of organisms living in and on sediment. Researchers are still working to understand this toxin's long-term implications for coastal ocean health.

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In 2021, SCCWRP and its partners began working to extend HABMAP's data collection capabilities by deploying underwater HAB sampling instruments to generate continuous streams of HAB data. The network of Imaging FlowCytobots – initially deployed at three HABMAP monitoring sites underneath piers – are intended to complement more limited, traditional field sampling done by hand.

Researchers are pairing the FlowCytobot data with newly developed automated image recognition and classification approaches to automatically identify and quantify HAB species; the goal is to provide earlier warnings about blooms.

Compared to the marine-focused HABMAP monitoring initiative, far less comprehensive snapshots exist for inland environments, where freshwater sampling has been historically sporadic and uneven. Indeed, for many water bodies, the only monitoring data available are those that get voluntarily submitted by local water body managers, who don't necessarily use consistent monitoring methods.

Scientists are working to fill freshwater monitoring gaps by developing a new generation of monitoring tools for lakes, streams and estuaries – with a focus on monitoring how toxins and cells move through aquatic environments, from inland lakes and reservoirs, through streams and rivers, and ultimately into estuaries and the ocean.

Because of the geographical complexity of monitoring freshwater HABs across California's many diverse water bodies, a major research focus has been developing monitoring tools that don't rely on conducting field sampling on site. Instead, researchers are using multispectral imagery and remote sensing data from drones and satellites to detect HABs and estimate their extent and duration.

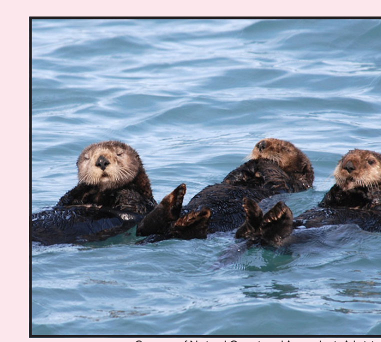
For example, SCCWRP and its partners successfully used satellite imaging data in 2022 to build a comprehensive portrait of when and where HABs have been occurring in California's large lakes and

Linking freshwater toxins to adverse marine effects

Deaths of dozens of endangered sea otters have been caused by exposure to freshwater toxins transferred through waterways to the coastal zone. Most HAB monitoring efforts to date have not accounted for these hydrological connections, limiting managers' ability to truly understand and manage potential health risks for humans and animals. Researchers are working to overcome these knowledge gaps by:

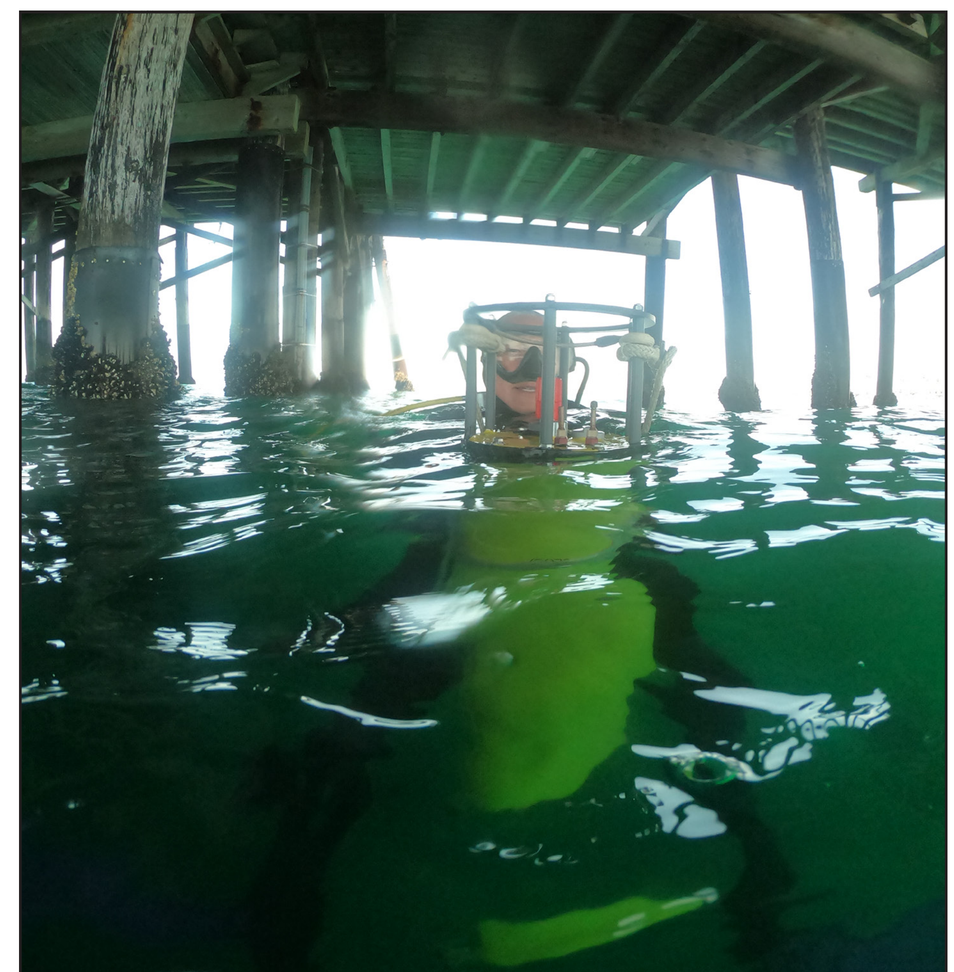
- coordinating monitoring across multiple jurisdictional boundaries
- deploying multiple types of sampling methods to optimize the insights gained through monitoring
- monitoring the toxins produced by both freshwater and marine HABs

The upcoming 2023 cycle of the Southern California Bight Regional Monitoring Program is planning to characterize how much toxins from inland freshwater environments are found in coastal shellfish and at what levels – insights that will help build foundational understanding of potential health risks for humans and marine animals.



Courtesy of National Oceanic and Atmospheric Administration

Endangered sea otters have died in California as a result of poisoning by toxin-producing blooms that originated in freshwater environments and were transported via waterways to the coastal ocean.



Courtesy of Melissa Carter, Scripps Institution of Oceanography

A dive crew lowers an Imaging FlowCytobot sampling instrument into the water underneath Newport Pier in Orange County to collect a continuous stream of data on algal blooms. Multiple instruments are being deployed to extend California's capacity to monitor coastal bloom events.

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Mussels can be contaminated by toxins from harmful algal blooms, creating an exposure pathway for humans who consume tainted seafood.

Marine mammal strandings

More than 400 sea lions and other marine mammals were reported stranded on California beaches in late summer 2022. They experienced seizures and disorientation that left them effectively incapacitated; the presumed culprit was poisoning by a neurotoxin produced by a ubiquitous HAB known as *Pseudo-nitzschia*.

Through partnerships with Southern California marine mammal centers, SCCWRP and other researchers are working to build modeling tools that can predict when marine mammals are likely to become stranded on beaches as a result of toxin poisoning.

During major bloom events, marine mammal rescue centers – which are mostly volunteer-driven operations – struggle to keep up with dramatic spikes in marine mammal strandings on beaches across California. Generally, about 40%-60% of all stranded mammals can recover if rescue teams are able to administer appropriate anti-seizure medications and/or get them moved from populated beaches to local rehabilitation centers.

The ongoing marine mammal research also will help paint a clearer picture of how toxin-producing blooms are spreading in coastal waters and affecting vulnerable marine life.

Courtesy of Channel Islands Marine & Wildlife Institute

A rescue crew from the Channel Islands Marine & Wildlife Institute prepares to transport a sea lion stranded on the beach as a result of neurotoxin exposure to a rehabilitation center for treatment.

reservoirs over the past five years. The proof-of-concept analysis illustrates how California can track trends in HABs over time to understand where blooms might be getting worse or improving.

As researchers have made progress developing and vetting freshwater HAB monitoring tools, they've simultaneously been developing monitoring strategies and monitoring designs that integrate hydrologically connected water bodies across a watershed. Researchers' long-term goal is to help management agencies work toward comprehensive, coordinated monitoring of freshwater HABs across California.

For these agencies to be able to coordinate monitoring, researchers must consider monitoring program designs that can account for the diversity of water body types in California, as well as the multiple ways that freshwater HABs can impact beneficial uses for these water bodies.

"Leveraged, coordinated monitoring is essential for building up California's freshwater HABs monitoring capacity, which is why we have invested in the development of a California HAB Monitoring Strategy and Framework," said Marisa Van Dyke, a Senior Environmental Scientist and co-lead of the Freshwater HABs Program for the California State Water Resources Control Board. "We hope to build it out to match the level of efforts of California's existing HABMAP program for the coastal marine environment."

Investigating drivers of toxic blooms

While expanded HAB monitoring has helped California to more comprehensively track and manage these events as they occur, many California lakes and reservoirs are experiencing such severe and chronic HAB challenges that managers need to do more than just to monitor and respond to problems.

Managers also need to diagnose which specific environmental conditions are triggering blooms at a particular site, so they can be more proactive in their approaches to mitigating the frequency, duration and intensity of these events.

Scientists are working on multiple fronts to provide these insights.

First, researchers are working to understand how improved management of major causes of blooms could better mitigate HAB events.

One major factor that can fuel blooms is excess nutrient loading, particularly when combined with warming water temperatures projected with climate change. Indeed, many water bodies face the dual challenge of accumulated legacy nutrients that linger for decades as well as new sources from ongoing nutrient loading. Other major factors that can promote blooms include changes in water mixing and flow – changes that can result from, for example, modifications to the shape of a stream channel.

SCCWRP has been working extensively to characterize the relationship between different levels of nutrients and algal blooms across water bodies in California, and how these insights are linked to the likelihood of toxic cyanobacterial blooms. The California State Water Resources Control Board already has been exploring how to use this body of science to develop numeric cyanotoxin, algal biomass and nutrient objectives that would define the upper limits of levels of these parameters that water bodies statewide can sustainably assimilate.

"In order to improve water quality conditions and reduce HABs, management strategies are needed to address legacy nutrients," said Dr. Meredith Howard, an Environmental Program Manager for the Central Valley Regional Water Quality Control Board. "The focus of SCCWRP's research on relating nutrients to the risk of toxic cyanobacterial blooms will provide critical information to inform these management approaches."

Second, researchers are working to understand the site-specific environmental triggers that cause blooms to produce toxins.

Not all blooms produce toxins in all water bodies, and when they do, toxin production can vary substantially in both magnitude and timing. Environmental conditions that can trigger toxin production include insufficient mixing in the water column, known as stratification, as well as changes in nutrient concentrations and ratios, changes in water temperature and carbon dioxide levels, and grazing, parasitism and other biological community interactions.

Scientists believe that cellular-level interactions between HAB cells and their environment are triggering these unicellular organisms to turn on and off their toxin-producing genes.

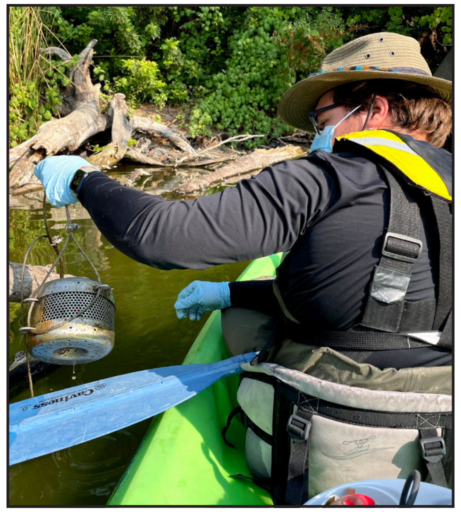
In 2020, SCCWRP and its partners began examining how to use DNA-based methods to identify specific types of HABs in freshwater environments that have the ability to produce toxins, as well as when these genes are being turned on or off.

In one ongoing study, researchers are tracking how the ratio of toxin-producing cyanobacteria to non-toxin-producing cyanobacteria changes throughout multiple bloom events in Clear Lake, the largest freshwater lake in California. Clear Lake experiences chronic cyanobacteria blooms that sometimes last for months.

This study, along with a comparable ongoing one in marine waters, is laying

A SCCWRP field crew collects water-quality data during a bloom event in North Lake, part of the Whittier Narrows Recreation Area in Los Angeles County. Researchers are working to identify actions that managers could take to mitigate these ecologically disruptive events.

Clear Lake, the largest freshwater lake in California, is home to elevated levels of toxins produced by cyanobacteria blooms. Researchers are working to identify the specific environmental conditions that trigger cyanobacteria to turn on and off their toxin-production genes.



SCCWRP's Cody Fees deploys a field instrument to measure concentrations of cyanotoxins in North Lake in the Whittier Narrows Recreation Area. Water-quality managers need better tools for predicting bloom events so they can take more effective mitigation measures.

the foundation for researchers to begin identifying the specific environmental conditions that favor the presence of toxin-producing HAB species and what conditions trigger these species to turn on and off their toxin-production genes.

Researchers' long-term goal is to build tools that make it possible for managers to identify the top local causes of toxin-producing blooms in individual water bodies, so managers can take informed actions to reduce and mitigate these threats.

"If we knew what the primary drivers of HABs are in a watershed or water body, we'd be in a much better position to develop a targeted strategy to allocate resources that are going to be effective in mitigating and hopefully eliminating the threat," said Dr. Keith Bouma-Gregson, a Biologist for the U.S. Geological Survey.

Predicting when, where toxic blooms will happen

By the time HAB toxins are detected in the environment, the ecological disruption is difficult to mitigate.

The most effective thing that managers and other environmental groups can do in these cases is to mitigate potential adverse health effects for humans, their domestic pets and aquatic life.

Ideally, this process starts with ramping up monitoring efforts to determine where problems might be spreading.

Meanwhile, to protect public health, managers can close contaminated water bodies and/or issue health advisories and post warning signs. Similarly, wildlife rescue organizations can prepare to support sickened sea lions and other mammals by recruiting additional volunteers and ordering adequate treatment supplies and medications.

But if management agencies and other groups could determine in advance which areas are most vulnerable to toxin-producing bloom events and when these events are most likely to occur, they could engage in more informed long-term planning.

For example, if aquaculture and fishery operations knew when and where toxic blooms were most likely to occur, they could better plan when and where to harvest to minimize the risks of experiencing contaminated seafood. They could even consider permanently or seasonally relocating their harvesting operations to less vulnerable areas.

In recent years, researchers have begun working to build computer models that predict when and where toxic blooms will happen in the coastal ocean.

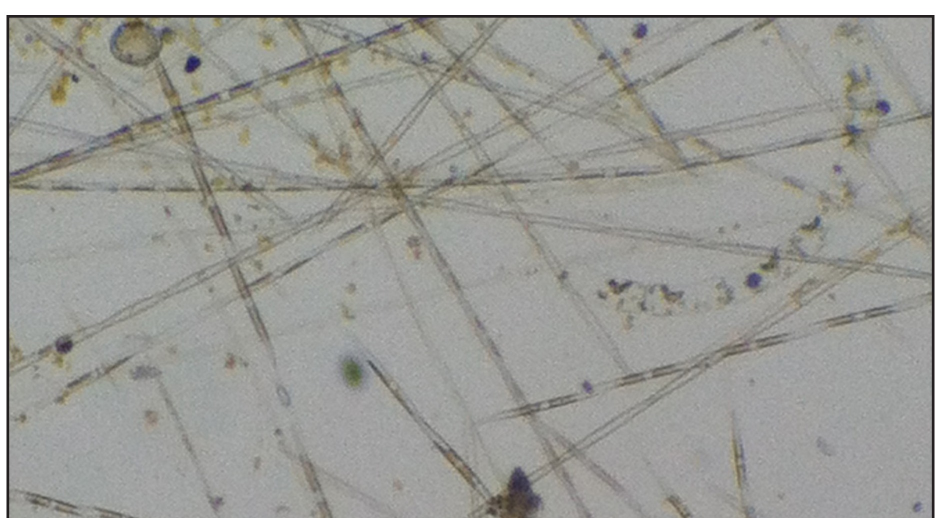
In 2022, a California team of researchers, including at SCCWRP, developed a computer model for predicting the occurrence of *Pseudo-nitzschia* blooms – among the most common types of marine algal blooms – in California coastal waters. *Pseudo-nitzschia* produces a toxin known as domoic acid.

The *Pseudo-nitzschia* model expands the capabilities of an existing coastal ocean model developed by the same team to predict how land-based nutrient discharges and changing climate conditions are affecting algal blooms, ocean acidification and hypoxia conditions in coastal waters.

Managers will be able to integrate the *Pseudo-nitzschia* model's predictions into California's existing predictive modeling framework, improving investigations of causal factors and existing forecasting capabilities – including daily published risk maps that outline the coastal areas most likely to experience domoic acid production.

Ultimately, researchers' goal is to use such HAB forecasting tools to more precisely pinpoint the specific local and global environmental conditions that are driving production of toxic blooms.

"The best way to reduce the occurrence of HABs is to understand the role of local and global drivers," said Dr. Clarissa Anderson, Executive Director of the Southern California Coastal Ocean Observing System and a HABs researcher. "That's how we'll be able to inform which actions managers should take – insights that are particularly important as managers increasingly look for expeditious, effective solutions for reducing the impacts caused by this growing management challenge."



Courtesy of Dr. David Caron, University of Southern California

Toxin-producing *Pseudo-nitzschia* cells, which appear as long needle-like chains under a microscope, above, can dominate marine phytoplankton communities in Southern California coastal waters. Researchers are building forecasting tools to predict when and where toxin-producing blooms are most likely to occur.

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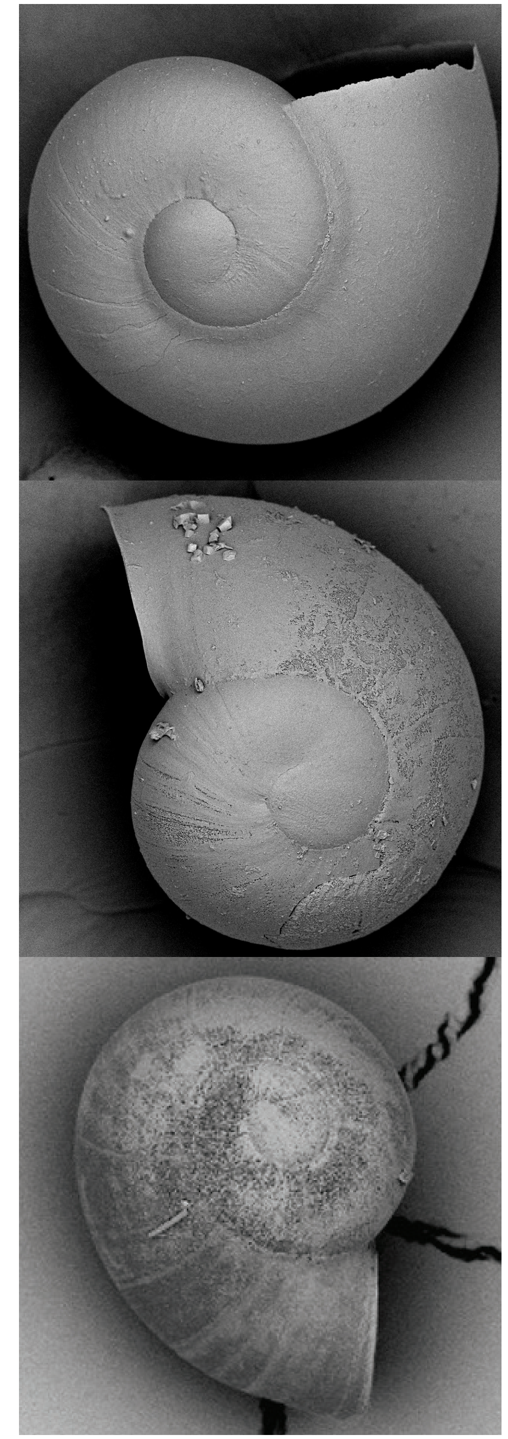
INVESTIGATING OCEAN ACIDIFICATION'S TRAJECTORY

Researchers are helping managers assess the ecological consequences of West Coast seawater chemistry changes



Ocean acidification in Southern California coastal waters is causing tiny sea snails known as pteropods to experience shell dissolution. From top, a healthy shell under a scanning electron microscope, a shell with mild shell dissolution, and a shell with moderate shell dissolution.

Ocean acidification isn't years or decades away – it's already playing out along the West Coast at a rate twice the global average.

Over the past decade, scientists have established that rising levels of global carbon dioxide emissions are triggering changes to coastal seawater chemistry via a phenomenon known as ocean acidification.

As seasonally corrosive conditions creep into the West Coast's ecologically and economically important coastal waters, shell-forming organisms are having a tougher time building their shells, including tiny sea snails known as pteropods that are a food source for many fish farmed along the coastline.

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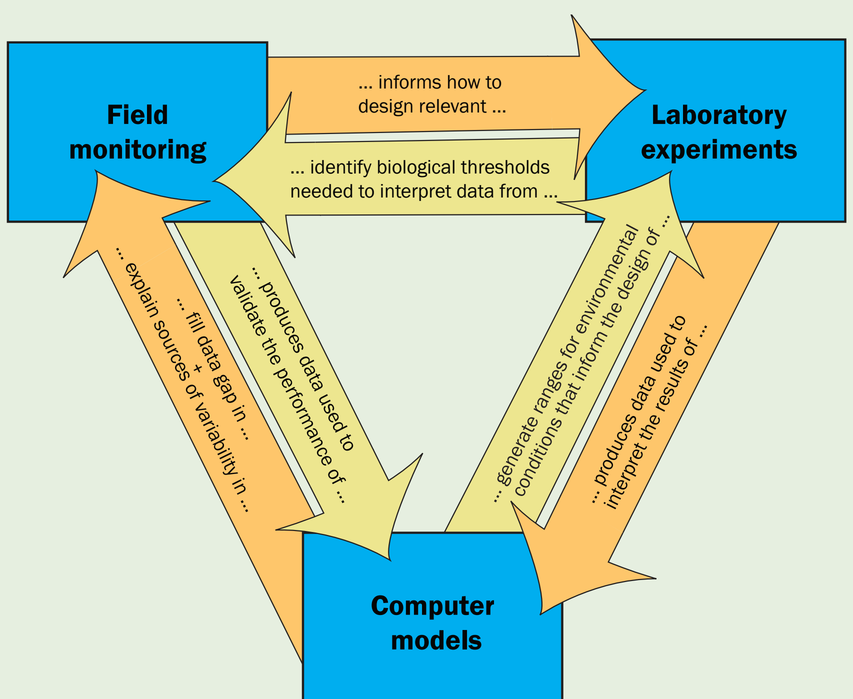
In Southern California, corrosive conditions thus far have primarily hit deeper coastal waters – and mostly during the spring and early summer months. Moreover, the consequences for Southern California marine life have been relatively muted compared to more northern waters.

But over time, these unfavorable conditions are expected to intensify, altering the habitability of coastal waters for a wide range of organisms. Furthermore, the effects of acidification will be accompanied by other consequential changes to coastal ocean habitats, including more intense hypoxia, or low dissolved oxygen levels.

A field crew lowers a CTD (conductivity, temperature, depth) rosette into the ocean to take multiple measurements of seawater chemistry. The Southern California Bight Regional Monitoring Program has collected the first comprehensive ocean acidification data sets for Southern California's continental shelf.

Three-pronged approach to understanding ocean acidification's trajectory

Researchers use three main lines of evidence to generate insights about how acidification is unfolding along the West Coast. Each line of evidence generates information and data that can benefit the other two lines of evidence.



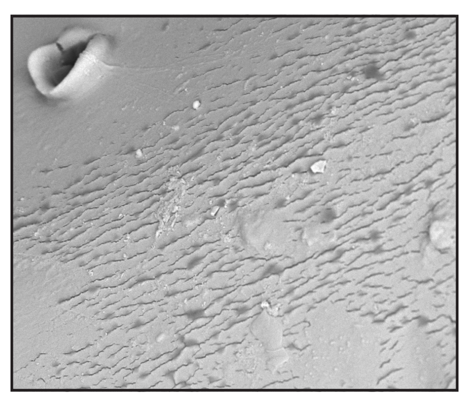
For the West Coast ocean management community to decide if and how to respond, managers need to understand the trajectory of these changes, including where adverse ecological effects will be most pronounced. Managers also need to know how, when, and where to step in to optimally mitigate these effects – beyond simply reducing and eliminating global greenhouse gas emissions.

A team of West Coast researchers has been working on multiple fronts to help managers expeditiously and effectively combat acidification's ecological effects.

First, researchers are developing robust monitoring programs – coordinated with partners across the West Coast – to offer more comprehensive, granular insights about the pace and intensity with which acidification is unfolding, and how the changes are affecting marine life.

Second, researchers are conducting dynamic exposure laboratory experiments to zero in on how different combinations of low pH and other environmental stressors such as oxygen and temperature are triggering disproportionately adverse effects for vulnerable marine life.

Finally, researchers are building powerful computer models for predicting the trajectory of acidification and other stressors in the coming years – models that can probe what types of management interventions might be effective in mitigating and offsetting the worst of acidification's effects.



Crab larvae in Southern California are experiencing early signs of shell dissolution, which are visible under a scanning electron microscope, above, as tiny pit marks, holes and ridges. If the damage reaches the shell's sensory receptor openings – like the one visible at top left – it could threaten their survival.

"Acidification and co-occurring stressors like hypoxia and heat waves are quickly becoming existential threats to the health of California's coastal ocean," said Dr. Justine Kimball, Senior Climate Change Program Manager for the California Ocean Protection Council. "Fortunately, through monitoring, research and modeling, we can lay a critically important scientific foundation now that's going to inform the decisions we make going forward about how to manage and protect our coastal ocean."

Collecting monitoring data

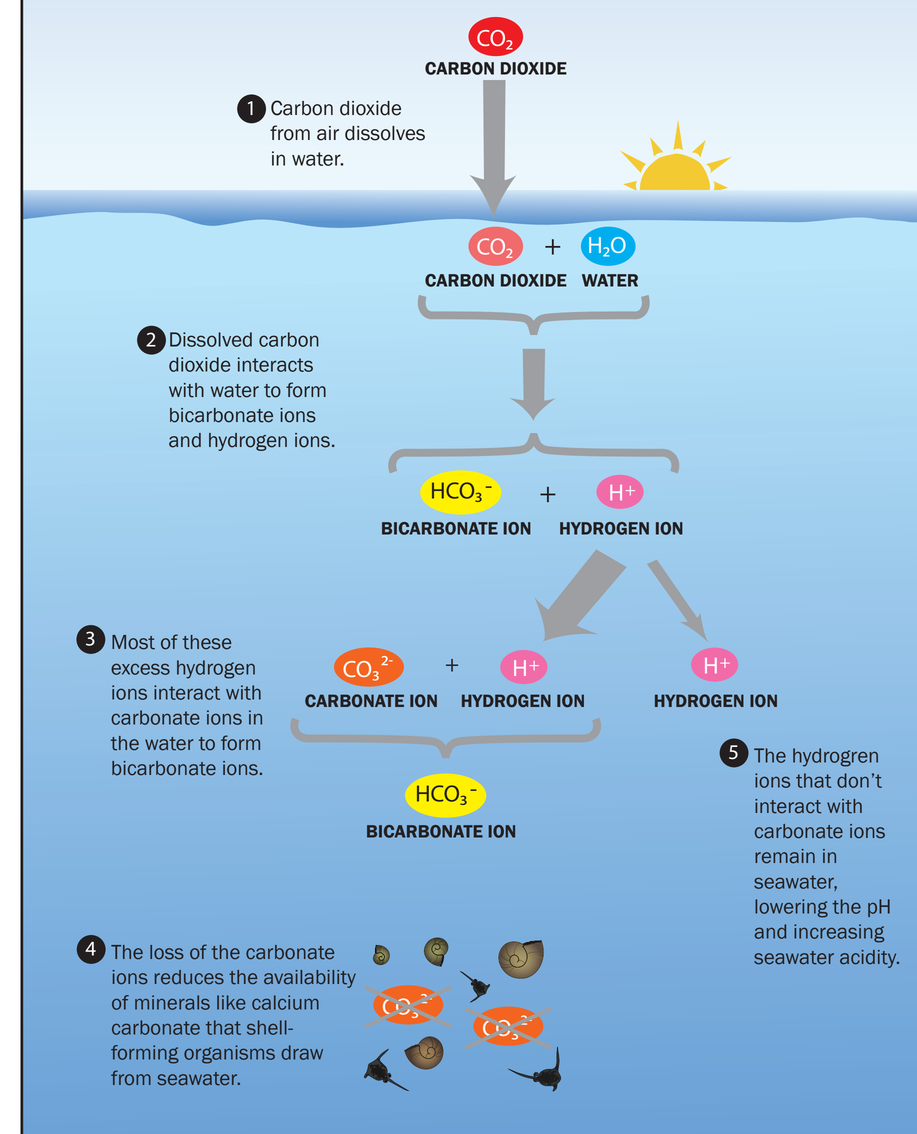
So far, the most significant ecological consequences of acidification along the West Coast have been documented in the Pacific Northwest, where declining pH levels have caused tens of millions of dollars of losses to shellfish growers.

But ocean circulation patterns make the entire North American West Coast disproportionately vulnerable to seasonally corrosive conditions.

For the past decade, the Southern California Bight Regional Monitoring Program has been tracking low-pH conditions in Southern California's coastal ocean by monitoring a biologically relevant measure of pH known as aragonite saturation state. This parameter is a measure of the concentrations of ions available to shell-forming aquatic life, including tiny sea snails known as pteropods and tiny crustaceans known as krill at the base of marine food webs.

How ocean acidification can adversely affect shell-forming organisms

Ocean acidification results in changes to seawater chemistry that lessen the availability of minerals that shell-forming organisms need.



A pair of plankton nets is lowered into Southern California's coastal ocean to collect small, shell-forming marine organisms vulnerable to ocean acidification. The biological data explain how marine life already are being affected by seasonally corrosive coastal conditions.

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A SCCWRP field crew collects tiny sea snails known as pteropods from a plankton net that has been towed through Southern California coastal waters. Organisms such as pteropods serve as sentinel indicators of some of the earliest effects of acidification in the region.

The Bight program's 2013 and 2018 monitoring cycles – known as Bight '13 and Bight '18, respectively – collected the region's first comprehensive acidification data sets for the relatively shallow, nearshore waters of Southern California's continental shelf.

The Bight program found that aragonite saturation state in coastal waters has been averaging about 2.0 annually – well above the threshold of 1.0 at which seawater is considered "corrosive" to sensitive marine life, and well above what is typically found in Northern California, Oregon and Washington coastal areas.

But further offshore in Southern California, at depths of about 400 feet, aragonite saturation state already is reaching levels as low as 1.0 annually. And during the spring months – when a natural phenomenon known as ocean upwelling brings low-pH waters close to shore – an aragonite saturation state of 1.0 can be found at depths of only around 260 feet.

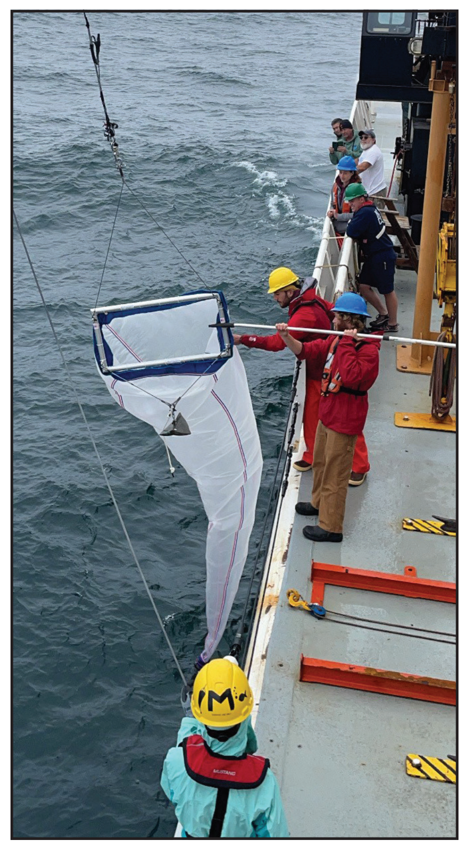
Already, researchers have begun working to estimate how these present-day conditions compare to pre-industrial times. Understanding the degree to which coastal seawater chemistry already has been altered by global carbon dioxide emissions will help contextualize for managers the predictions that scientists are making about future ocean conditions.

Meanwhile, to understand how marine life already are being affected by the seasonally corrosive coastal conditions, the Bight '18 program has begun developing standardized protocols for monitoring the shells of crab larvae and pteropods. Because these two types of shell-forming organisms are found in abundance in Southern California's coastal ocean, these organisms can serve as sentinel indicators of some of the earliest adverse effects of acidification in the region.

Over the past few years, SCCWRP has helped coordinate the rollout of these biological sampling and analysis methods among multiple West Coast monitoring programs, enabling monitoring data to be pooled to produce a single, seamless picture of acidification conditions.

So far, the Bight program has not uniformly observed shell dissolution, and when it was present, the dissolution was generally mild – and linked to the presence of low-pH conditions in colder, deeper waters.

Among crab larvae, the Bight program found that less than 5% of the surface



Southern California researchers have partnered with the National Oceanic and Atmospheric Administration's West Coast Ocean Acidification Survey, pictured above during a monitoring cruise, and other monitoring groups to produce a comprehensive picture of acidification conditions along the U.S. West Coast.

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area of each external shell – known as the carapace – was affected, although early signs of dissolution were pervasive across Southern California sampling sites.

Among pteropods, one of the two species examined – *Limacina* – exhibited shell dissolution trends similar to the crab larvae, while the second pteropod species – *Heliconoides* – showed more intense shell dissolution patterns, underscoring the complexities of understanding how acidification affects sensitive marine life.

"If the survival of species at the bottom of marine food webs is threatened by acidification, the biological consequences have the potential to reverberate through coastal ecosystems," said Dr. Kristy Kroeker, Associate Professor of Ecology and Evolutionary Biology at the University of California, Santa Cruz. "We have an opportunity now to do everything we can to figure out what's happening and if we can mitigate or offset the biological effects."

Manipulating environmental conditions in a lab

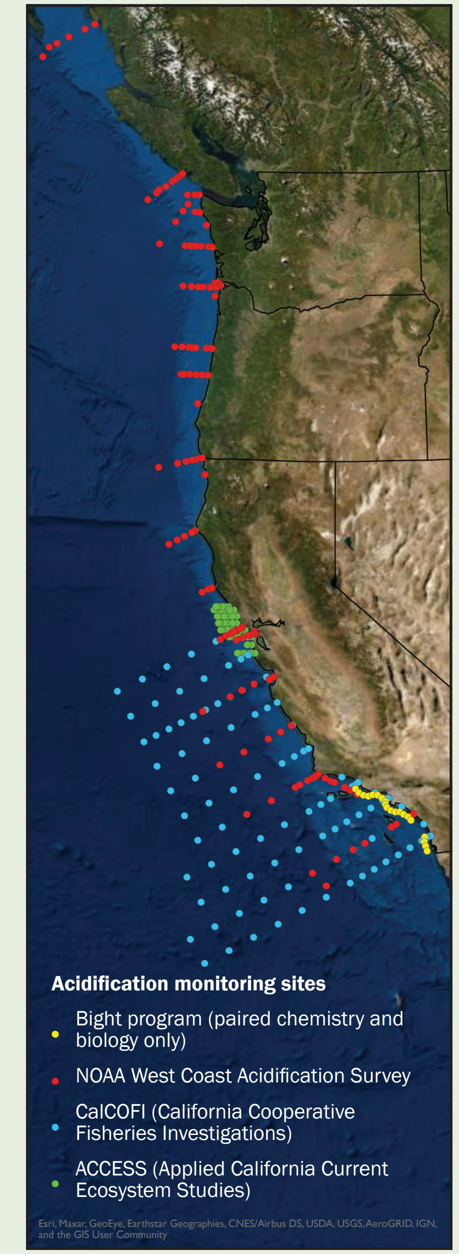
Acidification isn't the only stress to hit aquatic life. As acidification intensifies, the survival of vulnerable organisms is being threatened by other environmental changes playing out concurrently, including more hypoxia.

Intensifying hypoxia is a consequence of the ocean not being able to hold as much oxygen as seawater warms in lockstep with climate change. Further depressing dissolved oxygen levels are nutrient-laden human discharges into coastal waters; these excess nutrients can trigger algal blooms that, when they die, consume oxygen.

Because the suboptimal environmental conditions will last longer and be more intense in certain areas of the coastal ocean, coastal ocean managers will need thresholds that define for them when conditions reach a point where they need to take action. Managers also will need insights into which areas will be disproportionately affected and when the most consequential combinations of these disruptive conditions will occur.

One of the key ways that researchers are gaining these insights is via state-of-the-art dynamic exposure laboratory studies that examine how aquatic organisms respond in a controlled setting to fluctuations in pH, dissolved oxygen and other environmental parameters.

SCCWRP is one of only a handful of laboratories worldwide to invest in such a laboratory setup, enabling researchers to create different combinations of low pH and low dissolved oxygen levels in small chambers known as microcosms.



By coordinating acidification monitoring with three different West Coast programs, the Bight program has enabled all four groups to produce a single, unified portrait of coastal acidification conditions. Above, the monitoring sites where the Bight program has been collecting paired chemistry and biology data are plotted alongside all monitoring sites for the other three programs. As with the Bight program, the other three programs are collecting paired data sets from only a subset of their monitoring sites.

Building a West Coast-wide picture of acidification

To build a West Coast-wide picture of acidification, the Bight program aligned its monitoring survey in 2020 and 2021 with three other acidification monitoring programs.

In Southern California, this coordinated monitoring effort is enabling researchers to create a comprehensive picture of acidification, with data points as close as a half mile from shore to about 120 miles offshore.

» The National Oceanic and Atmospheric Administration's **West Coast Ocean Acidification Survey** is conducting offshore monitoring from British Columbia to the U.S.-Mexico border.

» The **California Cooperative Fisheries Investigations (CalCOFI)** is monitoring offshore areas from San Francisco Bay to the U.S.-Mexico border.

» The **Applied California Current Ecosystem Studies (ACCESS)** program is monitoring Northern California coastal waters in transects near San Francisco Bay.

Because the programs have been using consistent sampling methods, the data are directly comparable to other regions of the West Coast, enabling the programs to produce a single, seamless picture of acidification conditions from British Columbia to the U.S.-Mexico border.

In 2021, SCCWRP worked with NOAA scientists and other collaborators to test-drive new biology sampling protocols that are focused around analyzing the shells of pteropods and crab larvae, then trained all four programs to use the same paired chemistry and biology monitoring protocols, ensuring high-quality, standardized acidification data can be collected across California and beyond.

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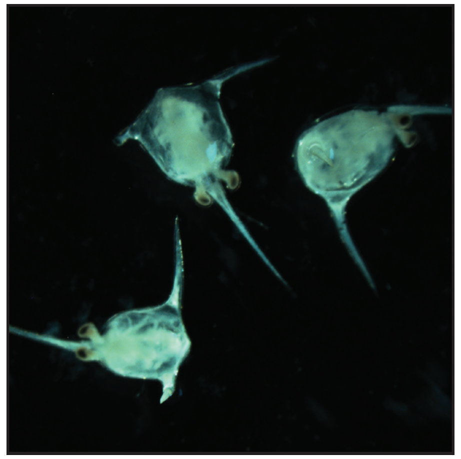
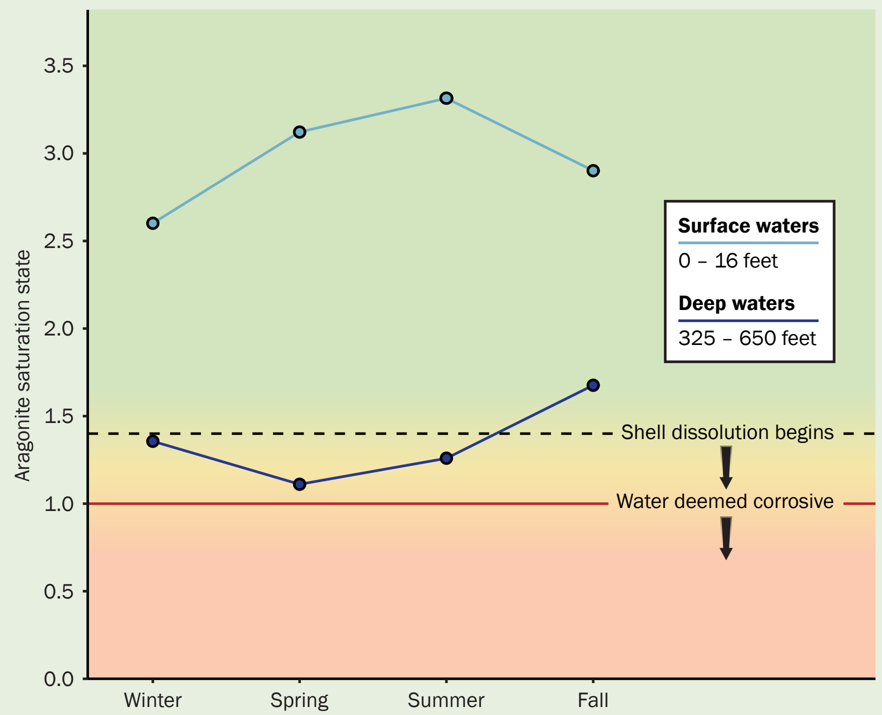


Researchers are using crab larvae, top, and pteropods, bottom, to track the biological consequences of ocean acidification in Southern California coastal waters.

Critical aragonite saturation state

In the spring, when a phenomenon known as ocean upwelling brings carbon dioxide-rich water close to shore, the Southern California Bight Regional Monitoring Program found that average aragonite saturation state in Southern California's deep coastal waters approaches levels considered corrosive to shell-forming organisms. The program is using two organisms – crab larvae and pteropods – to track the biological consequences of changing seawater chemistry.



Researchers are using the dynamic exposure laboratory to study precisely how sensitive marine life responds to different potential future environmental conditions, and identify the thresholds at which different combinations of stressors begin to trigger lethal and sublethal biological responses.

For example, SCCWRP's dynamic exposure experiments have shown that when acidification is combined with higher water temperatures, vulnerable aquatic life begin experiencing adverse biological effects in waters with less severe acidification conditions. The findings provide perspective about how much more consequential acidification combined with another stressor is for marine life vs. acidification alone.

"Because of the potential for synergistic effects, it is so important that we study acidification in the context of co-occurring stressors," says Dr. Shallin Busch, Deputy Director of the Conservation Biology Division at the National Oceanic and Atmospheric Administration's Northwest Fisheries Science Center. "Dynamic exposure studies are how we gain insights into how animals respond to the environmental conditions they will experience under global change."

Using modeling to predict future conditions

Field monitoring data and laboratory experiments have generated a wealth of insights about how acidification has been unfolding in coastal waters and the potential for biological effects.

But these data points are limited in that they cannot predict future conditions – especially whether various potential management interventions intended to offset or mitigate the ecological effects will be effective.

Computer modeling can help overcome these limitations, enabling researchers to understand how oceanographic processes influence pH and oxygen levels so that these conditions can be modeled into the future.

In California, a team of researchers, co-led by SCCWRP, is using two computer models in tandem – the Regional Ocean Modeling System (ROMS) and Biogeochemical Elemental Cycling (BEC) – to explain the trajectory of acidification in coastal waters and how human activities on land are altering this trajectory.

» ROMS is a physical circulation model that predicts how ocean water circulates – a key predictor of how pollution discharges from land will disperse in coastal waters.

» BEC is an ocean biogeochemical model that predicts how nutrients fuel growth of algal blooms that, upon their death, are decomposed by bacteria, which, in turn, consume oxygen and lower pH.

The goal of the ROMS-BEC modeling

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SCCWRP's Dr. Christina Frieder uses SCCWRP's dynamic exposure laboratory to study how fluctuations in pH, dissolved oxygen and other environmental parameters trigger adverse effects in sensitive marine life. The dynamic exposure experiments are helping researchers identify the thresholds at which different combinations of environmental conditions begin to trigger biological responses.

program is to estimate the influence that human activities are having on acidification and hypoxia and to investigate potential solutions to mitigate these effects, before making any large-scale management investments.

First, researchers are using modeling to produce "hotspot" maps that reveal which areas along California's coastline could be particularly vulnerable to acidification, hypoxia and warming temperatures. These hotspot maps – when contextualized with information on the locations of nutrient-intensive human discharges, designated fisheries zones and ecologically protected coastal areas – will help coastal managers determine where and how to intervene to protect marine life.

For example, managers might decide that certain Marine Protected Areas (MPAs) in California won't be as well-suited to serve as refuges for vulnerable marine communities as acidification intensifies. In response, they could put more focus and resources on mitigating these changes, and/or protecting and enhancing quality of life in other MPAs that can more effectively serve as refugia.

Second, scientists are using modeling to investigate whether the trajectory of acidification has already been meaningfully altered by land-based nutrient discharges to California's coastal ocean. The introduction of excess nutrients to coastal waters – from sources including treated wastewater discharges, and agricultural and urban runoff – can trigger biogeochemical cycling processes that have the potential to exacerbate coastal acidification.

Third, the modeling is being used to project how climate change will alter the trajectory of acidification, oxygen levels and water temperature in the coming decades, and how differing levels of investments in solutions designed to limit carbon dioxide emissions and remove carbon dioxide from seawater could potentially alter how these changes play out.

Using modeling to evaluate potential solutions

The same computer models being used to study acidification's trajectory also are being used to evaluate whether potential management solutions for alleviating adverse biological effects will be effective.

For example, based on preliminary nitrogen management modeling scenarios, the California State Water Resources Control Board has begun drafting a plan to incentivize wastewater treatment agencies that discharge their effluent to the coastal ocean to remove at least some of the nitrogen in wastewater prior to discharge.

Similarly, researchers are examining where nutrient-heavy discharges may be adversely affecting coastal areas that are particularly vulnerable to intensifying acidification. These insights can help guide discussions about how these discharges should be managed going forward.

Another potential solution being investigated is examining whether sensitive organisms could be better protected if they could live near underwater kelp farms that draw carbon dioxide out of the water via natural photosynthetic processes.

Ocean managers are considering cultivating kelp farms in specific coastal areas if these underwater plants can be shown to meaningfully alleviate biological effects on vulnerable organisms. Like plants on land, aquatic plants take up carbon dioxide from water and release oxygen into water during photosynthesis.

Unlike natural kelp forests, however, the harvested kelp – which can grow up to two feet a day – would be removed permanently from coastal waters and potentially get used as a food source, ensuring the carbon sequestration process is not reversed as the plants die and decompose.

In Southern California, SCCWRP is part of a project co-led by the Universities of California, Irvine and Los Angeles, that is examining how to optimally build

Use cases for modeling tools

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 to combat water-quality challenges vs. the risk of choosing the wrong solution or an inadequate solution
- Use a common set of facts and data to reach consensus on the best courses of action

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Courtesy of Javier Infante

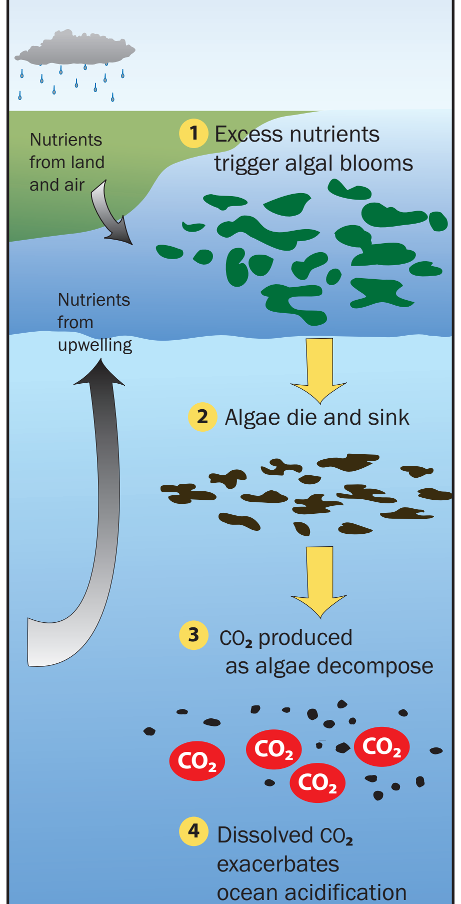
A field crew from the aquaculture company Ocean Rainforest examines kelp that has been growing on ropes suspended in an underwater farm off the coast of Santa Barbara. Researchers are using computer modeling to explore how offshore kelp farms might be used to reduce the ecological effects of ocean acidification.

underwater kelp farms suspended on underwater ropes. Modeling tools are being developed not only to investigate the carbon sequestration potential of these kelp farms, but also how to optimize the placement and design of these farms in coastal waters to maximize yield and minimize environmental effects.

Meanwhile, as part of an ongoing effort to restore kelp and seagrass beds in shallow coastal environments, researchers also are using computer modeling to document the optimal habitat conditions to guide restoration. As with kelp farming, the goal is to restore these natural habitats in order to maximize their carbon sequestration potential.

"We are very hopeful that kelp farms and seagrass restoration efforts are going to hold promise to help buffer coastal waters from intensifying acidification among other benefits," said Dr. Kristen Davis, Associate Professor of Civil and Environmental Engineering at the University of California, Irvine. "At a local level, we cannot stop an intensifying global phenomenon, but we can identify local solutions that may be able to help mitigate and offset its worst effects. Models are a really important part of the toolkit to guide these place-based decisions."

How nutrients exacerbate ocean acidification along the West Coast



Quantifying uncertainty in modeling tools

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.

To ensure that coastal ocean modeling tools are able to make reliable predictions about the trajectory of acidification, researchers have been quantifying 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 the 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

Given the magnitude of management implications associated with the Southern California modeling work, SCCWRP and its member agencies also are exploring formation of an expert review panel to independently evaluate model uncertainty. The more ways that modeling uncertainty gets quantified, the more confidence that managers can have in a model's predictions – and thus the more likely managers are to make informed decisions based on modeling insights.

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Accomplishments

SCCWRP is a national leader in aquatic sciences research, with a comprehensive research agenda that spans a diverse array of water-quality issues confronting the environmental management community.

SCCWRP mission

To enhance the scientific foundation for management of Southern California's ocean and coastal watersheds

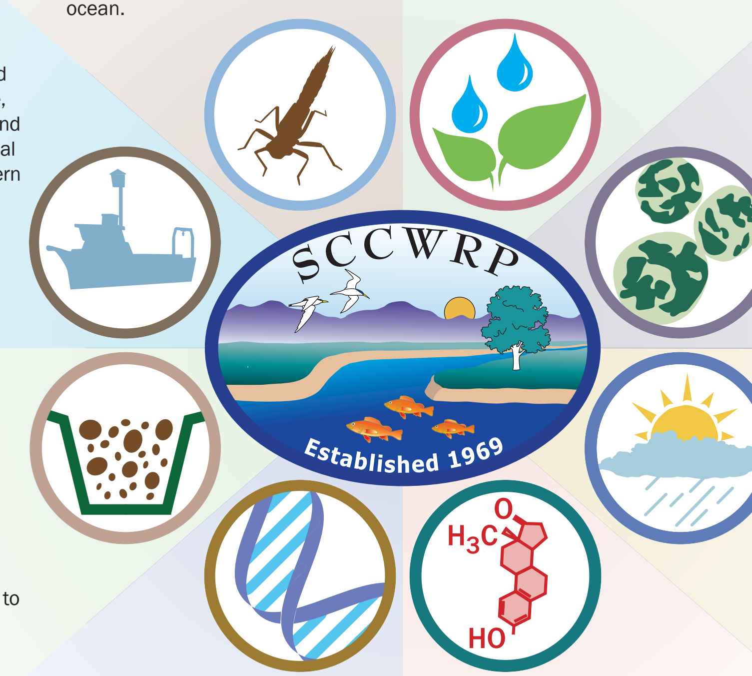
Research themes

SCCWRP's research agenda is organized around eight major thematic areas

50 Number of peer-reviewed journal articles and book chapters co-authored by SCCWRP that appear in this Annual Report

19 Number of technical reports co-authored by SCCWRP that appear in this Annual Report

151 Number of leadership roles that SCCWRP scientists hold with professional societies, external advisory committees and editorial boards of scientific journals **Page 71**



Bioassessment

As environmental managers increasingly turn to measuring the health of aquatic systems through biological assessments – or bioassessment – SCCWRP is developing next-generation approaches that use benthic invertebrates, algae and other organisms to evaluate ecological condition across a variety of environments, from streams to the coastal ocean.

Ecohydrology

As environmental managers work to protect aquatic systems and the biological communities they support from human-induced alterations to hydrological flow patterns, SCCWRP is working to better understand these ecohydrological relationships and how to develop science-informed best management practices around them.

Regional Monitoring

To give environmental managers comprehensive, big-picture snapshots of the condition of aquatic systems and how they are changing over time, SCCWRP facilitates the design and execution of multi-agency regional monitoring – notably, the Southern California Bight Regional Monitoring Program and the Southern California Stormwater Monitoring Coalition Regional Watershed Monitoring Program.

Eutrophication

With anthropogenic nutrient inputs a leading cause of eutrophication – or accelerated accumulation of organic matter from overgrowth of aquatic plants and algae – SCCWRP is working to help environmental managers understand the deleterious impacts of excessive nutrients and how they can more effectively manage nutrient loading to water bodies.

Stormwater BMPs

As stormwater BMPs (best management practices) are implemented to reduce contamination in wet- and dry-weather runoff, SCCWRP is building a technical foundation to help environmental managers optimize the long-term effectiveness of these stormwater control measures.

Climate Change

As environmental managers seek out next-generation solutions for mitigating and offsetting the local impacts of global carbon dioxide emissions, SCCWRP is developing strategies to optimally position vulnerable aquatic systems – and the biological communities they support – to cope with and adapt to climate change.

Microbial Water Quality

With runoff and discharge introducing potentially pathogenic waterborne microbes into coastal waters, especially at populated beaches, SCCWRP is working to more rapidly and effectively detect this microbial contamination, identify the source(s) of the contamination, and understand the risk of illness from water contact.

Contaminants of Emerging Concern

To help environmental managers identify which of the tens of thousands of largely unmonitored CECs in aquatic systems pose the greatest potential health risks to wildlife and humans, SCCWRP is developing novel approaches to rapidly and cost-effectively screen water bodies for CECs, connect screening-level monitoring data to higher-level biological responses, and understand exposure routes.

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Interactive, web-based stream causal assessment tool developed

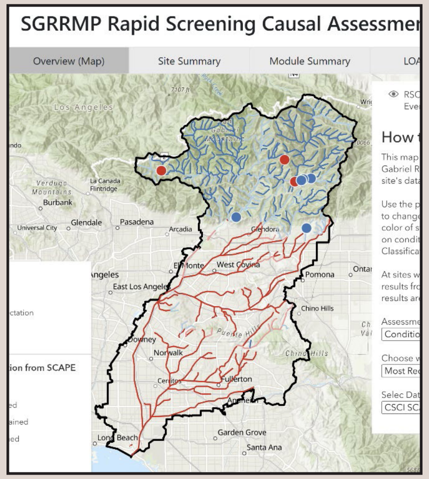
SCCWRP and its partners have developed a user-friendly, web-based tool to help managers rapidly evaluate the likely vs. unlikely causes of degraded biological condition in streams in the San Gabriel River watershed.

The web interface for the Rapid Screening Causal Assessment (RSCA) tool – completed in 2022 – is designed to speed up the traditionally time-consuming process of analyzing stream bioassessment data to pinpoint which stressors are responsible for poor stream condition. It builds on previous work in the San Diego and Santa Ana River watersheds.

The screening tool considers a wide range of potential stressors that commonly impair the health of Southern California streams, including habitat degradation, eutrophication, elevated ionic concentration, altered water temperature and altered flows. Screening-level causal assessment analyses for individual stream sites are presented on an interactive, visual dashboard.

The RSCA helps managers understand which stressors are most likely to threaten biologically healthy streams and enable them to take informed actions to protect these streams. The tool can also provide feedback on data gaps in monitoring programs and future recommendations.

Although the screening tool was initially built for application in the San Gabriel River watershed, researchers' goal is to eventually scale it up for use statewide.



The web interface for the Rapid Screening Causal Assessment (RSCA) tool – developed initially for the San Gabriel River Regional Monitoring Program (SGRRMP) – is intended to help managers rapidly evaluate the likely vs. unlikely causes of degraded biological condition across a watershed. The web tool could eventually be expanded for use statewide.

Tool developed to help prioritize among multiple stream restoration, protection projects

SCCWRP and its partners have developed a set of tools to help California watershed managers identify watershed restoration and protection projects that are most likely to achieve the greatest improvements to stream health and optimally benefit communities disproportionately affected by stream degradation.

The set of statewide tools, released in 2022 and described in a SCCWRP technical report, provides a systematic way for watershed managers to take advantage of existing data collected from various sources – including stream bioassessment data from statewide databases, and maps of areas subject to a variety of landscape stressors – to prioritize among multiple potential restoration and protection projects across a watershed.

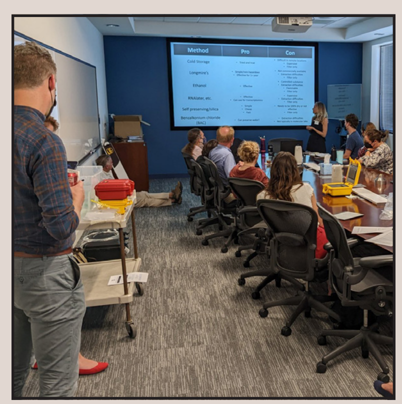
The tool set can be used to conduct screening-level prioritization exercises for watersheds across California that lack a critical mass of detailed, site-specific investigations.

Workshop works to transition eDNA methods to managers

More than 300 researchers and environmental managers gathered at SCCWRP and online during a national scientific workshop in 2022 to coordinate and advance strategies for transitioning DNA-based methods for identifying aquatic organisms from pilot-scale studies to broad-scale adoption by the end-user management community.

The 2nd National Workshop on Marine Environmental DNA, hosted by SCCWRP, showcased for managers that identifying aquatic organisms by the DNA they shed into their environment, known as environmental DNA (eDNA), is a proven technology that is ready for incorporation into routine environmental management programs.

The biggest remaining barrier is the lack of coordination among the many researchers and management agencies that are working – largely in siloes – to standardize eDNA sampling, processing and analysis protocols.



Attendees at the 2nd National Workshop on Marine Environmental DNA, held in fall 2022, learn about field sampling methods for environmental DNA (eDNA) in a SCCWRP conference room. The workshop focused on identifying strategies and solutions for transitioning eDNA methods to routine management adoption and use.

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The Second National Workshop on Marine eDNA: A workshop to accelerate the incorporation of eDNA science into environmental management applications

Carol A. Stepien[1,2], Susanna Theroux[3], Stephen B. Weisberg[3]

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[3]Southern California Coastal Water Research Project Authority, Costa Mesa, CA

ABSTRACT

The Second National Workshop on Environmental DNA was held on September 12–15, 2022, at the Southern California Coastal Water Research Project (SCCWRP) in Southern California and was focused on transitioning eDNA from research to management applications. The Workshop was attended by 150 people in-person and an additional 200 more online. Workshop attendees represented a broad cross-section of disciplines and backgrounds, including research scientists, state, and federal agencies, and those in the environmental management sector. This diverse collection of attendees assembled with the goal of achieving cross-sector collaboration and working together to identify the necessary next steps to move eDNA methods into the management application mainstream. The Workshop structure included a Training Day oriented towards environmental managers and those new to eDNA science, to facilitate a common ground for discussions on subsequent days. The Plenary Day focused on case studies about eDNA applications and culminated with a roundtable panel discussion with local, state, and federal agency representatives on eDNA method readiness and the road to method adoption. Among the key takeaways from the Workshop was bridging the communication gap between researchers and managers because scientists often focus on technical details and the unknowns, giving the impression that eDNA science is not yet mature, whereas managers want to hear consensus statements about readiness and a roadmap for method adoption, including standard operating procedures, lab accreditation, and unified sequence libraries. This outcome was a clear directive for many scientists in attendance that it is time to stop letting perfect be the enemy of good and to focus future efforts on method harmonization and a national strategy towards method adoption. The Workshop concluded with a working session of invited participants to identify key priorities and needs to achieve the goals highlighted in the Workshop discussions.

CITATION

Stepien, C.A., S. Theroux, S.B. Weisberg. 2022. The Second National Workshop on Marine eDNA: A workshop to accelerate the incorporation of eDNA science into environmental management application. *Environmental DNA* DOI:10.1002/edn3.379.

SCCWRP Journal Article #1300
Full text available online: www.sccwrp.org/publications

Prioritizing stream protection, restoration and management actions using landscape modeling and spatial analysis

Eric D. Stein[1], Jeffery S. Brown[1], Alexis Canney[1], Megan Mirkhanian[1], Heili Lowman[2], Kevin O'Connor[3], Ross Clark[3]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA
[2]Department of Natural Resources and Environmental Science, University of Nevada, Reno, NV
[3]Central Coast Wetlands Group, Moss Landing Marine Labs, Moss Landing, CA

ABSTRACT

Watersheds are often degraded by human activities, reducing their ability to provide ecosystem functions and services. While governmental agencies have put forward plans for improving watershed health, resources are limited, and choices must be made as to which watersheds to prioritize and what actions to take. Prioritization tools with sufficient specificity, resolution, and automation are needed to guide decisions on restoration and management actions across large scales. To address this need, we developed a set of tools to support the protection of streams and associated riparian habitats across the state of California. We developed and tested watershed condition estimation models based on bioassessment data, used the EPA's StreamCat dataset to identify stressors, incorporated environmental justice factors and developed reach-specific models to prioritize actions. We applied the prioritization tools statewide and were able to identify 18% of stream reaches that are in good condition but that are most vulnerable to existing stressors and an additional 19% of stream reaches that are degraded and are highest priority for restoration and management. The remaining 63% of stream reaches were prioritized for protection and periodic monitoring or minor remedial actions. The results of this project can help regional stakeholders and agencies prioritize hundreds of millions of dollars being spent to protect, acquire, and restore stream and riparian habitats. The methods are directly transferable by using any regional condition and stress data that can be readily obtained.

CITATION

Stein, E.D., J.S. Brown, A. Canney, M. Mirkhanian, H. Lowman, K. O'Connor, R. Clark. 2022. Prioritizing Stream Protection, Restoration and Management Actions Using Landscape Modeling and Spatial Analysis. *Water* 14:1375.

SCCWRP Journal Article #1264
Full text available online: www.sccwrp.org/publications

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Additional considerations for incorporating ecosystem services into compensatory mitigation programs

William Ainslie[1], Eric D. Stein[2]

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[2]Southern California Coastal Water Research Project, Costa Mesa, CA

Abstract

Compensatory mitigation for impacts to aquatic resources in the United States is primarily driven by the federal §404(b)(1) Guidelines under the Clean Water Act which include the 2008 Mitigation Rule. The Mitigation Rule is largely focused on the restoration of aquatic ecosystem functions, although language in the Rule defines "services" as "the benefits that human populations receive from functions that occur in ecosystems," or ecosystem services (ES). The Rule outlines 12 informational elements that mitigation providers must consider in every mitigation proposal. Aspects of defining objectives, site selection, collecting baseline information, determining credits, developing a work plan, performance standards, monitoring long term, and adaptive management from the Rule have many overlaps with the restoration effectiveness and monitoring framework (Chapter 2) and therefore are amenable to incorporating ES, including final ecosystem goods and services (FEGS). Although regulatory language in the Rule includes terms and concepts pertaining to ES, detailed language about specifically incorporating them is lacking. In addition, from an implementation standpoint, there are gaps and needs that would have to be filled before ES and FEGS could be incorporated into compensatory mitigation practice, especially in regards to: consistent terminology around a standard set of ES and beneficiaries; structured assessment tools that produce quantifiable outcomes; process for establishing defensible benchmarks for compliance; training and quality control program to ensure appropriate application; standard data and metadata formats for inclusion of information on ES in tracking systems.

Citation

Ainslie, W., E.D. Stein. 2022. Additional Considerations for Incorporating Ecosystem Services into Compensatory Mitigation Programs. in: C.A. Jackson, T.H. DeWitt (eds.), *Incorporating Ecosystem Services into Restoration Effectiveness Monitoring & Assessment: Frameworks, Tools, and Examples* pp. 177-201. U.S. Environmental Protection Agency. Washington, D.C.

SCCWRP Book Chapter #1294
Full text available online: www.sccwrp.org/publications

Aboveground competition influences density-dependent effects of cordgrass on sediment biogeochemistry

Janet B. Walker[1,2,3], Shelby Rinehart[1,2,4], Gabriel Greenberg-Pines[1,2,5], Wendi K. White[1,2,6], Ric DeSantiago[1,2,7], David A. Lipson[1], Jeremy D. Long[1,2]

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Abstract

Interspecific interactions between plants influence plant phenotype, distribution, abundance, and community structure. Each of these can, in turn, impact sediment biogeochemistry. Although the population and community level impacts of these interactions have been extensively studied, less is known about their effect on sediment biogeochemistry. This is surprising given that many plants are categorized as foundation species that exert strong control on community structure. In southern California salt marshes, we used clipping experiments to manipulate aboveground neighbor presence to study interactions between two dominant plants, Pacific cordgrass (*Spartina foliosa*) and perennial pickleweed (*Sarcocornia pacifica*). We also measured how changes in cordgrass stem density influenced sediment biogeochemistry. Pickleweed suppressed cordgrass stem density but had no effect on aboveground biomass. For every cordgrass stem lost per square meter, porewater ammonium increased 0.3–1.0 μM. Thus, aboveground competition with pickleweed weakened the effects of cordgrass on sediment biogeochemistry. Predictions about plant–soil feedbacks, especially under future climate scenarios, will be improved when plant–plant interactions are considered, particularly those containing dominant and foundation species.

Citation

Walker, J.B., S. Rinehart, G. Greenberg-Pines, W.K. White, R. DeSantiago, D.A. Lipson, J.D. Long. 2022. Aboveground competition influences density-dependent effects of cordgrass on sediment biogeochemistry. *Ecology and Evolution* 12:e8722.

SCCWRP Journal Article #1265
Full text available online: www.sccwrp.org/publications

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Prioritizing stream protection, restoration and management actions using landscape modeling and spatial analysis

Eric D. Stein[1], Jeffrey S. Brown[1], Alexis Canney[1], Megan Mirkhanian[1], Heili Lowman[2], Kevin O'Connor[3], Ross Clark[3]

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[3]Central Coast Wetlands Group, Moss Landing Marine Labs, Moss Landing, CA

Citation

Stein, E.D., J.S. Brown, A. Canney, M. Mirkhanian, H. Lowman, K. O'Connor, R. Clark. 2022. Prioritizing Stream Protection, Restoration and Management Actions Using Landscape Modeling and Spatial Analysis. Technical Report 1246. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1246
Full text available online: www.sccwrp.org/publications

An integrated framework for evaluating wetland and stream compensatory mitigation

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[2]Environmental Law Institute, Washington, D.C.
[3]U.S. Environmental Protection Agency, Washington, D.C.

Citation

Stein, E.D., J.S. Brown, N. Bishop, R. Kihslinger, B.J. Topping, P. Hough. 2022. An Integrated Framework for Evaluating Wetland and Stream Compensatory Mitigation. Technical Report 1209. Environmental Protection Agency. Washington, DC.

SCCWRP Technical Report #1209
Full text available online: www.sccwrp.org/publications

An integrated framework for evaluating wetland and stream compensatory mitigation – Summary of pilot applications

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[3]University of Georgia, Athens, GA
[4]U.S. Environmental Protection Agency, Washington, D.C.

Citation

Stein, E.D., J.S. Brown, T. Smith, C. Cox, N. Nibbelink, K. Sheehan Hill, B.J. Topping, P. Hough. 2022. An Integrated Framework for Evaluating Wetland and Stream Compensatory Mitigation - Summary of Pilot Applications. Technical Report 1210. Environmental Protection Agency. Washington, DC.

SCCWRP Technical Report #1210
Full text available online: www.sccwrp.org/publications

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Study demonstrates how to use framework to restore more natural flows to streams

SCCWRP and its partners have completed a three-year study demonstrating how watershed managers can build a rigorous scientific foundation for integrating environmental flow considerations into their stream restoration planning efforts.

The study, completed in 2022, used a standardized, multi-tiered framework known as the California Environmental Flows Framework to systematically study 23,000 linear feet of degraded stream habitat in southern Orange County, with a focus on evaluating how altered, unnatural flow patterns are contributing to poor stream biology.

Stream managers will be able to use the study's insights to decide what specific, targeted actions they should take where to reverse the area's unnatural flow patterns and work toward achieving the greatest improvements to ecological health. These actions are expected to include installation of flow-capture devices across multiple adjacent watersheds to reduce unnatural dry-weather flows.

During the study, SCCWRP and its partners used extensive bioassessment data collected from across Southern California to develop flow-ecology models that relate levels of flow alteration to biological health.

A storm drain discharges unnatural dry-weather flows into a tributary of Arroyo Trabuco Creek in southern Orange County. Researchers have completed a study that sheds light on how stream managers can take a science-informed approach to deciding how they should reverse the area's unnatural flow patterns and improve 23,000 linear feet of degraded stream habitat.

Beta version of stream flow classification tool developed for Great Plains region

SCCWRP and its partners have completed development of the beta version of a tool that can rapidly distinguish among perennial, intermittent and ephemeral streams in the U.S. Great Plains region, complementing tools previously developed for two other U.S. regions.

The flow duration classification tool – described in a user manual released in 2022 – uses a combination of biological and geomorphic lines of evidence to classify streams based on the duration of their surface flows.

The Streamflow Duration Assessment Method (SDAM) tool is a collaboration of SCCWRP, the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers. To date, the tool has been developed for the Great Plains, Arid West and Western Mountains regions.

The SDAM tool is designed to support regulatory programs that require stream flow duration classifications, including a recent federal rule change that relies on stream flow duration to identify Waters of the United States.

The Frio River in Texas is one of more than 400 sites that SCCWRP and its partners sampled as part of a project to develop a tool that can rapidly distinguish among perennial, intermittent and ephemeral streams in the U.S. Great Plains region, which includes parts of Texas.

Draft technical foundation developed for cannabis growers

SCCWRP and its partners have completed the development of a proposed scientific workflow intended to provide the technical foundation for California cannabis growers to demonstrate that the water they are requesting to divert from nearby streams to support cannabis cultivation does not adversely affect the streams' ecological health.

The draft workflow, submitted in late 2022 for review by the State Water Resources Control Board, consists of a process to develop in-stream flow criteria using the recently developed California Environmental Flows Framework, as well as a suite of web-based tools to assess potential ecological risks from diverting stream flows to support cannabis cultivation. Recreational marijuana was legalized in California in 2016.

The workflow will help the State Water Board determine how the individual and cumulative effects of cannabis growers' proposed stream flow diversions could adversely affect flow patterns.

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Developing ecological flows needs in a highly altered region: Application of California Environmental Flows Framework in southern California, USA

Kristine T. Taniguchi-Quan[1], Katie Irving[1], Eric D. Stein[1], Aaron Poresky[2], Richard A. Wildman Jr.[2], Amanda Aprahamian[3], Cindy Rivers[3], Grant Sharp[3], Sarah M. Yarnell[4], Jamie R. Feldman[2]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA
[2]Geosyntec Consultants, Inc., Portland, OR
[3]Orange County Public Works, Orange, CA
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ABSTRACT

Flow alteration is a pervasive issue across highly urbanized watersheds that can impact the physical and biological condition of streams. In highly altered systems, flows may support novel ecosystems that may not have been found under natural conditions and reference-based environmental flow targets may not be relevant. Moreover, stream impairments such as altered channel morphology may make reference-based environmental flow targets less effective in supporting ecosystem functions. Here, we develop an approach for determining ecological flow needs in highly modified systems to support existing ecological uses utilizing the California Environmental Flows Framework (CEFF). CEFF was established to provide guidance on developing environmental flow recommendations across California's diverse physical landscape and broad array of management contexts. This paper illustrates the application of CEFF in informing ecologically-based flow restoration in a highly altered region of South Orange County, California. The steps of CEFF were implemented including a stakeholder process to establish goals and provide input throughout the project; identifying the natural ranges of functional flow metrics, or distinct components of the natural flow regime that support ecosystem functions; refining ecological flow needs to account for altered channel morphology and the life history needs of riparian and fish species; and assessing flow alteration to inform management strategies. Key considerations and lessons learned are discussed in the context of developing ecological flow needs in highly altered systems including when non-flow related management actions (i.e., channel rehabilitation) are necessary to achieve ecological goals.

CITATION

Taniguchi-Quan, K.T., K. Irving, E.D. Stein, A. Poresky, R.A. Wildman Jr., A. Aprahamian, C. Rivers, G. Sharp, S.M. Yarnell, J.R. Feldman. 2022. Developing Ecological Flow Needs in a Highly Altered Region: Application of California Environmental Flows Framework in Southern California, USA. *Frontiers in Environmental Science* 10:787631.

SCCWRP Journal Article #1252
Full text available online: www.sccwrp.org/publications

Editorial: Environmental flows in an uncertain future

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ABSTRACT

The implementation of comprehensive environmental flow programs for all freshwater ecosystems worldwide, has never been more urgent. Globally, human population growth and activities are placing increasing pressure on freshwater resources, leading to competition for ever scarcer water and overallocation. Coupled with climate change and increased incidences of drought and flooding, these shifting patterns of water use, and allocation have severely impacted flow magnitudes, durations, and timing in rivers around the world and caused widespread degradation of aquatic biodiversity and ecosystem condition. These effects are exacerbated by the associated changes in temperature, contaminants, nutrients, and sediments which are modulated by altered flows. Increasing non-stationary conditions associated with climate change introduce additional uncertainties and complicate challenges in achieving water security under increasing demand, modified environmental conditions and socioeconomic constraints. The combination of uncertainty in downscaled climate predictions, effects of prolonged droughts, and unpredictability in patterns of future water demand for urban, agricultural, and industrial uses makes long-term implementation of environmental flows programs challenging. There also remain considerable challenges in predicting how the ecosystem will respond to streamflow conditions outside those in recent history. Moreover, changing social and political priorities make it difficult to predict which innovative and integrated solutions to water resource management programs aimed reducing water scarcity can be effective, while still protecting the environment.

CITATION

Stein, E.D., A.C. Horne, R.E. Tharme, J. Tonkin. 2022. Editorial: Environmental flows in an uncertain future. *Frontiers in Environmental Science* 10:1-5.

SCCWRP Journal Article #1295
Full text available online: www.sccwrp.org/publications

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Modeling functional flows in California's Rivers

Theodore E. Grantham[1,2], Daren M. Carlisle[3], Jeanette Howard[4], Belize Lane[5], Robert Lusardi[6,7], Alyssa Obester[8], Samuel Sandoval-Solis[2,9], Bronwen Stanford[8], Eric D. Stein[10], Kristine T. Taniguchi-Quan[10], Sarah M. Yarnell[6], Julie K. H. Zimmerman[4]

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Abstract

Environmental flows are critical to the recovery and conservation of freshwater ecosystems worldwide. However, estimating the flows needed to sustain ecosystem health across large, diverse landscapes is challenging. To advance protections of environmental flows for streams in California, United States, we developed a statewide modeling approach focused on functional components of the natural flow regime. Functional flow components in California streams—fall pulse flows, wet season peak flows and base flows, spring recession flows, and dry season baseflows—support essential physical and ecological processes in riverine ecosystems. These functional flow components can be represented by functional flow metrics (FFMs) and quantified by their magnitude, timing, frequency, duration, and rate-of-change from daily streamflow records. After calculating FFMs at reference-quality streamflow gages in California, we used machine-learning methods to estimate their natural range of values for all stream reaches in the state based on physical watershed characteristics, and climatic factors. We found that the models performed well in predicting FFMs in streams across a diversity of landscape and climate contexts, according to a suite of model performance criteria. Using the predicted FFM values, we established initial estimates of ecological flows that are expected to support critical ecosystem functions and be broadly protective of ecosystem health. Modeling functional flows at large regional scales offers a pathway for increasing the pace and scale of environmental flow protections in California and beyond.

Citation

Grantham, T.E., D.M. Carlisle, J. Howard, B. Lane, R. Lusardi, A. Obester, S. Sandoval-Solis, B. Stanford, E.D. Stein, K.T. Taniguchi-Quan, S.M. Yarnell, J.K.H. Zimmerman. 2022. Modeling Functional Flows in California's Rivers. *Frontiers in Environmental Science* 10:787473.

SCCWRP Journal Article #1255
Full text available online: www.sccwrp.org/publications

Identifying functional flow linkages between stream alteration and biological stream condition indices across California

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Abstract

Large state or regional environmental flow programs, such as the one based on the California Environmental Flows Framework, rely on broadly applicable relationships between flow and ecology to inform management decisions. California, despite having high flow and bioassessment data density, has not established relationships between specific elements of the annual hydrograph and biological stream condition. To address this, we spatially and temporally linked USGS gage stations and biological assessment sites in California to identify suitable paired sites for comparisons of streamflow alteration with biological condition at a statewide scale. Flows were assessed using a set of functional flow metrics that provide a comprehensive way to compare alteration and seasonal variation in streamflow across different locations. Biological response was evaluated using the California Stream Condition Index (CSCI) and Algal Stream Condition Index (ASCI), which quantify biological conditions by translating benthic invertebrate or algal resources and watershed-scale environmental data into an overall measure of stream health. These indices provide a consistent statewide standard for interpreting bioassessment data, and thus, a means of quantitatively comparing stream conditions throughout the state. The results indicate that indices of biological stream condition were most closely associated with flow alteration in seasonality and timing metrics, such as fall pulse timing, dry-season timing, and wet season timing. Magnitude metrics such as dry-season baseflow, wet season baseflow, and the fall pulse magnitude were also important in influencing biological stream conditions. Development of ecological flow needs in large-scale environmental programs should consider that alteration to any of the seasonal flow components (e.g., dry-season baseflow, fall pulse flow, wet-season baseflow, spring recession flow) may be important in restructuring biological communities.

Citation

Peek, R., K. Irving, S.M. Yarnell, R. Lusardi, E.D. Stein, R.D. Mazor. 2022. Identifying Functional Flow Linkages Between Stream Alteration and Biological Stream Condition Indices Across California. *Frontiers in Environmental Science* 9:790667.

SCCWRP Journal Article #1240
Full text available online: www.sccwrp.org/publications

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Balancing water reuse and ecological support goals in an effluent dominated river

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Abstract

Flows in urban rivers are increasingly managed to support water supply needs while also protecting and/or restoring instream ecological functions, goals that are often in opposition to each other. Effluent-dominated rivers (i.e., rivers that consist primarily of discharged treated wastewater) pose a particular challenge because changes in effluent discharge may impact river ecology. A functional flows approach, in which metrics from the annual hydrograph correspond to ecological processes, was applied to understand the hydro-ecological implications of wastewater reuse in the Los Angeles River watershed (Los Angeles County, California, USA). The Los Angeles River, like many urban rivers, is dominated by effluent, particularly during dry weather. An hourly hydrologic model was created, calibrated, and validated in EPA SWMM for the Los Angeles River watershed to investigate how increases in wastewater reuse (i.e., decreases in discharge to the river) may impact river flows and subsequently ecology and recreation in the river. Current flows are shown to support freshwater marsh, riparian habitat, fish migration, and wading shorebird habitat, in addition to recreational kayaking. Functional flow metrics were assessed under future management scenarios including reducing discharge to increase recycling at three wastewater treatment plants within the watershed. Both wet-season and dry-season baseflows were most sensitive to increasing wastewater reuse, with an average decrease of 51–56% (0.93 cms) from current baseflows. Sensitivity curves that relate potential changes in wastewater discharge to changes in functional flows show that a 4% decrease in current wastewater discharge may negatively impact habitat for indicator species during the dry season. More opportunity exists for wastewater reuse during the wet season, when current wastewater discharge may be reduced by 24% with minimal impacts to ecology and recreation. The developed approach has the potential to inform similar tradeoff decisions in other urban rivers where flows are dominated by wastewater or stormdrain discharge.

Citation

Wolfand, J.M., K.T. Taniguchi-Quan, R. Abdi, E. Gallo, K. Irving, D. Philippus, J.B. Rogers, E.D. Stein, T.S. Hogue. 2022. Balancing water reuse and ecological support goals in an effluent dominated river. *Journal of Hydrology X* 15:100124.

SCCWRP Journal Article #1250
Full text available online: www.sccwrp.org/publications

Dilution and pollution: Assessing the impacts of water reuse and flow reduction on water quality in the Los Angeles River basin

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Abstract

Los Angeles (LA), California, USA is one of many population-dense, arid cities whose treated wastewater discharge comprises most of the river flow (up to 70% in the LA River). Like other arid cities, LA plans to improve water supply by reusing treated wastewater and diverting nonstorm stormdrain flows. This study quantifies the impact of these management actions on pollutant loads and concentrations in the LA River. Daily pollutant loads and concentrations for total suspended solids (TSS), total dissolved solids (TDS), copper, zinc, and lead were predicted using EPA SWMM across nine wastewater reuse and nonstorm stormdrain diversion scenarios. Reduced flows generally decreased daily loads for all pollutants, but the impact on daily concentrations varied. Concentrations of TDS, TSS, copper, and lead increased with wastewater reuse, while zinc concentrations increased with the reduction of nonstorm stormdrain flows. Copper, zinc, and TDS water quality objectives were met less frequently with increasing flow reduction. These results elucidate the potential impacts of flow reductions on water quality and will help inform management decisions in effluent-dominated rivers.

Citation

Wolfand, J.M., A. Sytsma, V.L. Hennon, E.D. Stein, T.S. Hogue. 2022. Dilution and Pollution: Assessing the Impacts of Water Reuse and Flow Reduction on Water Quality in the Los Angeles River Basin. *Environmental Science and Technology* DOI:10.1021/acsestwater.2c00005

SCCWRP Journal Article #1283
Full text available by request: pubrequest@sccwrp.org

Closing the gap on wicked urban stream restoration problems: A framework to integrate science and community values

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Abstract

Restoring the health of urban streams has many of the characteristics of a wicked problem. Addressing a wicked problem requires managers, academics, practitioners, and community members to make negotiated tradeoffs and compromises to satisfy the values and perspectives of diverse stakeholders involved in setting restoration project goals and objectives. We conducted a gap analysis on 11 urban stream restoration projects to identify disconnections, underperformance issues, and missing processes in the project structures used to develop restoration project goals and objectives. We examined the gap analysis results to investigate whether managers appropriately identified problem statements and met stated objectives. Projects that aimed to restore overall stream health commonly fell short for various reasons, including limited stakeholder and community input and buy-in, revealing potential limitations in the breadth of objectives, values, and stakeholder perspectives and knowledge types. Projects that emphasized integrating community values and diverse knowledge types tended to meet the expected outcomes of restoring stream processes through incremental solutions. Managers implementing more holistic solutions and values-driven approaches are more likely to consider diverse viewpoints from a variety of community local institutions. Based on these and other results, we propose a conceptual framework that integrates diverse perspectives and knowledge to enhance social and ecological outcomes of urban stream restoration. The framework also emphasizes the importance of setting objectives that support incremental solutions to foster more realistic expectations amongst stakeholders.

Citation

Murphy, B.M., K. Russell, C.C. Stillwell, R. Hawley, M. Scoggins, K.G. Hopkins, M.J. Burns, K.T. Taniguchi-Quan, K.H. Macneale, R. Smith. 2022. Closing the gap on wicked urban stream restoration problems: A framework to integrate science and community values. *Freshwater Science* 41:3.

SCCWRP Journal Article: #1273
Full text available online: www.sccwrp.org/publications

Application of flow-ecology analysis to inform prioritization for stream restoration and management actions

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Abstract

A key challenge in managing flow alteration is determining the severity and pattern of alteration associated with the degradation of biological communities. Understanding these patterns helps managers prioritize locations for restoration and flow management actions. However, the choices made about how to use these flow-ecology relationships can have profound implications on management decisions (e.g., which biological endpoints, which thresholds, which seasonal flow components to use). We describe a process for using flow-ecology relationships to prioritize management actions that 1) Represents the most relevant components of the annual hydrograph, 2) Demonstrates an appropriate level of sensitivity in order to discriminate locations to inform decision making, 3) Aims to protect multiple biological assemblages, 4) Reduces misclassification of priority areas (i.e., error of omission). Our approach is based on the functional flows approach which uses multiple flow metrics that describe the frequency, timing, magnitude, duration, and rate of change of seasonal process-based components of the annual hydrograph. Using this approach, we performed a flow-ecology analysis of regional bioassessment data, through which we determined where flow alteration impacts biology and prioritized reaches for changes in flow management to protect aquatic resources in a highly urbanized region of southern California, where managing scarce water resources leads to difficult decisions about tradeoffs that require technical information. We identified three important functional flow metrics for each of two bioassessment indices, one based on benthic macroinvertebrates, and another based on benthic algae. Based on thresholds that describe levels of alteration as well as thresholds describing the probability of achieving a healthy biological condition, we compared nine biological threshold combinations for each index. We found instances of flow alteration that impact biological condition highly variable (0–100% of subbasins) between combinations and we present a method for finding the most appropriate combination for prioritizing locations for flow management. We apply the final thresholds to the study region and propose 16 subbasins of high priority for implementing flow management and restoration. Importantly, we show that focusing on a single biological group would result in biologically altered locations being effectively ignored.

Citation

Irving, K., K.T. Taniguchi-Quan, A. Aprahamian, C. Rivers, G. Sharp, R.D. Mazor, S. Theroux, A. Holt, R. Peek, E.D. Stein. 2022. Application of Flow-Ecology Analysis to Inform Prioritization for Stream Restoration and Management Actions. *Frontiers in Environmental Science* 9:787462.

SCCWRP Journal Article: #1251
Full text available online: www.sccwrp.org/publications

Functional flows in groundwater-influenced streams: Application of the California Environmental Flows Framework to determine ecological flow needs

Sarah M. Yarnell[1], Ann Willis[1], Alyssa Obester[2], Ryan A. Peek[1], Robert A. Lusardi[1,3], Julie Zimmerman[4], Theodore E. Grantham[5], Eric D. Stein[6]

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Abstract

Environmental flows, or the practice of allocating water in river systems for ecological purposes, is a leading strategy for conserving aquatic species and improving river health. However, consideration of surface-groundwater connectivity is seldom addressed in environmental flow development due to a lack of methodologies that account for groundwater contributions to instream flow. Groundwater-influenced streams have been identified as key refugia for native biota under a rapidly changing climate. These ecosystems are anticipated to be more resistant to climate change because groundwater input buffers the adverse effects of low flows and high temperatures, particularly in the dry season. Less understood, however, is the relative contribution of groundwater inputs to streamflow and how these surface-groundwater water interactions should be accounted for in environmental flow assessments and management actions. In order to assess ecological flow needs in groundwater-influenced streams, we applied the California Environmental Flows Framework (CEFF) in two river systems in California, United States. The Little Shasta River and the lower Cosumnes River are representative of many groundwater-influenced streams throughout the semi-arid western United States. Historically, perennial streamflow once sustained diverse native aquatic species in these ecosystems, but water withdrawals for irrigated agriculture has resulted in periodic stream dewatering. We found CEFF was useful in quantifying ecological flow needs for seasonal components of the flow regime that support ecosystem functionality. In particular, CEFF offered flexibility to incorporate information on the seasonal and spatial dimensions of groundwater influences in the development of ecological flow targets. The focus on ecosystem functions in CEFF, and ability to account for groundwater influences on those functions, creates opportunities for integrated surface-groundwater management strategies that support the recovery and protection of streamflows in groundwater-influenced streams.

Citation

Yarnell, S.M., A. Willis, A. Obester, R.A. Peek, R.A. Lusardi, J. Zimmerman, T.E. Grantham, E.D. Stein. 2022. Functional Flows in Groundwater-Influenced Streams: Application of the California Environmental Flows Framework to Determine Ecological Flow Needs. *Frontiers in Environmental Science* 9:788295.

SCCWRP Journal Article: #1249
Full text available online: www.sccwrp.org/publications

Allocations and environmental flows

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Abstract

Over the past 30 years, much has been learned from strategies used around the world to establish and implement environmental flow programs. Approaches vary from highly prescriptive regulatory requirements to largely voluntary programs. These examples have shown that allocating water to the environment does not necessarily constrain human uses and can have benefits for both agriculture and ecosystems. Some efforts attempt to reduce conflict between agriculture and the environment by limiting water allocations spatially, while others attempt to reconcile competing water demands through comprehensive, regional allocation schemes that vary with climate conditions over time. Here we summarize strategies for water allocation planning and implementation that can be used to balance environmental and agricultural water needs. Effective strategies incorporate: a holistic environmental water allocation approach that focuses on protecting overall ecological structure and functions; environmental flow protections at broad spatial and temporal scales; consideration of surface–ground water interactions and the relationships between flow, sediment, temperature, and water quality. From an implementation perspective, approaches that establish a volumetric water budget for the environment based on interannual variation in water availability, integrate across programs in a transparent manner, are broadly inclusive, and incorporate traditional values and perspectives have the highest likelihood of success. Environmental flow strategies that consider technical solutions, establish clear objectives and anticipate how environmental water will be allocated under different water year types, and are sensitive to social issues and concerns will increase certainty in how much water is allocated for agriculture and the environment. Beyond reconciling conflicts between competing demands, emerging technical and institutional approaches to environmental flows can improve resiliency of water management programs to climate change by preventing the over-exploitation of water supplies, enhancing flexibility, and providing a framework for adaptation.

Citation

Stein, E.D., M.E. McClain, A. Sengupta, T.E. Grantham, J. Zimmerman, S.M. Yarnell. 2022. Allocations and Environmental Flows. in: J. Rouillard, C. Babbitt, E. Challies, J.D. Rinaudo (eds.), *Water Resources Allocation and Agriculture: Transitioning from Open to Regulated Access* pp. 49-59. IWA Publishing. London, UK.

SCCWRP Book Chapter #1281
Full text available by request: pubrequest@sccwrp.org

Thermal suitability of the Los Angeles River for cold water resident and migrating fish under physical restoration alternatives

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Abstract

Anthropogenic development has adversely affected river habitat and species diversity in urban rivers, and existing habitats are jeopardized by future uncertainties in water resources management and climate. The Los Angeles River (LAR), for example, is a highly modified system that has been mostly channelized for flood control purposes, has altered hydrologic and hydraulic conditions, and is thermally altered (warmed), which severely limits the habitat suitability for cold water fish species. Efforts are currently underway to provide suitable environmental flows and improve channel hydraulic conditions, such as depth and velocity, for *adult* fish migration from the Pacific Ocean to upstream spawning areas. However, the thermal responses of restoration alternatives for resident and migrating cold water fish have not been fully investigated. Using a mechanistic model, we simulated the LAR's water temperature under baseline conditions and future alternative restoration scenarios for migration of the native, anadromous steelhead trout in Southern California and the historically resident Santa Ana sucker. We considered three scenarios: 1) increasing roughness of the low-flow channel, 2) increasing the depth and width of the low-flow channel, and 3) allowing subsurface inflow to the river at a soft bottom reach in the LA downtown area. Our analysis indicates that the maximum weekly average temperature (MaxWAT) in the baseline condition was 28.9 °C, suggesting that the current river temperatures would act as a limiting factor during the steelhead migration season and habitat for Santa Ana sucker. The MaxWAT dropped about 3%–28 °C after applying all the considered scenarios at the study site, which is 3 °C higher than the determined steelhead survival threshold. Our simulations suggest that without consideration of thermal restoration, restoring hydraulic conditions may be insufficient to support cold water fish migration or year-round resident native fish populations, particularly with potential river temperature increases due to climate change.

Citation

Abdi, R., A. Rust, J.M. Wolfand, K.T. Taniguchi-Quan, K. Irving, D. Philippus, E.D. Stein, T.S. Hogue. 2022. Thermal Suitability of the Los Angeles River for Cold Water Resident and Migrating Fish Under Physical Restoration Alternatives. *Frontiers in Environmental Science* 9:749085.

SCCWRP Journal Article #1241
Full text available online: www.sccwrp.org/publications

Runoff and sediment loads in the Tijuana River: Dam effects, extreme events, and change during urbanization

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Abstract

Study region: Tijuana River watershed on the US-Mexico border, where urbanization, estuarine sedimentation, and beach erosion incentivize quantification of runoff and suspended sediment loads (SSL) and concentrations (SSC).

Study focus: Rainfall, runoff and SSL were quantified for 2001–2019 (storm-wise) and 1962–2019 (annual) using sediment rating curves and bootstrapping to quantify uncertainty.

New hydrological insights: Annual runoff increased for a given rainfall depth following channelization and the start of imported water in 1978–79, and during urbanization over 1980–2019. SSC for a given runoff fell between 1970 s and 2000 s, but annual SSL increased severalfold due to higher annual runoff. Half the SSL over 2001–2019 occurred during nine storms. Nearly half (48 %) of annual SSL occurred in the six wettest years over 1962–2019, though years with recurrence interval 2–10 years accounted for 50 %. Neglecting the impact of dams on the SSL-rainfall relationship during extreme wet years over-estimated annual SSL by a factor of 7 and by up to 30x for the wettest year. Long-term mean suspended sediment yield (119 tons km^{-2} yr^{-1}) is similar to other southern California watersheds but much lower than observed (5000 tons km^{-2} yr^{-1}) in a small watershed that also drains to the Tijuana estuary. Accumulation of sediment in the estuary may be driven by undammed side canyons, and by low runoff that cannot transport sediment to the coast.

Citation

Biggs, T., A. Zeigler, K.T. Taniguchi-Quan. 2022. Runoff and sediment loads in the Tijuana River: Dam effects, extreme events, and change during urbanization. *Journal of Hydrology: Regional Studies* 42:101162.

SCCWRP Journal Article #1277
Full text available online: www.sccwrp.org/publications

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Restoring geomorphic integrity in urban streams via mechanistically based storm water management: Minimizing excess sediment transport capacity

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Abstract

Stream channel erosion, enlargement, and habitat degradation are ubiquitous in urban watersheds with conventional stormwater management that increase channel-eroding flows relative to undeveloped watersheds. Hydrologic-based restoration aims to discharge a more natural flow regime via stormwater management interventions. Whether such interventions facilitate geomorphic recovery depends, in part, on the degree to which they restrict discharges that would otherwise contribute to channel erosion. Erosion potential (E), the ratio of post-developed to predeveloped sediment transport capacity, provides a simplified, mechanistic framework to quantify the relative influence of stormwater interventions on the geomorphic effectiveness of the flow regime. This paper compiles ca. five years of data following stormwater-based interventions in three distinct settings in the United States and Australia to demonstrate how the E framework can elucidate the role of hydrologic restoration interventions in facilitating trajectories of geomorphic recovery (or lack thereof). In a previously developed watershed with unstable streams, substantial reductions in E in one stream coincided with a trajectory of geomorphic recovery, whereas the control stream without E-reducing interventions exhibited continued instability. Furthermore, a stream downstream of a greenfield development that optimized their stormwater control measures to match the sediment transport capacity of the predeveloped regime (E = 1) was able to maintain a recovery trajectory in a legacy-impacted setting that is otherwise highly susceptible to hydromodification. Streambed material size, channel evolution stage, and the hydrogeomorphic setting also likely affect the level of E reduction necessary to promote geomorphic recovery, with coarser-grained and over-widened streams potentially needing less reduction than finer-grained and more entrenched channels. Although available space and funding will limit the ability to fully reduce E in previously developed watersheds, these case studies underscore the value of using stormwater control measures to maximize reductions in E if geomorphic stability is a goal of stormwater interventions.

Citation

Hawley, R.J., K. Russell, K.T. Taniguchi-Quan. 2022. Restoring geomorphic integrity in urban streams via mechanistically-based storm water management: minimizing excess sediment transport capacity. *Urban Ecosystems* DOI:10.1007/s11252-022-01221-y.

SCCWRP Journal Article #1260
Full text available online: www.sccwrp.org/publications

Evaluation of hydrologic alteration to inform flow management decisions in south Orange County coastal watersheds

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[3]*County of Orange – OC Public Works, Orange, CA*

Citation

Taniguchi-Quan, K.T., K. Irving, R.A. Wildman Jr., A. Poresky, J.R. Feldman, E.D. Stein, A. Aprahamian, C. Rivers, G. Sharp. 2022. Evaluation of Hydrologic Alteration to Inform Flow Management Decisions in South Orange County Coastal Watersheds. Technical Report 1245. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1245
Full text available online: www.sccwrp.org/publications

Development and evaluation of the beta Streamflow Duration Assessment Method for the Western Mountains: Data supplement

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Citation

Mazor, R.D., B. Topping, T.L. Nadeau, K.M. Fritz, J. Kelso. 2022. Development and Evaluation of the Beta Streamflow Duration Assessment Method for the Western Mountains: Data Supplement. Technical Report 1222.B. U.S. Environmental Protection Agency. Washington, D.C.

SCCWRP Technical Report #1222.B
Full text available by online: www.sccwrp.org/publications

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User manual for a beta Streamflow Duration Assessment Method for the Great Plains of the United States – Version 1.0

Amy James[1], Tracie-Lynn Nadeau[2,3], Ken M. Fritz[4], Brian Topping[2], Rachel Fertik Edgerton[2], Julia Kelso[5], Raphael Mazor[6]

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[6]Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

James, A., T.L. Nadeau, K.M. Fritz, B. Topping, R.F. Edgerton, R.D. Mazor. 2022. User Manual for a Beta Streamflow Duration Assessment Method for the Great Plains of the United States - Version 1. 0.. Technical Report 1292. U.S. Environmental Protection Agency. Washington, D.C.

SCCWRP Technical Report #1292
Full text available online: www.sccwrp.org/publications

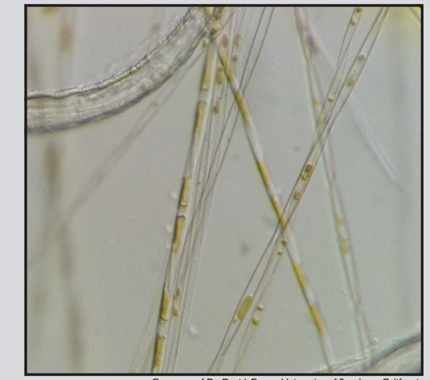
Tool developed to predict when, where toxic HABs will occur

SCCWRP and its partners have developed a computer model for predicting when and where toxins produced by a common type of marine algal bloom can be expected to occur along the California coast.

The model, developed in 2022, builds off preliminary modeling work by the University of California, Santa Cruz to understand the drivers and impacts of *Pseudo-nitzschia* blooms on coastal marine life.

Pseudo-nitzschia – among the most common types of marine algal blooms in California coastal waters – produces a neurotoxin known as domoic acid that can poison wildlife and humans who consume contaminated seafood.

Managers will be able to integrate the *Pseudo-nitzschia* model's predictions into California's existing predictive modeling capabilities, improving investigations of causal factors and existing forecasting capabilities – including daily published risk maps that outline the coastal areas most likely to experience domoic acid production. Ultimately, researchers' goal is to use such HAB forecasting tools to more precisely pinpoint the specific local and global environmental conditions that are driving production of toxic blooms.



Courtesy of Dr. David Caron, University of Southern California

Toxin-producing *Pseudo-nitzschia* cells, which appear above as long needle-like chains under a microscope, can dominate marine phytoplankton communities in Southern California coastal waters. Researchers have developed a new modeling tool to predict when and where toxins produced by *Pseudo-nitzschia* can be expected to occur along the California coast.

The *Pseudo-nitzschia* model expands the capabilities of an existing coastal ocean model that was developed by the same modeling team to predict how land-based nutrient discharges and changing climate conditions are affecting algal blooms, ocean acidification and hypoxia conditions in coastal waters.

Study provides statewide picture of when, where HABs are occurring in lakes, reservoirs

SCCWRP and its partners have successfully used satellite imaging data to build a comprehensive portrait of when and where ecologically disruptive harmful algal blooms (HABs) have been occurring in California's large lakes and reservoirs over the past five years.

The proof-of-concept study, completed in 2022 for the five years prior, illustrates how California can track HABs status and trends at the frequency and scale needed to effectively intervene to manage this growing environmental problem in lakes and reservoirs. California's HABs management efforts to date have been limited by patchy, sporadic HABs sampling efforts.

The study's findings can help managers understand when and where HABs threats are greatest, engage in long-term planning and prioritization, and consider developing policies and programs to minimize adverse environmental effects.

Foundation established for protecting sediment-dwellers in estuaries from organic matter

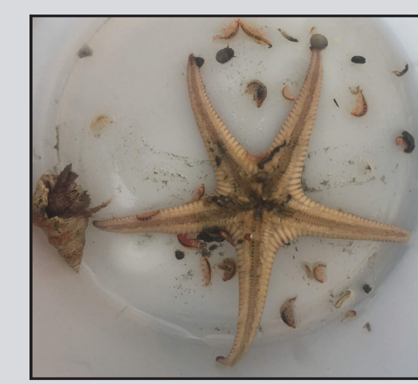
SCCWRP has developed a technical foundation for protecting sediment-dwelling organisms in California estuaries from the harmful effects of exposure to excess organic matter.

The technical work product, completed in 2022, consists of a set of nitrogen thresholds for estuary sediments that can clarify for managers when the estuary's sediment-dwelling invertebrate communities are likely to be adversely affected by excessive levels of degraded organic matter.

Measuring nitrogen levels is a way to estimate the amount of degraded organic matter in sediment. Excess levels of this organic matter can be toxic to aquatic life.

Already, California's coastal Regional Water Quality Control Boards have begun using the sediment nitrogen thresholds to guide development of TMDLs (total maximum daily loads) for nitrogen.

Managers also have used the thresholds to identify locations where high levels of degraded organic matter already exist, so that these areas can be targeted for cleanup.



SCCWRP has developed a technical foundation for protecting sediment-dwelling organisms, shown above, from the harmful effects of exposure to excess organic matter in California estuaries. The organic matter settles on the seafloor following eutrophication events.

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Eutrophication thresholds associated with protection of biological integrity in California wadable streams

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ABSTRACT

Eutrophication is one of the most pervasive stressors impacting streams, often leading to loss of biodiversity or change in natural functions. To protect against these adverse effects, managers can set targets for environmental indicators to limit eutrophication that are likely to maintain high biological integrity. To identify protective management targets, we evaluated the responses of three bioassessment indices (one for benthic macroinvertebrates and two for benthic algae assemblages) to five eutrophication indicators (total nitrogen [TN], total phosphorus [TP], benthic chlorophyll-a [chl-a], benthic ash-free dry mass [AFDM], and percent macroalgal cover [% cover] of the streambed). First, we used a bioassessment data set of 1249 sites in California to create logistic regression models of the likelihood of achieving several biointegrity goals for each index along increasing gradients of each indicator. Then, we evaluated eutrophication thresholds at concentrations corresponding to several relative probabilities (from 50 to 95 %), reflecting a range of policy makers' potential tolerance for risk of failing to meet biointegrity goals. Finally, we validated the thresholds with relative risk assessment, and identified the lowest validated threshold across the three indices. All eutrophication indicators were significantly associated with increased risks to biointegrity, resulting in a set of validated thresholds for each biointegrity goal. For example, thresholds of 0.24 mg/L TN, 0.05 mg/L TP, 44 mg/m^2 benthic chl-a, 2.5 mg/cm^2 AFDM, and 26 % cover would achieve index scores above the 10th percentile of reference (a biointegrity goal that has been used in certain regulatory applications) with an 80 % probability. If these thresholds were applied ambient monitoring statewide dataset, TN was the most pervasively exceeded threshold (37 % of sites), particularly within the highly agricultural Central Valley (76 %), although exceedances of TN and AFDM were also common in the urbanized South Coast region (68 % and 72 % of sites, respectively).

CITATION

Mazor, R.D., M. Sutula, S. Theroux, M. Beck, P.R. Ode. 2022. Eutrophication thresholds associated with protection of biological integrity in California wadeable streams. *Ecological Indicators* 142:109180.

SCCWRP Journal Article #1282
Full text available by request: pubrequest@sccwrp.org

Establishing biologically relevant sediment organic matter thresholds for estuaries and embayments of the Southern California Bight, USA

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ABSTRACT

Estuaries, lagoons, and embayments are key components of the coastal ecosystem and they are pervasively exposed to a variety of stressors – the most common of which is eutrophication. In shallow water coastal systems, eutrophication typically manifests as shifts in sediment oxygen horizons and accumulation of toxic reduced compounds in the porewater, which have direct, negative effects on the benthic fauna that live in these sediments. To catalog, prevent, and remediate these stressors, the coastal zone management community has expressed a need to identify targets for biostimulatory compounds and products in the environment that are protective of biological integrity of coastal waters. In response to this need, the present study identified and validated a series of sediment total organic carbon (TOC) and total nitrogen (TN) concentrations associated with changes in macrobenthic community composition across the estuaries and embayments of the Southern California Bight (SCB). Using data from a regional monitoring program, benthic community condition, quantified using the M-AMBI condition assessment index, was modelled as a function of TOC or TN concentration using logistic regression. Then, we evaluated eutrophication thresholds at concentrations corresponding to several relative probabilities (from 0.6 to 0.8), reflecting a range of policy makers' potential tolerance for risk of failing to meet biointegrity goals. Organic matter thresholds were extracted from the regressions that were predictive of healthy macrobenthic community condition at a 0.8 probability (1.23 mg g^−1 TN, 15.51 mg g^{-1} TOC), 0.7 probability (2.58 mg g^{-1} TN, 22.9 mg g^−1 TOC), or 0.6 probability (3.68 mg g^{-1} TN, 28.96 mg g^{-1} TOC) – as an illustration of how these types of stressor response models could be used to set targets for management of these ecosystems. These thresholds were subsequently validated by applying them to data held back from the model creation and by comparing them to taxon-specific inflection points identified from TITAN changepoint analysis of the macrobenthic/TOC/TN calibration data. The different TOC and TN thresholds correctly classified between 67 and 86% of the validation samples, with most of the misclassifications being instances of low organic matter concentration but poor community condition (i.e., false positives). The TOC thresholds identified from our Southern California dataset fell within a similar range (10–35 mg g^{-1}) that has been linked to benthic community impacts from a variety of coastal ocean sites across the Northern Hemisphere. The consistency in thresholds across multiple habitats and different types of biota is suggestive of a general, quantitative threshold for organic matter accumulation in near shore sediment habitats and could be useful for informing the management of coastal ecosystems and setting targets biostimulatory stressors in these systems.

CITATION

Walker, J.B., D.J. Gillett, M. Sutula. 2022. Establishing biologically relevant sediment organic matter thresholds for estuaries and embayments of the Southern California Bight, USA. *Ecological Indicators* 143:1-12.

SCCWRP Journal Article #1288
Full text available online: www.sccwrp.org/publications

Integrative monitoring strategy for marine and freshwater harmful algal blooms and toxins across the freshwater-to-marine continuum

Meredith D. A. Howard[1], Jayme Smith[2], David A. Caron[3], Raphael M. Kudela[4], Keith Loftin[5], Kendra Hayashi[4], Rich Fadness[6], Susan Fricke[7], Jacob Kann[8], Miranda Roethler[9], Avery Tatters[10], Susanna Theroux[2]

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[2]Southern California Coastal Water Research Project, Costa Mesa, CA
[3]University of Southern California, Los Angeles, California
[4]University of California, Santa Cruz, CA
[5]U.S. Geological Survey, Kansas Water Science Center, Lawrence, KS
[6]North Coast Regional Water Quality Control Board, Santa Rosa, CA
[7]Karuk Tribe, Happy Camp, CA
[8]Aquatic Ecosystem Sciences, Ashland, OR
[9]Miranda Roethler, University of Washington, Seattle, WA
[10]Avery Tatters, U.S. Environmental Protection Agency Gulf Ecosystem Measurement and Modeling Division Laboratory, Gulf Breeze, FL

ABSTRACT

Many coastal states throughout the USA have observed negative effects in marine and estuarine environments caused by cyanotoxins produced in inland waterbodies that were transported downstream or produced in the estuaries. Estuaries and other downstream receiving waters now face the dual risk of impacts from harmful algal blooms (HABs) that occur in the coastal ocean as well as those originating in inland watersheds. Despite this risk, most HAB monitoring efforts do not account for hydrological connections in their monitoring strategies and designs. Monitoring efforts in California have revealed the persistent detection of cyanotoxins across the freshwater-to-marine continuum. These studies underscore the importance of inland waters as conduits for the transfer of cyanotoxins to the marine environment and highlight the importance of approaches that can monitor across hydrologically connected waterbodies. A HAB monitoring strategy is presented for the freshwater-to-marine continuum to inform HAB management and mitigation efforts and address the physical and hydrologic challenges encountered when monitoring in these systems. Three main recommendations are presented based on published studies, new datasets, and existing monitoring programs. First, HAB monitoring would benefit from coordinated and cohesive efforts across hydrologically interconnected waterbodies and across organizational and political boundaries and jurisdictions. Second, a combination of sampling modalities would provide the most effective monitoring for HAB toxin dynamics and transport across hydrologically connected waterbodies, from headwater sources to downstream receiving waterbodies. Third, routine monitoring is needed for toxin mixtures at the land–sea interface including algal toxins of marine origins as well as cyanotoxins that are sourced from inland freshwater or produced in estuaries. Case studies from California are presented to illustrate the implementation of these recommendations, but these recommendations can also be applied to inland states or regions where the downstream receiving waterbody is a freshwater lake, reservoir, or river.

CITATION

Howard, M.D.A., J. Smith, D.A. Caron, R.M. Kudela, K. Loftin, K. Hayashi, R. Fadness, S. Fricke, J. Kann, M. Roethler, A. Tatters, S. Theroux. 2022. Integrative monitoring strategy for marine and freshwater harmful algal blooms and toxins across the freshwater-to-marine continuum. *Integrated Environmental Assessment and Management* DOI:10.1002/ieam.4651.

SCCWRP Journal Article #1279
Full text available online: www.sccwrp.org/publications

Development, calibration, and evaluation of a model *Pseudo-nitzschia* and domoic acid production for regional ocean modeling studies

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ABSTRACT

Pseudo-nitzschia species are one of the leading causes of harmful algal blooms (HABs) along the western coast of the United States. Approximately half of known *Pseudo-nitzschia* strains can produce domoic acid (DA), a neurotoxin that can negatively impact wildlife and fisheries and put human life at risk through amnesic shellfish poisoning. Production and accumulation of DA, a secondary metabolite synthesized during periods of low primary metabolism, is triggered by environmental stressors such as nutrient limitation. To quantify and estimate the feedbacks between DA production and environmental conditions, we designed a simple mechanistic model of *Pseudo-nitzschia* and domoic acid dynamics, which we validate against batch and chemostat experiments. Our results suggest that, as nutrients other than nitrogen (i.e., silicon, phosphorus, and potentially iron) become limiting, DA production increases. Under Si limitation, we found an approximate doubling in DA production relative to N limitation. Additionally, our model indicates a positive relationship between light and DA production. These results support the idea that the relationship with nutrient limitation and light is based on direct impacts on *Pseudo-nitzschia* biosynthesis and biomass accumulation. Because it can easily be embedded

within existing coupled physical-ecosystem models, our model represents a step forward toward modeling the occurrence of *Pseudo-nitzschia* HABs and DA across the U.S. West Coast.

Citation

Moreno, A.R., C. Anderson, R.M. Kudela, M. Sutula, C. Edwards, D. Bianchi. 2022. Development, calibration, and evaluation of a model *Pseudo-nitzschia* and domoic acid production for regional ocean modeling studies. *Harmful Algae* 118:102296.

SCCWRP Journal Article #1291
Full text available online: www.sccwrp.org/publications

Reduced representation sequencing accurately quantified relative abundance and reveals population-level variation in *Pseudo-nitzchia spp.*

Carly D. Kenkel[1], Jayme Smith[2], Katherine A. Hubbard[3,4], Christina Chadwick[3], Nico Lorenzen[1], Avery O. Tatters[5], David A. Caron[1]

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[2]Southern California Coastal Water Research Project, Costa Mesa, CA,
[3]Florida Fish and Wildlife Conservation Commission-Fish and Wildlife Research Institute, St. Petersburg, FL
[4]Biology Department, Woods Hole Oceanographic Institution, Woods Hole, MA
[5]U.S. Environmental Protection Agency, Gulf Ecosystem Measurement and Modeling Division, Gulf Breeze, FL

Abstract

Certain species within the genus *Pseudo-nitzschia* are able to produce the neurotoxin domoic acid (DA), which can cause illness in humans, mass-mortality of marine animals, and closure of commercial and recreational shellfisheries during toxic events. Understanding and forecasting blooms of these harmful species is a primary management goal. However, accurately predicting the onset and severity of bloom events remains difficult, in part because the underlying drivers of bloom formation have not been fully resolved. Furthermore, *Pseudonitzschia* species often co-occur, and recent work suggests that the genetic composition of a *Pseudo-nitzschia* bloom may be a better predictor of toxicity than prevailing environmental conditions. We developed a novel next-generation sequencing assay using restriction site-associated DNA (2b-RAD) genotyping and applied it to mock *Pseudo-nitzschia* communities generated by mixing cultures of different species in known abundances. On average, 94% of the variance in observed species abundance was explained by the expected abundance. In addition, the false positive rate was low (0.45% on average) and unrelated to read depth, and false negatives were never observed. Application of this method to environmental DNA samples collected during natural *Pseudonitzschia spp.* bloom events in Southern California revealed that increases in DA were associated with increases in the relative abundance of *P. australis*. Although the absolute correlation across time-points was weak, an independent species fingerprinting assay (Automated Ribosomal Intergenic Spacer Analysis) supported this and identified other potentially toxic species. Finally, we assessed population-level genomic variation by mining SNPs from the environmental 2bRAD dataset. Consistent shifts in allele frequencies in *P. pungens* and *P. subpacifica* were detected between high and low DA years, suggesting that different intraspecific variants may be associated with prevailing environmental conditions or the presence of DA. Taken together, this method presents a potentially cost-effective and high-throughput approach for studies aiming to evaluate both population and species dynamics in mixed samples.

Citation

Kenkel, C.D., J. Smith, K.A. Hubbard, C. Chadwick, N. Lorenzen, A.O. Tatters, D.A. Caron. 2022. Reduced representation sequencing accurately quantifies relative abundance and reveals population-level variation in *Pseudo-nitzschia ssp. Harmful Algae* 118:1-13.

SCCWRP Journal Article #1287
Full text available by request: pubrequest@sccwrp.org

Daily dynamics of contrasting spring algal blooms in Santa Monica Bay (central Southern California Bight)

Gerid A. Ollison[1], Sarah K. Hu[2], Julie V. Hopper[1], Brittany P. Stewart[1], Jayme Smith[3], Jennifer L. Beatty[1], Laura K. Rink[4], David A. Caron[1]

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[2]Woods Hole Oceanographic Institution, Marine Chemistry and Geochemistry, Woods Hole, MA
[3]Southern California Coastal Water Research Project, Costa Mesa, CA
[4]Heal the Bay Aquarium, Santa Monica, CA

Abstract

Protistan algae (phytoplankton) dominate coastal upwelling ecosystems where they form massive blooms that support the world's most important fisheries and constitute an important sink for atmospheric CO_2. Bloom initiation is well understood, but the biotic and abiotic forces that shape short-term dynamics in community composition are still poorly characterized. Here, high-frequency (daily) changes in relative abundance dynamics of the metabolically active protistan community were followed via expressed 18S V4 rRNA genes (RNA) throughout two algal blooms during the spring of 2018 and 2019 in Santa Monica Bay (central Southern California Bight). A diatom bloom formed after wind-driven, nutrient upwelling events in both years, but different taxa dominated each year. Whereas diatoms bloomed following elevated nutrients and declined after depletion each year, a massive dinoflagellate bloom manifested under relatively low inorganic nitrogen conditions following diatom bloom senescence in 2019 but not 2018. Network analysis revealed associations between diatoms and cercozoan putative parasitic taxa and syndinean parasites during 2019 that may have influenced the demise of the diatoms, and the transition to a dinoflagellate-dominated bloom.

Citation

Ollison, G.A., S.K. Hu, J.V. Hopper, B.P. Stewart, J. Smith, J.L. Beatty, L.K. Rink, D.A. Caron. 2022. Daily dynamics of contrasting spring algal blooms in Santa Monica Bay (Central Southern California Bight). *Environmental Microbiology* 2022:1-19.

SCCWRP Journal Article #1278
Full text available online: www.sccwrp.org/publications

Science supporting decisions on management of eutrophication in Elkhorn Slough estuary

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[1]Southern California Coastal Water Research Project, Costa Mesa, CA
[2]Tetra Tech, Lafayette, CA

Citation

Sutula, M., J. Butcher, S. Sarkar, S. Roy. 2022. Science Supporting Decisions on Management of Eutrophication in Elkhorn Slough Estuary. Technical Report 1259. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1259
Full text available online: www.sccwrp.org/publications

Environmental drivers of cyanobacterial harmful algal blooms and cyanotoxins in Clear Lake: 2020-2021

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[1]University of Southern California, Los Angeles, CA
[2]Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Florea, K., B. Stewart, E. Webb, D.A. Caron, J. Smith. 2022. Environmental Drivers of Cyanobacterial Harmful Algal Blooms and Cyanotoxins in Clear Lake: 2020-2021. Technical Report 1261. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1261
Full text available online: www.sccwrp.org/publications

Science supporting decisions on biostimulatory targets and management of eutrophication in the main stem of the Santa Margarita River watershed

Martha Sutula[1], Jonathan Butcher[2], Michelle Schmidt[2], Clint Boschen[2], Raphael Mazor[1], David Gillett[1], Kris Taniguchi-Quan[1], Katie Irving[1], Dana Shultz[1]

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[2]Tetra Tech, San Diego, CA

Citation

Sutula, M., J. Butcher, M. Schmidt, C. Boschen, R.D. Mazor, D.J. Gillett, K.T. Taniguchi-Quan, K. Irving, D. Shultz. 2022. Science Supporting Decisions on Biostimulatory Targets and Management of Eutrophication in the Main Stem of the Santa Margarita River Watershed. Technical Report 1185. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1185
Full text available online: www.sccwrp.org/publications

Acidification modeling examines potential management actions

SCCWRP and its partners have completed a preliminary set of analyses probing whether Southern California's water-quality management community could mitigate the ecological effects of coastal ocean acidification and hypoxia (OAH) by investing in a combination of nutrient reduction strategies and wastewater recycling practices.

The preliminary analyses, completed in 2022, involved running computer modeling simulations for eight different management scenarios on a supercomputer – a data-intensive simulation that took about six months.

The coastal OAH modeling tools were originally developed by a team of West Coast researchers that includes SCCWRP to examine how OAH will change coastal seawater chemistry in the future, including reducing the availability of dissolved oxygen and biologically important seawater minerals.

After the simulations were completed, researchers applied a suite of newly developed OAH biological assessment tools to the modeling results to examine if one or more of the eight management intervention scenarios could be expected to reduce OAH's biological effects on sensitive marine life. The preliminary modeling results were shared with stakeholders.

OAH is expected to increasingly constrain where across the coastal ocean that vulnerable marine species can survive. In particular, shell-forming organisms such as pteropods, or sea snails, will have a tougher time building their shells – an effect that could ripple through marine food webs.

Pteropods are among the organisms vulnerable to ocean acidification. Researchers have begun examining whether managers could mitigate potential ecological effects of coastal acidification by investing in nutrient reduction strategies and wastewater recycling practices.

Initial phase of ocean health report card developed for California managers

The California Ocean Protection Council (OPC) has released the first phase of a multi-component ocean health report card designed to provide managers and policymakers with comprehensive annual snapshots about the condition of California's coastal ocean.

The report card, published in the agency's 2022 State of the California Ocean and Coast Report, consists of narrative summaries across nine indicators, including fecal contamination, ocean acidification, marine mammals and kelp forests.

The partial report card enables California to begin tracking its progress toward meeting long-term management goals around protecting coastal ocean health.

The OPC effort parallels a complementary report card being developed for the U.S. West Coast by the West Coast Ocean Alliance (WCOA). SCCWRP is helping to craft several of the OPC report card's condition indicators and co-leading the team developing WCOA's indicators.

Both OPC and WCOA plan to release full report cards in 2025.

Courtesy of Occidental College Vantuna Research Group

SCCWRP is helping the California Ocean Protection Council and the West Coast Ocean Alliance to develop coastal ocean health report cards to provide managers with comprehensive annual snapshots about the condition of multiple indicators of ocean health, including kelp forests, above.

Tijuana River sediment fluxes estimated for effort to improve sediment management practices

SCCWRP and San Diego State University have successfully estimated the sediment fluxes being discharged from the Tijuana River at the U.S.-Mexico border to its coastal estuarine terminus – a key step in an ongoing effort to improve sediment management practices to mitigate the adverse ecological effects of these fluxes.

The two-year study, completed in 2022, is supporting an ongoing Tijuana River demonstration project intended to showcase how a more integrated approach to sediment management could improve outcomes for downstream coastal environments.

The project will use computer modeling to explain how interactions between sediment fluxes and the surrounding environment will respond to sea level rise and climate change.

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Enhancement of oceanic eddy activity by fine-scale orographic winds drives high productivity, low oxygen, and low pH conditions in the Santa Barbara Channel

Fayçal Kessouri[1,2], Lionel Renault[3], James C. McWilliams[2], Pierre Damien[2], Daniele Bianchi[2]

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[3]*University of Toulouse, Toulouse, France*

Abstract

The Santa Barbara Channel is one of the most productive regions of the California Current System. Yet, the physical processes that sustain this high productivity remain unclear. We use a high-resolution physical-biogeochemical model to show that submesoscale eddies generated by islands are energized by orographic effects on the wind, with significant impacts on nutrient, carbon, and oxygen cycles. These eddies are modulated by two co-occurring air-sea-land interactions: transfer of wind energy to ocean currents that intensifies ocean eddies, and a wind-current feedback that tends to dampen them. Here we show that the dampening is overwhelmed by fine scale wind patterns induced by the presence of surrounding capes and islands. The fine-scale winds cause an additional transfer of momentum from the atmosphere to the ocean that energizes submesoscale eddies. This drives upward doming of isopycnals in the center of the channel, allowing a more efficient injection of nutrients to the surface, and triggering intense phytoplankton blooms that nearly double productivity relative to the case without fine-scale winds. The intensification of the doming effect by the wind-curl and submesoscale eddies pumps deep low oxygen, acidic waters to the center of the cyclonic eddies. These eddies are then transported away from the Channel into the California Current, where they impact a wider area along the central coast, with potential ecological consequences. Our study highlights the important role of air-sea-land interactions in modulating coastal processes, and suggests that submesoscale resolving models are required to correctly represent coastal processes and their ecological impacts.

Citation

Kessouri, F., L. Renault, J.C. McWilliams, P. Damien, D. Bianchi. 2022. Enhancement of Oceanic Eddy Activity by Fine-Scale Orographic Winds Drives High Productivity, Low Oxygen, and Low pH Conditions in the Santa Barbara Channel. *Journal of Geophysical Research: Oceans* 127:1-14.

SCCWRP Journal Article #1299
Full text available by request: pubrequest@sccwrp.org

Oxygen budget of the north-western Mediterranean deep-convection region

Caroline Ulses[1,2], Claude Estournel[1], Marine Fourrier[3], Laurent Coppola[3], Fayçal Kessouri[2,4], Dominique Lefèvre[5], Patrick Marsaleix[1]

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[3]*Laboratoire d'Océanographie de Villefranche, Sorbonne Université, Villefranche-sur-Mer, France*
[4]*Southern California Coastal Water Research Project, Costa Mesa, CA*
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Abstract

The north-western Mediterranean deep convection plays a crucial role in the general circulation and biogeochemical cycles of the Mediterranean Sea. The DEWEX (DEnse Water EXperiment) project aimed to better understand this role through an intensive observation platform combined with a modelling framework. We developed a three-dimensional coupled physical and biogeochemical model to estimate the cycling and budget of dissolved oxygen in the entire north-western Mediterranean deep-convection area over the period September 2012 to September 2013. After showing that the simulated dissolved oxygen concentrations are in a good agreement with the in-situ data collected from research cruises and Argo floats, we analyse the seasonal cycle of the air–sea oxygen exchanges, as well as physical and biogeochemical oxygen fluxes, and we estimate an annual oxygen budget. Our study indicates that the annual air-to-sea fluxes in the deep-convection area amounted to 20 mol $m^{-2} yr^{-1}$. A total of 88% of the annual uptake of atmospheric oxygen, i.e. 18 mol m^{-2}, occurred during the intense vertical mixing period. The model shows that an amount of 27 mol m^{-2} of oxygen, injected at the sea surface and produced through photosynthesis, was transferred under the euphotic layer, mainly during deep convection. An amount of 20 mol m^{-2} of oxygen was then gradually exported in the aphotic layers to the south and west of the western basin, notably, through the spreading of dense waters recently formed. The decline in the deep-convection intensity in this region predicted by the end of the century in recent projections may have important consequences on the overall uptake of atmospheric oxygen in the Mediterranean Sea and on the oxygen exchanges with the Atlantic Ocean, which appear necessary to better quantify in the context of the expansion of low-oxygen zones.

Citation

Ulses, C., C. Estournel, M. Fourrier, L. Coppola, F. Kessouri, D. Lefevre, P. Marsaleix. 2021. Oxygen budget of the north-western Mediterranean deep-convection region. *Biogeosciences* 18:937-960.

SCCWRP Journal Article #1178
Full text available online: www.sccwrp.org/publications

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The multi-decadal simulation of marsh topography under sea level rise and episodic sediment loads

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Abstract

Coastal marsh within Mediterranean climate zones is exposed to episodic watershed runoff and sediment loads that occur during storm events. Simulating future marsh accretion under sea level rise calls for attention to: (a) physical processes acting over the time scale of storm events and (b) biophysical processes acting over time scales longer than storm events. Using the upper Newport Bay in Southern California as a case study, we examine the influence of event-scale processes on simulated change in marsh topography by comparing: (a) a biophysical model that integrates with an annual time step and neglects event-scale processes (BP-Annual), (b) a physical model that resolves event-scale processes but neglects biophysical interactions (P-Event), and (c) a biophysical model that resolves event-scale physical processes and biophysical processes at annual and longer time scales (BP-Event). A calibrated BP-Event model shows that large (>20-year return period) episodic storm events are major drivers of marsh accretion, depositing up to 30 cm of sediment in one event. Greater deposition is predicted near fluvial sources and tidal channels and less on marshes further from fluvial sources and tidal channels. In contrast, the BP-Annual model poorly resolves spatial structure in marsh accretion as a consequence of neglecting event-scale processes. Furthermore, the P-Event model significantly overestimates marsh accretion as a consequence of neglecting marsh surface compaction driven by annual scale biophysical processes. Differences between BP-Event and BP-Annual models translate up to 20 cm per century in marsh surface elevation.

Citation

Brand, M.W., K. Buffington, J.B. Rogers, K. Thorne, E.D. Stein, B.F. Sanders. 2022. The Multi-Decadal Simulation of Marsh Topography Under Sea Level Rise and Episodic Sediment Loads. *Journal of Geophysical Research* 127:1-20.

SCCWRP Journal Article #1286
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Human and ecosystem health in coastal systems

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Abstract

U.S. coastal economies and communities are facing an unprecedented and growing number of impacts to coastal ecosystems including beach and fishery closures, harmful algal blooms, loss of critical habitat, as well as shoreline damage. This paper synthesizes our present understanding of the dynamics of human and ecosystem health in coastal systems with a focus on the need to better understand nearshore physical process interactions with coastal pollutants and ecosystems (e.g. fate and transport, circulation, depositional environment, climate change). It is organized around two major topical areas and six subtopic areas: 1) Identifying and mitigating coastal pollutants, including fecal pollution, nutrients and harmful algal blooms, and microplastics; and 2) Resilient coastal ecosystems, which focuses on coastal fisheries, shellfish and natural and nature-based features (NNBF). Societal needs and the tools and technologies needed to address them are discussed for each subtopic. Recommendations for scientific research, observations, community engagement, and policies aim to help prioritize future research and investments. A better understanding of coastal physical processes and interactions with coastal pollutants and resilient ecosystems (e.g. fate and transport, circulation, depositional environment, climate change) is a critical need. Other research recommendations include the need to quantify potential threats to human and ecosystem health through accurate risk assessments and to quantify the resulting hazard risk reduction of natural and nature-based features; improve pollutant and ecosystem impacts forecasting by integrating frequent and new data points into existing and novel models; collect environmental data to calibrate and validate models to predict future impacts on coastal ecosystems and their evolution due to anthropogenic stressors (land-based pollution, overfishing, coastal development), climate change, and sea level rise; and develop lower cost and rapid response tools to help coastal managers better respond to pollutant and ecosystem threats.

Citation

Elko, N., D. Foster, G. Kleinheinz, B. Raubenheimer, S. Brander, J. Kinzelman, J.P. Kritzer, D. Munroe, C. Storlazzi, M. Sutula, A. Mercer, S. Coffin, C. Fraioli, L. Ginger, E. Morrison, G. Parent-Doliner, C. Akan, A. Canestrelli, M. DiBenedetto, J. Lang, J. Simm. 2022. Human and ecosystem health in coastal systems. *Shore & Beach* 90:64-91.

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Restoration in the context of climate change

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Abstract

Climate change represents an existential threat to many aspects of the South Florida ecosystem and the people who value and rely on it. The committee discussed the need to consider rise in sea ,level, change in precipitation patterns, and increasing temperature conditions in several previous reports (NASEM, 2016, 2018, 2021; NRC, 2014). In this chapter the committee reiterates many of the concerns expressed in previous reports and focuses on how climate change and variability can pose risks to the Comprehensive Everglades Restoration Plan (CERP) at various stages of its development and implementation. The committee offers the current Biscayne Bay Southern Everglades Ecosystem Restoration (BBSEER) project as an example of the critical need to consider climate change in planning. Next, the committee discusses how some aspects of climate change can influence the operations of CERP projects, highlighting the Lake Okeechobee operations, and reviews the role of System Operating Manuals in efforts to adapt to climate change. Finally, the committee describes the programmatic implications of recent and future changes in climate and how they influence the ecosystem if they are not meaningfully considered. As the CERP pivots from planning to operating projects to optimize ecosystem responses, both at a project and system scale, it becomes even more important to make climate change a central consideration in all aspects of the CERP to ensure that the nation's investments in restoration continue to reap benefits for decades to come.

Citation

Reed, D.J., C. Brown , A.D. Steinman, M.A. Sutula, D.H. Wardrop. 2022. Restoration in the Context of Climate Change. in: National Academies of Sciences, Engineering, and Medicine (ed.), *Progress Toward Restoring the Everglades: The Ninth Biennial Review—2022* pp. 137-168. The National Academies Press. Washington, D.C.

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Aquatic resource type conversion evaluation framework – Version 2.0

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Citation

Stein, E.D., J.S. Brown, J.D. Siu. 2022. Aquatic Resource Type Conversion Evaluation Framework Version 2.0. Technical Report 1110. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1110
Full text available online: www.sccwrp.org/publications

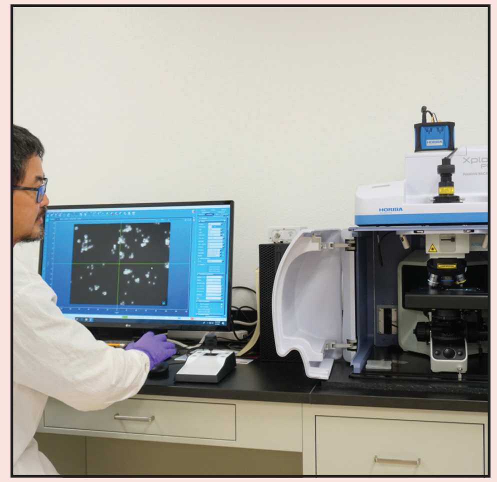
Climate Change Accomplishments

SCCWRP helps establish basis for microplastics management

A series of international SCCWRP-facilitated scientific studies and workshops that have examined how to better monitor microplastics contamination and assess its ecological consequences has helped form the scientific foundation for a pair of statewide actions that has helped solidify California's place as a global leader in managing microplastic pollution.

First, the California Ocean Protection Council in February 2022 published a statewide microplastics strategy for the coastal ocean that calls for a coordinated, multi-pronged series of actions to combat microplastics pollution. A number of the research recommendations outlined in the draft strategy were informed by an international, SCCWRP-facilitated scientific workshop that developed expert consensus on the critical thresholds at which aquatic organisms begin to experience adverse biological effects from microplastics exposure.

Second, the State Water Resources Control Board in September 2022 approved a policy requiring drinking water facilities in California to monitor microplastics for four years; the policy is based largely on an international SCCWRP-facilitated study that developed best-practices recommendations for measuring and monitoring microplastics in drinking water.



SCCWRP's Dr. Wayne Lao uses a Raman spectroscopy instrument to examine microplastic particles in a water sample. SCCWRP has helped California build a scientific foundation for how to improve monitoring of microplastics contamination and assess its ecological consequences.

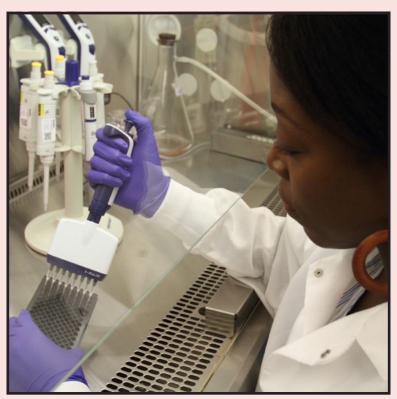
California's experience with bioanalytical screening informs international guidance

California's recent experiences incorporating bioanalytical screening technology into recycled-water monitoring programs are prominently featured in a new set of international guidance documents intended to promote adoption of the technology across the European Union and other parts of the world.

The guidance documents – unveiled in 2022 by the international Global Water Research Coalition (GWRC) – cover sampling strategies, selection and application of relevant bioanalytical tools, and interpretation and monitoring of trigger levels. SCCWRP's Dr. Alvina Mehinto contributed to the documents as a member of the project's international nine-member advisory group.

California is the first in the world to require the use of bioanalytical screen technology for monitoring recycled water for potable reuse.

The Organization for Economic Co-operation and Development (OECD) has begun discussing how to use the GWRC workshop's products to recommend development of policy around bioanalytical screening technology. During a 2022 workshop, SCCWRP shared perspectives with OECD on implementing the tools.



SCCWRP's Dr. Alvina Mehinto transfers cells into assay wells for a bioanalytical screening test. A new set of guidance documents intended to promote international adoption of bioanalytical screening technology prominently incorporates California's recent experiences using the technology.

Study shows how to use bioanalytical screening to monitor sediment contamination

SCCWRP and its partners have completed a three-year effort to demonstrate how bioanalytical screening technology can be incorporated into the Southern California Bight 2018 Regional Monitoring Program to help track the ecological impacts of CECs in coastal sediment.

The study, published in 2022, involved screening Bight '18 sediment samples using a trio of bioanalytical cell assays that SCCWRP has been working to adapt for routine environmental monitoring.

Researchers found that bioanalytical screening serves as a valuable additional line of evidence to assess chemical exposure and to detect chemicals not being routinely monitored.

During the study, researchers subsequently used non-targeted chemical analysis to confirm the presence of other chemicals not being measured via targeted chemistry analysis, and to identify potential toxicants.

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Quantitative assessment of visual microscopy as a tool for microplastic research: Recommendations for improving methods and reporting

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Abstract

Microscopy is often the first step in microplastic analysis and is generally followed by spectroscopy to confirm material type. The value of microscopy lies in its ability to provide count, size, color, and morphological information to inform toxicity and source apportionment. To assess the accuracy and precision of microscopy, we conducted a method evaluation study. Twenty-two laboratories from six countries were provided three blind spiked clean water samples and asked to follow a standard operating procedure. The samples contained a known number of microplastics with different morphologies (fiber, fragment, sphere), colors (clear, white, green, blue, red, and orange), polymer types (PE, PS, PVC, and PET), and sizes (ranging from roughly 3–2000 µm), and natural materials (natural hair, fibers, and shells; 100–7000 µm) that could be mistaken for microplastics (i.e., false positives). Particle recovery was poor for the smallest size fraction (3–20 µm). Average recovery (±StDev) for all reported particles >50 µm was 94.5 ± 56.3%. After quality checks, recovery for >50 µm spiked particles was 51.3 ± 21.7%. Recovery varied based on morphology and color, with poorest recovery for fibers and the largest deviations for clear and white particles. Experience mattered; less experienced laboratories tended to report higher concentration and had a higher variance among replicates. Participants identified opportunity for increased accuracy and precision through training, improved color and morphology keys, and method alterations relevant to size fractionation. The resulting data informs future work, constraining and highlighting the value of microscopy for microplastics.

Citation

Kotar, S., R. McNeish, C. Murphy-Hagan, V. Renick, C.T. Lee, C. Steele, A. Lusher, C. Moore, E. Minor, J. Schroeder, P. Helm, K. Rickabaugh, H.D. Frond, K. Gesulga, W. Lao, K. Munno, L.M. Thornton Hampton, S.B. Weisberg, C.S. Wong, G. Amarpuri, R.C. Andrews, S.M. Barnett, S. Christiansen, W. Cowger, K. Crampond, F. Du, A.B. Gray, J. Hankett, K. Ho, J. Jaeger, C. Lilley, L. Mai, O. Mina, E. Lee, S. Primpke, S. Singh, J. Skovly, T. Slifko, S. Sukumaran, B. Bavel, J.V. Brocklin, F. Vollnhals, C. Wu, C.M. Rochman . 2022. Quantitative assessment of visual microscopy as a tool for microplastic research: Recommendations for improving methods and reporting. *Chemosphere* 308:1-9.

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Full text available by request: pubrequest@sccwrp.org

Monitoring microplastics in drinking water: An interlaboratory study to inform effective methods for quantifying and characterizing microplastics

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Abstract

California Senate Bill 1422 requires the development of State-approved standardized methods for quantifying and characterizing microplastics in drinking water. Accordingly, we led an interlaboratory microplastic method evaluation study, with 22 participating laboratories from six countries,

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to evaluate the performance of widely used methods: sample extraction via filtering/sieving, optical microscopy, FTIR spectroscopy, and Raman spectroscopy. Three spiked samples of simulated clean water and a laboratory blank were sent to each laboratory with a prescribed standard operating procedure for particle extraction, quantification, and characterization. The samples contained known amounts of microparticles within four size fractions (1–20 μm, 20–212 μm, 212–500 μm, >500 μm), four polymer types (PE, PS, PVC, and PET), and six colors (clear, white, green, blue, red, and orange). They also included false positives (natural hair, fibers, and shells) that may be mistaken for microplastics. Among laboratories, mean particle recovery using stereomicroscopy was 76% ± 10% (SE). For particles in the three largest size fractions, mean recovery was 92% ± 12% SD. On average, laboratory contamination from blank samples was 91 particles (± 141 SD). FTIR and Raman spectroscopy accurately identified microplastics by polymer type for 95% and 91% of particles analyzed, respectively. Per particle, FTIR spectroscopy required the longest time for analysis (12 min ± 9 SD). Participants demonstrated excellent recovery and chemical identification for particles greater than 50 μm in size, with opportunity for increased accuracy and precision through training and further method refinement. This work has informed methods and QA/QC for microplastics monitoring in drinking water in the State of California.

Citation

De Frond, H., L.M. Thornton Hampton, S. Kotar, K. Gesulga, C. Matuch, W. Lao, S.B. Weisberg, C.S. Wong, C.M. Rochman. 2022. Monitoring microplastics in drinking water: An interlaboratory study to inform effective methods for quantifying and characterizing microplastics. *Chemosphere* 298:134282.

SCCWRP Journal Article #1256
Full text available by request: pubrequest@sccwrp.org

Current state of microplastic pollution research data: Trends in availability and sources of open data

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Abstract

The rapid growth in microplastic pollution research is influencing funding priorities, environmental policy, and public perceptions of risks to water quality and environmental and human health. Ensuring that environmental microplastics research data are findable, accessible, interoperable, and reusable (FAIR) is essential to inform policy and mitigation strategies. We present a bibliographic analysis of data sharing practices in the environmental microplastics research community, highlighting the state of openness of microplastics data. A stratified (by year) random subset of 785 of 6,608 microplastics articles indexed in Web of Science indicates that, since 2006, less than a third (28.5%) contained a data sharing statement. These statements further show that most often, the data were provided in the articles' supplementary material (38.8%) and only 13.8% via a data repository. Of the 279 microplastics datasets found in online data repositories, 20.4% presented only metadata with access to the data requiring additional approval. Although increasing, the rate of microplastic data sharing still lags behind that of publication of peer-reviewed articles on environmental microplastics. About a quarter of the repository data originated from North America (12.8%) and Europe (13.4%). Marine and estuarine environments are the most frequently sampled systems (26.2%); sediments (18.8%) and water (15.3%) are the predominant media. Of the available datasets accessible, 15.4% and 18.2% do not have adequate metadata to determine the sampling location and media type, respectively. We discuss five recommendations to strengthen data sharing practices in the environmental microplastic research community.

Citation

Jenkins, T., B.D. Persaud, W. Cowger, K. Szigeti, D.G. Roche, E. Clary, S. Slowinski, B. Lei, A. Abeynayaka, E.S. Nyadjro, T. Maes, L.M. Thornton Hampton, M. Bergmann, J. Aherne, A.S. Mason, J.F. Honek, F. Rezanezhad, A.L. Lusher, A.M. Booth, R.D.L. Smith, P. Van Cappellan. 2022. Current State of Microplastic Pollution Research Data: Trends in Availability and Sources of Open Data. *Frontiers in Environmental Science* 10:912107.

SCCWRP Journal Article #1276
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Understanding health effects pathways and thresholds: Filling a critical need to support microplastics management

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Abstract

Microplastics are pervasive in the aqueous environment, having been reported in air, lakes, ocean, drinking water, sediment, snow, animals, and even humans. Since plastic pollution was first documented in the marine environment in the 1970's, production has increased more than 10-fold, and inputs into the environment are expected to triple over the next ~ 20 years. Since plastic degrades over extremely long timescales and is ingested, inhaled, or absorbed throughout the food chain from microscopic organisms to humans, contamination is causing increasing concern for environmental managers. Many animals cannot distinguish microplastics from food, creating the potential for satiation challenges that can lead to decreased growth, reproduction, and survival. Once microplastics enter food webs, they can be consumed by humans through seafood and other means. Compounding the bioaccumulation challenge and toxicity of plastic particles by themselves is that plastics can serve as vectors for added chemicals and attached pathogens, creating a potential exposure pathway for multiple types of contaminants. Additionally, the smallest microplastics can penetrate the gut wall and accumulate in tissues that obstruct organ function.

Citation

Coffin, S., S.B. Weisberg. 2022. Understanding health effects pathways and thresholds: filling a critical need to support microplastics management. *Microplastics and Nanoplastics* 2:11.

SCCWRP Journal Article #1267
Full text available online: www.sccwrp.org/publications

Risk characterization of microplastics in San Francisco Bay, California

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Abstract

Assessing microplastics risk to aquatic ecosystems has been limited by lack of holistic exposure data and poor understanding of biological response thresholds. Here we take advantage of two recent advances, a toxicological meta-analysis that produced biotic response thresholds and a method to quantitatively correct exposure data for sampling methodology biases, to assess microplastic exposure risk in San Francisco Bay, California, USA. Using compartment-specific particle size abundance data, we rescaled empirical surface water monitoring data obtained from manta trawls (> 333 μm) to a broader size (1 to 5000 μm) range, corrected for biases in fiber undercounting and spectroscopic subsampling, and assessed the introduced uncertainty using probabilistic methods. We then compared these rescaled concentrations to four risk thresholds developed to inform risk management for California for each of two effect categories/mechanisms - tissue translocation-mediated effects and food dilution - each aligned to ecologically relevant dose metrics of surface area and volume, respectively. More than three-quarters of samples exceeded the most conservative food dilution threshold, which rose to 85% when considering just the Central Bay. Within the Central Bay, 38% of the samples exceeded a higher threshold associated with management planning, which was statistically significant at the 95% confidence interval. For tissue translocation-mediated effects, no samples exceeded any threshold with statistical significance. The risk associated with food dilution is higher than that found in other systems, which likely reflects this study having been conducted for an enclosed water body. A sensitivity analysis indicated that the largest contributor to assessment variability was associated with estimation of ambient concentration exposure due to correcting for fiber undercounting. Even after compensating for biases associated with fibers and other small particles, concentrations from the trawl samples were still significantly lower than the 1-L grab samples taken at the same time, suggesting our SFB risk estimates are an underestimate. We chose to rely on the trawl data because the 1-L grab sample volume was too small to provide accurate spatial representation, but future risk characterization studies would be improved by using in-line filtration pumps that sample larger volumes while capturing a fuller range of particle size than a towed net.

Citation

Coffin, S., S.B. Weisberg, C. Rochman, M. Kooi, A.A. Koelmans. 2022. Risk Characterization of Microplastics in San Francisco Bay, California. *Microplastics and Nanoplastics* 2:19.

SCCWRP Journal Article #1284
Full text available online: www.sccwrp.org/publications

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Characterizing microplastic hazards: Which concentration metrics and particle characteristics are most informative for understanding toxicity in aquatic organisms?

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Abstract

There is definitive evidence that microplastics, defined as plastic particles less than 5 mm in size, are ubiquitous in the environment and can cause harm to aquatic organisms. These findings have prompted legislators and environmental regulators to seek out strategies for managing risk. However, microplastics are also an incredibly diverse contaminant suite, comprising a complex mixture of physical and chemical characteristics (e.g., sizes, morphologies, polymer types, chemical additives, sorbed chemicals, and impurities), making it challenging to identify which particle characteristics might influence the associated hazards to aquatic life. In addition, there is a lack of consensus on how microplastic concentrations should be reported. This not only makes it difficult to compare concentrations across studies, but it also begs the question as to which concentration metric may be most informative for hazard characterization. Thus, an international panel of experts was convened to identify 1) which concentration metrics (e.g., mass or count per unit of volume or mass) are most informative for the development of health-based thresholds and risk assessment and 2) which microplastic characteristics best inform toxicological concerns. Based on existing knowledge, it is recommended that microplastic concentrations in toxicity tests are calculated from both mass and count at minimum, though ideally researchers should report additional metrics, such as volume and surface area, which may be more informative for specific toxicity mechanisms. Regarding particle characteristics, there is sufficient evidence to conclude that particle size is a critical determinant of toxicological outcomes, particularly for the mechanisms of food dilution and tissue translocation.

Citation

Thornton Hampton, L.M., S.M. Brander, S. Coffin, M. Cole, L. Hermabessiere, A.A. Koelmans, C.M. Rochman. 2022. Characterizing microplastic hazards: which concentration metrics and particle characteristics are most informative for understanding toxicity in aquatic organisms? *Microplastics and Nanoplastics* 2:20.

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Research recommendations to better understand the potential health impacts of microplastics to humans and aquatic ecosystems

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Abstract

To assess the potential risk of microplastic exposure to humans and aquatic ecosystems, reliable toxicity data is needed. This includes a more complete foundational understanding of microplastic toxicity and better characterization of the hazards they may present. To expand this understanding, an international group of experts was convened in 2020–2021 to identify critical thresholds at which microplastics found in drinking and ambient waters present a health risk to humans and aquatic organisms. However, their findings were limited by notable data gaps in the literature. Here, we identify those shortcomings and describe four categories of research recommendations needed to address them: 1) adequate particle characterization and selection for toxicity testing; 2) appropriate experimental study designs that allow for the derivation of dose-response curves; 3) establishment of adverse outcome pathways for microplastics; and 4) a clearer understanding of microplastic exposure, particularly for human health. By addressing these four data gaps, researchers will gain a better understanding of the key drivers of microplastic toxicity and the concentrations at which adverse effects may occur, allowing a better understanding of the potential risk that microplastics exposure might pose to human and aquatic ecosystems.

Citation

Thornton Hampton, L.M., H. Bouwmeester, S.M. Brander, S. Coffin, M. Cole, L. Hermabessiere, A.C. Mehinto, E. Miller, C.M. Rochman, S.B. Weisberg. 2022. Research recommendations to better understand the potential health impacts of microplastics to humans and aquatic ecosystems. *Microplastics and Nanoplastics* 2:18.

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Risk-based management framework for microplastics in aquatic ecosystems

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Abstract

Microplastic particles (MPs) are ubiquitous across a wide range of aquatic habitats but determining an appropriate level of risk management is hindered by a poor understanding of environmental risk. Here, we introduce a risk management framework for aquatic ecosystems that identifies four critical management thresholds, ranging from low regulatory concern to the highest level of concern where pollution control measures could be introduced to mitigate environmental emissions. The four thresholds were derived using a species sensitivity distribution (SSD) approach and the best available data from the peer-reviewed literature. This included a total of 290 data points extracted from 21 peer-reviewed microplastic toxicity studies meeting a minimal set of pre-defined quality criteria. The meta-analysis resulted in the development of critical thresholds for two effects mechanisms: food dilution with thresholds ranging from ~ 0.5 to 35 particles/L, and tissue translocation with thresholds ranging from ~ 60 to 4100 particles/L. This project was completed within an expert working group, which assigned high confidence to the management framework and associated analytical approach for developing thresholds, and very low to high confidence in the numerical thresholds. Consequently, several research recommendations are presented, which would strengthen confidence in quantifying threshold values for use in risk assessment and management. These recommendations include a need for high quality toxicity tests, and for an improved understanding of the mechanisms of action to better establish links to ecologically relevant adverse effects.

Citation

Mehinto, A.C., S. Coffin, A.A. Koelmans, S.M. Brander, M. Wagner, L.M. Thornton Hampton, A.G. Burton, E. Miller, T. Gouin, S.B. Weisberg, C.M. Rochman. 2022. Risk-based management framework for microplastics in aquatic ecosystems.*Microplastics and Nanoplastics* 2:17.

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Full text available online: www.sccwrp.org/publications

Development and application of a health-based framework for informing regulatory action in relation to exposure of microplastic particles in California drinking water

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Abstract

Microplastics have been documented in drinking water, but their effects on human health from ingestion, or the concentrations at which those effects begin to manifest, are not established. Here, we report on the outcome of a virtual expert workshop conducted between October 2020 and October 2021 in which a comprehensive review of mammalian hazard studies was conducted. A key objective of this assessment was to evaluate the feasibility and confidence in deriving a human health-based threshold value to inform development of the State of California's monitoring and management strategy for microplastics in drinking water. A tiered approach was adopted to evaluate the quality and reliability of studies identified from a review of the peer-reviewed scientific literature. A total of 41 *in vitro* and 31 *in vivo* studies using mammals were identified and subjected to a Tier 1 screening and prioritization exercise, which was based on an evaluation of how each of the studies addressed various quality criteria. Prioritized studies were identified largely based on their application and reporting of dose–response relationships. Given that methods for extrapolating between *in vitro* and *in vivo* systems are currently lacking, only oral exposure *in vivo* studies were identified as fit-for-purpose within the context of this workshop. Twelve mammalian toxicity studies were prioritized and subjected to a Tier 2 qualitative evaluation by external experts. Of the 12 studies, 7 report adverse effects on male and female reproductive systems, while 5 reported effects on various other physiological endpoints. It is notable that the majority of studies (83%) subjected to Tier 2 evaluation report results from exposure to a single polymer type (polystyrene spheres), representing a

size range of 0.040 to 20 µm. No single study met all desired quality criteria, but collectively toxicological effects with respect to biomarkers of inflammation and oxidative stress represented a consistent trend. While it was possible to derive a conservative screening level to inform monitoring activities, it was not possible to extrapolate a human–health-based threshold value for microplastics, which is largely due to concerns regarding the relative quality and reliability of current data, but also due to the inability to extrapolate data from studies using monodisperse plastic particles, such as polystyrene spheres to an environmentally relevant exposure of microplastics. Nevertheless, a conservative screening level value was used to estimate a volume of drinking water (1000 L) that could be used to support monitoring activities and improve our overall understanding of exposure in California's drinking water. In order to increase confidence in our ability to derive a human–health-based threshold value in the future, several research recommendations are provided, with an emphasis towards strengthening how toxicity studies should be conducted in the future and an improved understanding of human exposure to microplastics, insights critically important to better inform future risk assessments.

Citation

Coffin, S., H. Bouwmeester, S. Brander, P. Damdimopoulou, T. Gouin, L. Hermabessiere, E. Khan, A.A. Koelmans, C.L. Lemieux, K. Teerds, M. Wagner, S.B. Weisberg, S. Wright. 2022. Development and application of a health-based framework for informing regulatory action in relation to exposure of microplastic particles in California drinking water. *Microplastics and Nanoplastics* 2:1-30.

SCCWRP Journal Article #1285
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A living tool for the continued exploration of microplastic toxicity

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Abstract

Throughout the past decade, many studies have reported adverse effects in biota following microplastic exposure. Yet, the field is still emerging as the current understanding of microplastic toxicity is limited. At the same time, recent legislative mandates have required environmental regulators to devise strategies to mitigate microplastic pollution and develop health-based thresholds for the protection of human and ecosystem health. The current publication rate also presents a unique challenge as scientists, environmental managers, and other communities may find it difficult to keep up with microplastic research as it rapidly evolves. At present, there is no tool that compiles and synthesizes the data from these studies to allow for visualization, interpretation, or analysis. Here, we present the Toxicity of Microplastics Explorer (ToMEx), an open access database and open source accompanying R Shiny web application that enables users to upload, search, visualize, and analyze microplastic toxicity data. Though ToMEx was originally created to facilitate the development of health-based thresholds to support California legislations, maintaining the database by the greater scientific community will be invaluable to furthering research and informing policies globally. The database and web applications may be accessed at https://microplastics.sccwrp.org/.

Citation

Thornton Hampton, L.M., H. Lowman, S. Coffin, E. Darin, H. De Frond, L. Hermabessiere, E. Miller, V.N. de Ruijter, A. Faltynkova, S. Kotar, L. Monclus, S. Siddiqui, J. Völker, S. Brander, A.A. Koelmans, C.M. Rochman, M. Wagner, A.C. Mehinto. 2022. A living tool for the continued exploration of microplastic toxicity. *Microplastics and Nanoplastics* 2:13.

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Screening and prioritization of nano- and microplastic particle toxicity studies for evaluating human health risks – Development and application of a toxicity study assessment tool

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Abstract

Concern regarding the human health implications that exposure to nano- and microplastic particles (NMPs) potentially represents is increasing. While there have been several years of research reporting on the ecotoxicological effects of NMPs, human health toxicology studies have only recently emerged. The available human health hazard data are thus limited, with potential concern regarding the relevance and reliability for understanding the potential human health implications. In this study we develop and apply a NMP toxicity screening assessment tool (NMP-TSAT) for evaluating human health effects studies against a suite of quality assurance and quality control (QA/QC) criteria for both *in vivo* and *in vitro* studies. A total of 74 studies representing either inhalation or oral exposure pathways were identified and evaluated. Assessment categories include particle characterization, experimental design, and applicability for risk assessment; with critical and noncritical criteria organized to allow screening and prioritization. It is observed that the majority of studies evaluated using the NMP-TSAT have been performed on monodisperse particles, predominately spheres (≈60%), consisting of polystyrene (≈46%). The majority of studies have tested particles < 5 µm, with a minimal particle size of 10 nm and a maximum particle size of about 200 µm. The total assessment score (TAS) possible for *in vivo* studies is 52, whereas for *in vitro* studies it is 46, which is based on receiving a maximum score of 2 against 26 and 23 criteria, respectively. The evaluated TAS ranged from between 12 and 44 and 16–34, for *in vivo* and *in vitro* studies, respectively. Given the challenges associated with prioritizing studies based on ranking them according to their TAS we propose a Tiered approach, whereby studies are initially screened based on how they score against various critical criteria, which have been defined for their relevance for assessing the hazards and risks for human health. In this instance, studies that score a minimum of '1' against each of the critical criteria, regardless of how they rank according to their TAS, are prioritized as part of a Tier 1 screening and prioritization phase, which would then be followed by an expert evaluation, representing a Tier 2 level of assessment. Using this approach we identify 10 oral ingestion and 2 inhalation studies that score at least 1 against all critical criteria. Lastly, several key observations for strengthening future effects studies are identified, these include a need for the generation and access to standard reference materials representative of human exposure to NMPs for use in toxicity test systems and/or the improved characterization and verification of test particle characteristics, and the adoption of study design guidance, such as recommended by OECD, when conducting either *in vivo* inhalation or oral ingestion toxicity tests.

Citation

Gouin, T., R. Ellis-Hutchings, L.M. Thornton Hampton, C.L. Lemieux, S.L. Wright. 2022. Screening and prioritization of nano- and microplastic particle toxicity studies for evaluating human health risks – development and application of a toxicity study assessment tool. *Microplastics and Nanoplastics* 2:2.

SCCWRP Journal Article #1266
Full text available online: www.sccwrp.org/publications

Bioanalytical and chemical-specific screening of contaminants of concern in three California (USA) watersheds

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Abstract

To broaden the scope of contaminants monitored in human-impacted riverine systems, water, sediment, and treated wastewater effluent were analyzed using receptor-based cell assays that provide an integrated response to chemicals based on their mode of biological activity. Samples were collected from three California (USA) watershed with varying degrees of urbanization and discharge from municipal wastewater treatment plants (WWTPs). To complement cell assay results, samples were also analyzed for a suite of contaminants of emerging concern (CECs) using gas and liquid chromatography-mass spectrometry (GC- and LC-MS/MS). For most water and sediment samples, bioassay equivalent concentrations for estrogen and glucocorticoid receptor assays (ER and GR-BEQs, respectively) were near or below reporting limits. Measured CEC concentrations compared to monitoring trigger values established by a science advisory panel indicated minimal to moderate concern in water but suggested that select pesticides (pyrethroids and fipronil) had accumulated to levels of greater concern in river sediments. Integrating robust, standardized bioanalytical tools such as the ER and GR assays utilized in this study into existing chemical-specific monitoring and assessment efforts will enhance future CEC monitoring efforts in impacted riverine systems and coastal watersheds.

Citation

Maruya, K.A., W. Lao, D.R. Vandervort, R. Fadness, M. Lyons, A.C. Mehinto. 2022. Bioanalytical and chemical-specific screening of contaminants of concern in three California (USA) watersheds. *Heliyon* 8:e09534.

SCCWRP Journal Article #1272
Full text available online: www.sccwrp.org/publications

Accounting for transgenerational effects of toxicant exposure in population models alters the predicted long-term population status

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Abstract

Acute environmental stressors such as short-term exposure to pollutants can have lasting effects on organisms, potentially impacting future generations. Parental exposure to toxicants can result in changes to the epigenome (e.g., DNA methylation) that are passed down to subsequent, unexposed generations. However, it is diffcult to gauge the cumulative population-scale impacts of epigenetic effects from laboratory experiments alone. Here, we developed a size- and age-structured delay-coordinate population model to evaluate the long-term consequences of epigenetic modifcations on population sustainability. The model emulated changes in growth, mortality, and fecundity in the F0, F1, and F2 generations observed in experiments in which larval Menidia beryllina were exposed to environmentally relevant concentrations of bifenthrin (Bif), ethinylestradiol (EE2), levonorgestrel (LV), or trenbolone (TB) in the parent generation (F0) and reared in clean water up to the F2 generation. Our analysis suggests potentially dramatic population-level effects of repeated, chronic exposures of early-life stage fsh that are not captured by models not accounting for those effects. Simulated exposures led to substantial declines in population abundance (LV and Bif) or near-extinction (EE2 and TB) with the exact trajectory and timeline of population decline dependent on the combination of F0, F1, and F2 effects produced by each compound. Even acute one-time exposures of each compound led to declines and recovery over multiple years due to lagged epigenetic effects. These results demonstrate the potential for environmentally relevant concentrations of commonly used compounds to impact the population dynamics and sustainability of an ecologically relevant species and model organism.

Citation

Brander, S.M., J.W. White, B.M. DeCourten, K. Major, S.J. Hutton, R.E. Connon, A.C. Mehinto. 2022. Accounting for transgenerational effects of toxicant exposure in population models alters the predicted long-term population status. *Environmental Epigenetics* DOI:10.193/ecp/dvac023.

SCCWRP Journal Article #1303
Full text available online: www.sccwrp.org/publications

Effects of biofouling on the uptake of perfluorinated alkyl acids by organic-diffusive gradients in thin films passive samplers

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Abstract

While organic-diffusive gradients in thin films (o-DGT) passive samplers have been used to assess organic contaminants in water, the effects of biofouling on accurate analyte quantification by o-DGT are poorly understood. We evaluated the effects of biofouling on the uptake of six common perfluoroalkyl substances (PFAS) using a previously developed polyacrylamide-WAX (weak anion exchange) o-DGT without a filter membrane. Linear uptake ($R^2 > 0.91$) over 21 days was observed in fouled samplers. The measured sampling rates (R_s) and accumulated masses of PFAS in pre-fouled o-DGT were significantly lower ($p < 0.05$, 20–39% relative error) than in control-fouled samplers. However, compared to clean o-DGT (no biofouling), the R_s of most PFAS in control-fouled samplers (i.e., those with clean diffusive and binding gels initially) were not affected by biofouling. Under flowing (~5.8 cm s^{-1}) and static conditions, the measured diffusive boundary layer (DBL) thicknesses for clean o-DGT were 0.016 and 0.082 cm, respectively, whereas the effective *in situ* biofilm thicknesses for fouled o-DGT were 0.018 and 0.14 cm, respectively. These results suggest that biofilm growth does not have significant effects on target PFAS sampling by o-DGT under typical flowing conditions (≥2 cm s^{-1}). However, rapid surface growth of biofilm on o-DGT deployed in quiescent waters over long periods of time may exacerbate the adverse effects of biofilms, necessitating the estimation of biofilm thickness *in situ*. This study provides new insights for evaluating the capability of o-DGT samplers when biofilm growth can be significant.

Citation

Wang, P., J.K. Challis, Z.X. He, C.S. Wong, E.Y. Zeng. 2022. Effects of biofouling on the uptake of perfluorinated alkyl acids by organic-diffusive gradients in thin films passive samplers. *Environmental Science: Processes & Impacts* 24:242.

SCCWRP Journal Article #1253
Full text available by request: pubrequest@sccwrp.org

Fate of thiamethoxam from treated seeds in mesocosms and response of aquatic invertebrate communities

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Abstract

Thiamethoxam is a neonicotinoid insecticide widely applied in the Canadian Prairies. It has been detected in surface waters of agro-ecosystems, including wetlands, but the potential effects on non-target invertebrate communities in these wetlands have not been well characterized. In an effort to understand better the fate of thiamethoxam in wetlands and the response of invertebrates (zooplankton and emergent insects), model systems were used to mimic wetland flooding into planted fields. Outdoor mesocosms were treated with a single application of thiamethoxam-treated canola seeds at three treatment levels based on a recommended seeding rate (i.e., 6 kg/ha; 1×, 10×, and 100× seeding rate) and monitored over ten weeks. The mean half-life of thiamethoxam in the water column was 6.2 d. There was no ecologically meaningful impact on zooplankton abundances or community structure among treatments. Statistically significant differences were observed in aquatic insect abundance between control mesocosms and the two greatest thiamethoxam treatments (10× and 100× seeding rate). The observed results indicate exposure to thiamethoxam at environmentally relevant concentrations likely does not represent a significant ecological risk to abundance and community structure of wetland zooplankton and emergent insects.

Citation

Vanderpont, A.K., C. Lobson, Z. Lu, K. Luong, M. Arentsen, T. Vera, D. Moore, M.S. White, R.S. Prosser, C.S. Wong, M.L. Hanson. 2022. Fate of thiamethoxam from treated seeds in mesocosms and response of aquatic invertebrate communities. *Ecotoxicology* DOI:10.1007/s10646-021-02500-8.

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Full text available by request: pubrequest@sccwrp.org

Promoting the stability and adsorptive capacity of Fe_3O_4-embedded expanded graphite with an aminopropyltriethoxysilane–polydopamine coating for the removal of copper(II) from water

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Abstract

In this study, three magnetic graphites, namely, EGF, GAF, and GFA + KH550, were prepared, which were loaded either with Fe_3O_4 or with Fe_3O_4 and PDA or with Fe_3O_4, PDA, and KH550 onto expanded graphite. ATR-FTIR, XRD, XPS, SEM, TEM, and TGA characterization results showed that EGF, GAF, and GFA + KH550 were successfully prepared. Under the same initial copper concentration, the removal rates of copper ions by EGF, GFA, and GFA + KH550 were 86.2%, 96.9%, and 97.0%, respectively and the hazard index reductions of the three adsorbents were 2191 71 (EGF), 1843 68 (GFA), and 1664 102 (GFA + KH550), respectively. Therefore GFA + KH550 exhibited better removal of Cu(II) than EGF and GFA, for PDA and KH550 provided more adsorption-active sites like –OH and –NH. Here, the adsorption of GFA + KH550 fitted the pseudo-second-order kinetic and Langmuir models well within the testing range, which means that adsorption occurs on a monolayer surface between Cu(II) and the adsorption sites. The intraparticle diffusion model and various thermodynamic parameters demonstrated that Cu(II) was adsorbed on GFA + KH550 mainly *via* external surface diffusion and that the process was both endothermic and spontaneous. Recycling experiments show that GFA + KH550 has a satisfactory recyclability, and the way of direct recovery by magnets exhibits good magnetic induction. GFA + KH550 was applied in lake water and artificial seawater samples and exhibited better removal of copper than that in DI water under the same environmental conditions for the existence of macromolecular organic matter. Furthermore, the adsorption capacity of copper ions was not relative to the salinity of water. The application of GFA + KH550 demonstrated the potential for application in water treatment procedures.

Citation

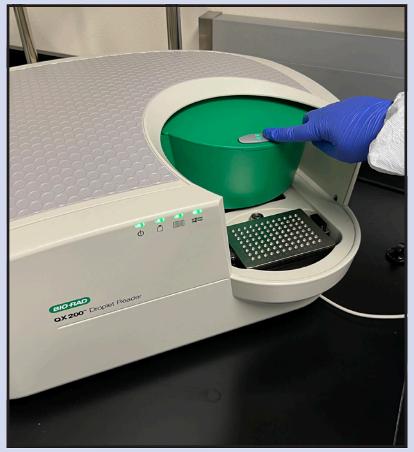
Wang, S., W. Lao, Y. He, H. Shi, Q. Ye, J. Ma. 2021. Promoting the stability and adsorptive capacity of Fe3O4-embedded expanded graphite with an aminopropyltriethoxysilane-polydopamine coating for the removal of copper(II) from water. *RSC Advances* 11:35673-35686.

SCCWRP Journal Article #1293
Full text available online: www.sccwrp.org/publications

County first to monitor beach fecal pollution via ddPCR

San Diego County has become the first municipality in the nation to end its reliance on decades-old methods for monitoring fecal contamination in beach water in favor of a rapid, DNA-based method that SCCWRP vetted and optimized for routine use in Southern California.

The droplet digital polymerase chain reaction (ddPCR) method – which the County began using in 2022 for routine beach water-quality monitoring – will enable public health officials to notify beachgoers about contaminated water on the same day that water samples are collected. By contrast, results from traditional, culture-based methods are typically not available for 24 to 72 hours after samples reach the laboratory – a reporting delay that can put beachgoers at elevated risk of exposure to waterborne fecal pathogens.



A droplet reader instrument is used in a laboratory to quantify fecal contamination in samples collected from beach water. San Diego County has become the first U.S. municipality to replace its traditional beach water-quality monitoring method with ddPCR, a rapid, DNA-based method vetted and optimized by SCCWRP.

The ddPCR method is being used at more than 50 County and State beach locations.

SCCWRP and its member agencies have spent nearly two decades exploring the feasibility of replacing culture-based methods with rapid, DNA-based methods for routine beach water-quality monitoring.

Developing similar method comparison studies can also pave the way for other Southern California municipalities to receive regulatory approval to implement ddPCR. The City of Los Angeles is following in San Diego County's footsteps, with plans to launch a method comparison study to demonstrate that the ddPCR method can produce equivalent results to culture-based methods.

Methods for monitoring COVID-19 in wastewater transitioned to State program

A SCCWRP-led statewide committee that developed methods for using wastewater streams to monitor COVID-19 infections in communities has successfully transitioned the methods to the California Department of Public Health (CDPH) for use in a routine statewide monitoring program.

The method transfer, which took place in 2022, was led by the California Water Quality Monitoring Council's Wastewater Based Epidemiology Committee, enabling CDPH to take over tracking COVID-19 virus levels in wastewater treatment plants across California.

Since the beginning of the COVID-19 pandemic, individual plants across California have been monitoring influent streams for the virus with support from partners, including SCCWRP, and, later, from the Wastewater Based Epidemiology Committee, which SCCWRP chairs.

Study probes utility of coliphage for detecting beach fecal contamination

The Southern California Bight 2018 Regional Monitoring Program has completed a study that found that an alternative, virus-based method for tracking fecal contamination can be used as an effective complement for established *Enterococcus* bacteria-based methods.

The method comparison study, led by SCCWRP and published in 2022, involved testing water quality at 12 Southern California beaches using a commonly used *Enterococcus* method alongside a newer alternative method that uses coliphage viruses to detect fecal contamination.

The Bight '18 microbiology study is motivated by recent efforts by the U.S. Environmental Protection Agency to develop regulatory thresholds for coliphage that will define for water-quality managers the levels at which coliphage contamination becomes indicative of a health threat to swimmers and others who enter recreational waters.

Coliphage, which is a virus that infects some fecal bacteria, more closely mimics the viral pathogens that sicken humans, underscoring the value of developing coliphage as a complement to traditional bacteria indicators.

Tiny coliphage viruses surround an *E. coli* cell. Coliphage, which is a virus that infects *E. coli* and other fecal bacteria, has been shown in a Bight '18 microbiology study to be an effective complement to established *Enterococcus* bacteria-based methods for tracking fecal contamination.

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SARS-CoV-2 RNA is enriched by orders of magnitude in primary settled solids relative to liquid wastewater at publicly owned treatment works

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Abstract

Wastewater-based epidemiology has gained attention throughout the world for detection of SARS-CoV-2 RNA in wastewater to supplement clinical testing. Raw wastewater consists of small particles, or solids, suspended in liquid. Methods have been developed to measure SARS-CoV-2 RNA in the liquid and the solid fraction of wastewater, with some studies reporting higher concentrations in the solid fraction. To investigate this relationship further, six laboratories collaborated to conduct a study across five publicly owned treatment works (POTWs) where both primary settled solids obtained from primary clarifiers and raw wastewater influent samples were collected and quantified for SARS-CoV-2 RNA. Settled solids and influent samples were processed by participating laboratories using their respective methods and retrospectively paired based on date of collection. SARS-CoV-2 RNA concentrations, on a mass equivalent basis, were higher in settled solids than in influent by approximately three orders of magnitude. Concentrations in matched settled solids and influent were positively and significantly correlated at all five POTWs. RNA concentrations in both settled solids and influent were correlated to COVID-19 incidence rates in the sewersheds and thus representative of disease occurrence; the settled solids methods appeared to produce a comparable relationship between SARS-CoV-2 RNA concentration measurements and incidence rates across all POTWs. Settled solids and influent methods showed comparable sensitivity, N gene detection frequency, and calculated empirical incidence rate lower limits. Analysis of settled solids for SARS-CoV-2 RNA has the advantage of using less sample volume to achieve similar sensitivity to influent methods.

Citation

Kim, S., L.C. Kennedy, M.K. Wolfe, C.S. Criddle, D.H. Duong, A. Topol, B.J. White, R.S. Kantor, K.L. Nelson, J.A. Steele, K. Langlois, J.F. Griffith, A.G. Zimmer-Faust, S.L. McLellan, M.K. Schussman, M. Ammerman, K.R. Wigginton, K.M. Bakker, A.B. Boehm. 2022. SARS-CoV-2 RNA is enriched by orders of magnitude in primary settled solids relative to liquid wastewater at publicly owned treatment works. *Environmental Science Water Research and Technology* 8:757-770.

SCCWRP Journal Article #1301
Full text available online: www.sccwrp.org/publications

Minimizing errors in RT-PCR detection and quantification of SARS-CoV-2 RNA for wastewater surveillance

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Abstract

Wastewater surveillance for pathogens using reverse transcription-polymerase chain reaction (RT-PCR) is an effective and resource-efficient tool for gathering community-level public health information, including the incidence of coronavirus disease-19 (COVID-19). Surveillance of Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2) in wastewater can potentially provide an early warning signal of COVID-19 infections in a community. The capacity of the world's environmental microbiology and virology laboratories for SARS-CoV-2 RNA characterization in wastewater is increasing rapidly. However, there are no standardized protocols or harmonized quality assurance and quality control (QA/QC) procedures for SARS-CoV-2 wastewater surveillance. This paper is a technical review of factors that can cause false-positive and false-negative errors in the surveillance of SARS-CoV-2 RNA in wastewater, culminating in recommended strategies that can be implemented to identify and mitigate some of these errors. Recommendations include stringent QA/QC measures, representative sampling approaches, effective virus concentration and efficient RNA extraction, PCR inhibition assessment, inclusion of sample processing controls, and considerations for RT-PCR assay selection and data interpretation. Clear data interpretation guidelines (e.g., determination of positive and negative samples) are critical, particularly when the incidence of SARS-CoV-2 in wastewater is low. Corrective and confirmatory actions must be in place for inconclusive results or results diverging from current trends (e.g., initial onset or reemergence of COVID-19 in a community). It is also prudent to perform interlaboratory comparisons to ensure results' reliability and interpretability for prospective and retrospective analyses. The strategies that are recommended in this review aim to improve SARS-CoV-2 characterization and detection for wastewater surveillance applications. A silver lining of the COVID-19 pandemic is that the efficacy of wastewater surveillance continues to be demonstrated during this global crisis. In the future, wastewater should also play an important role in the surveillance of a range of other communicable diseases.

Citation

Ahmed, W., S.L. Simpson, P.M. Bertsch, K. Bibby, A. Bivins, L.L. Blackall, S. Bofill-Mas, A. Bosch, J. Brandão, P.M. Choi, M. Ciesielski, E. Donner, N. D'Souza, A.H. Farnleitner, D. Gerrity, R. Gonzalez, J.F. Griffith, P. Gyawali, C.N. Haas, K.A. Hamilton, H.C. Hapuarachchi, V.J. Harwood, R. Haque, G. Jackson, S.J. Khan, W. Khan, M. Kitajima, A. Korajkic, G. La Rosa, B.A. Layton, E. Lipp, S.L. McLellan, B. McMinn, G. Medema, S. Metcalfe, W.G. Meijer, J.F. Mueller, H. Murphy, C.C. Naughton, R.T. Noble, S. Payyappat, S. Petterson, T. Pitkänen, V.B. Rajal, B. Reyneke, F.A. Roman Jr, J.B. Rose, M. Rusiñol, M.J. Sadowsky, L. Sala-Comorera, Y.X. Setoh, S.P. Sherchan, K. Sirikanchana, W. Smith, J.A. Steele, R. Sabburg, E.M. Symonds, P. Thai, K.V. Thomas, J. Tynan, S. Toze, J. Thompson, A.S. Whiteley, J.C. Wong, D. Sano, S. Wuertz, I. Xagoraraki, Q. Zhang, A.G. Zimmer-Faust, O.C. Shanks. 2022. Minimizing errors in RT-PCR detection and quantification of SARS-CoV-2 RNA for wastewater surveillance. *Science of the Total Environment* DOI:10.1016/j.scitotenv.2021.149877.

SCCWRP Journal Article #1225
Full text available online: www.sccwrp.org/publications

Assessing cross-laboratory performance for quantifying coliphage using EPA Method 1642

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Abstract

Aims: Widespread adoption of the new U.S. Environmental Protection Agency (USEPA) Method 1642 for enumeration of coliphage in recreational water requires demonstration that laboratories consistently meet internal method performance goals and yield results that are consistent across laboratories.

Methods and Results: Here we assess the performance of six laboratories processing a series of blind wastewater-and coliphage-spiked samples along with laboratory blanks. All laboratories met the method-defined recovery requirements when performance was averaged across samples, with the few failures on individual samples mostly occurring for less-experienced laboratories on the initial samples processed. Failures that occurred on later samples were generally attributed to easily correctable activities. Failure rates were higher for somatic vs. F+ coliphage, attributable to the more stringent performance criteria associated with somatic coliphage. There was no difference in failure rate between samples prepared in a marine water matrix compared to that in phosphate-buffered saline.

Conclusions: Variation among laboratories was similar to that previously reported for enterococci, the current bacterial indicator used for evaluating beach water quality for public health protection.

Significance and Impact of the Study: These findings suggest that laboratory performance is not an inhibitor to the adoption of coliphage as a new indicator for assessing recreational health risk.

Citation

Zimmer-Faust, A.G., J.F. Griffith, J.A. Steele, L. Asato, T. Chiem, S. Choi, A. Diaz, J. Guzman, M. Padilla, J. Quach-Cu, V. Ruiz, B. Santos, M. Woo, S.B. Weisberg. 2022. Assessing cross-laboratory performance for quantifying coliphage using EPA Method 1642. *Journal of Applied Microbiology* DOI:10.1111/jam.15523.

SCCWRP Journal Article #1268
Full text available by request: pubrequest@sccwrp.org

Health risks to children from exposure to fecally-contaminated recreational water

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Abstract

Background: Children may be at higher risk for swimming-associated illness following exposure to fecally-contaminated recreational waters. We analyzed a pooled data set of over 80,000 beachgoers from 13 beach sites across the United States to compare risks associated with the fecal indicator bacteria *Enterococcus* spp. (measured by colony forming units, CFU and quantitative polymerase chain reaction cell equivalents, qPCR CE) for different age groups across different exposures, sites and health endpoints.

Methods: Sites were categorized according to the predominant type of fecal contamination (human or non-human). Swimming exposures of varying intensity were considered according to degree of contact and time spent in the water. Health endpoints included gastrointestinal and respiratory symptoms and skin rashes. Logistic regression models were used to analyze the risk of illness as a function of fecal contamination in water as measured by *Enterococcus* spp. among the exposed groups. Non-swimmers (those who did not enter the water) were excluded from the models to reduce bias and facilitate comparison across groups.

Results: Gastrointestinal symptoms were the most sensitive health endpoint and strongest associations were observed with Enterococcus qPCR CE at sites impacted by human fecal contamination. Under several exposure scenarios, associations between illness and *Enterococcus* spp. levels were significantly higher among children compared to adolescents and adults. Respiratory symptoms were also associated with *Enterococcus* spp. exposures among young children at sites affected by human fecal sources, although small sample sizes resulted in imprecise estimates for these associations.

Citation

Wade, T.J., B.F. Arnold, K.C. Schiff, J.M. Colford Jr., S.B. Weisberg, J.F. Griffith, A.P. Dufour. 2022. Health risks to children from exposure to fecally-contaminated recreational water. *PLOS One* DOI:10.1371/journal.pone.0266749.

SCCWRP Journal Article #1262
Full text available online: www.sccwrp.org/publications

Relationships between indicators and pathogens in shellfish and water in Newport Bay, CA

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Citation

Zimmer-Faust, A.G., J.F. Griffith, J. Freshwater, J. Peng, S. Goong, S.B. Weisberg. 2022. Relationships between indicators and pathogens in shellfish and water in Newport Bay, CA. Technical Report 1193. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1193
Full text available online: www.sccwrp.org/publications

Toolkit developed for adaptive watershed management

SCCWRP and its partners have developed statewide guidance and a set of freely accessible web tools to help California stormwater managers take a consistent, standardized approach to periodically evaluating their long-term, multi-phased plans for improving runoff water quality.

The toolkit, described in a SCCWRP technical report published in 2022, represents broad management consensus on how to use data from stormwater monitoring programs, including performance data for BMPs (best management practices), to track progress toward water-quality improvement goals.

The toolkit also provides a common framework for managers to determine if and how they should pivot vs. stay the course as they implement the next phases of their watershed management plans.

The development of the toolkit comes at an opportune time for Southern California's stormwater management community.

Over the next few years, multiple stormwater agencies are preparing to revisit their watershed management plans that were codified into their discharge permits about five years prior under a philosophy known as Adaptive Watershed Management (AWM).

AWM requires dischargers to develop watershed management plans for improving runoff water quality and quantity incrementally over a multi-decade timeframe.

Runoff from a parking lot drains to a bioretention system containing special engineered soil media designed to remove contaminants. Runoff management solutions like this one are the focus of newly developed statewide guidance for how to periodically evaluate long-term, multi-phased plans for improving runoff water quality.

Study examining how transition to drought-tolerant landscaping can minimize runoff

SCCWRP and the County of San Diego have completed the initial phase of a study probing how replacing residential lawns with drought-tolerant landscaping can minimize runoff – a reduction that has the potential to lower pollutant levels entering storm drains.

The study's first phase, completed in 2022, represents a first-of-its-kind effort to quantify how much runoff can be eliminated by replacing turf and traditional spray irrigation with drought-tolerant landscaping and drip irrigation.

The first phase – in a residential community in Spring Valley – demonstrated that runoff is minimized from irrigation following turf replacement.

By assessing the potential of turf replacements to minimize dry-weather runoff, the County of San Diego study aims to help stormwater managers decide whether they should expand their investments in turf replacement programs.

Stormwater modeling conference helps connect SCCWRP to researchers worldwide

SCCWRP hosted an international engineering conference focused on improving modeling of urban stormwater drainage systems in early 2022 that attracted 146 researchers and practitioners – more than half from outside the United States.

The 12th Urban Drainage Modeling Conference, which was held for only the second time ever in the U.S. since it began in 1986, provided a forum for engineers, scientists and others to advance the modeling work that underlies many routine stormwater planning and permitting activities, including implementation of stormwater BMPs (best management practices).

The International Working Group on Data and Models selected SCCWRP as the conference's host, helping to raise the agency's profile within this international research community as a leader in improving management of wet- and dry-weather runoff.

Courtesy of Dr. Marko Hsu, Feng Chia University

In-person attendees at the 12th Urban Drainage Modeling Conference sit in socially distanced chairs in SCCWRP's main conference room, joined by remote attendees.

Participants agreed that stormwater researchers' shift toward open-source modeling tools has been a strategically important advance that has enabled more efficient implementation and progress across the field.

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Phosphorus leaching behavior from extensive green roof substrates

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Abstract

The substrate is the key component of a green roof system that directly influences the system's stormwater mitigation performance; however, it is also identified as a potentially significant source of contaminants. It is interesting whether substrate phosphorus discharge behavior is predictable and, if so, whether the study of substrate phosphorus leaching behavior is representative of the green roof system performance. The substrates tested were extracted from a 4-year-old extensive green roof and a 1-year-old proprietary substrate from an agricultural (Ag) green roof. The column test for the extensive green roof substrate (comprised of 90% v/v pumice and 10% v/v compost) was designed to simulate 3 years of precipitation in a 3-month period, based on field monitoring of rainfall from 2018 to 2020, and assuming precipitation occurred equally each month. Double the amount of precipitation was applied to the Ag substrate to make up for the shorter duration field exposure before the laboratory experiment. Total phosphorus (TP) concentrations in the permeate from the extensive and the Ag substrates showed exponential decreases with cumulative water flow. The decreasing rates of TP concentrations were similar regardless of the initial phosphorus in the two different substrates. Field monitoring indicated that the TP discharge from the newly built green roof behaved differently compared with its substrate in the laboratory. However, substrate tests could be an extension of field monitoring to estimate the phosphorus discharge for aged green roofs.

Citation

Cheng, Y., D.A. Vaccari, E. Fassman-Beck. 2022. Phosphorus Leaching Behavior from Extensive Green Roof Substrates. *Journal of Sustainable Water in the Built Environment* 8:06022003.

SCCWRP Journal Article #1296
Full text available by request: pubrequest@sccwrp.org

Multiyear study on phosphorus discharge from extensive sedum green roofs with substrate amendments

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Abstract

Green roofs are implemented for providing urban ecosystem services like stormwater management, but they have also been identified as a potentially significant source of phosphorus in the runoff, which may cause concern for downstream water quality. A multiyear evaluation of phosphorus in green roof discharge and alternatives for phosphorus mitigation was conducted using 32 pilot-scale experimental green roofs. The extensive green roofs were made from nonproprietary base substrates [90 volumetric percentage (%v/v) lightweight aggregate (either pumice or expanded clay) and 10%v=v compost] and planted with a variety of sedum species. The roofs were initially constructed in 2017, and 38 storm events were sampled over four growing seasons for precipitation, runoff volumes, and total phosphorus (TP) event mean concentrations (EMCs) in discharge from the experimental extensive green roofs and a reference roof. All extensive green roofs tested were a source of elevated TP EMCs compared with the reference roof for the entire monitoring period. The green roofs initially exhibited high TP EMCs and variability, ranging from 0.46 to 0.89 mg=L (first and third quartiles), compared with the reference roof (90% of TP EMCs were below 0.05 mg=L). Green roof TP EMCs decreased to 0.11 and 0.19 mg=L (first and third quartiles) by the fourth growing season. A combination of measurement and modeling determined that a net reduction in annual cumulative TP mass discharged from the green roofs compared with the reference roof may be achieved because of the stormwater retention capacity of the green roofs. Amending materials, including zeolite, wood-derived biochar, and oat hull–derived biochar, were tested as a downstream permeable reactive barrier or as an additive in the base substrate (zeolite only). A zeolite addition of 20%v=v resulted in lower TP EMCs discharged than the base green roofs (without amendments). None of the other materials tested showed TP mitigating effects. There was no difference in TP EMCs among base green roofs after one growing season. The study highlights the initial excessive phosphorus content of the substrates exceeds the needs of sedum species and results in rapid phosphorus release in runoff discharged from green roofs.

Citation

Cheng, Y., D.A. Vaccari, B.G. Johannesson, E. Fassman-Beck. 2022. Multiyear Study on Phosphorus Discharge from Extensive Sedum Green Roofs with Substrate Amendments. *Journal of Sustainable Water in the Built Environment* 8:04022014.

SCCWRP Journal Article #1297
Full text available by request: pubrequest@sccwrp.org

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Permeable pavement maintenance: A review of literature to assess clogging, predict maintenance frequency, and compare maintenance techniques

Ryan J. Winston[1], Elizabeth Fassman-Beck[2]

[1]Ohio State University, Columbus, OH
[2]Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Winston, R.J., E. Fassman-Beck. 2022. Permeable Pavement Maintenance: A Review of Literature to Assess Clogging, Predict Maintenance Frequency, and Compare Maintenance Techniques. Technical Report 1280. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1280
Full text available online: www.sccwrp.org/publications

SMC Regional BMP Monitoring Network work plan 2022-2023 – Version 1.0

Elizabeth Fassman-Beck[1], Ken Schiff[1]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Fassman-Beck, E., K.C. Schiff. 2022. SMC Regional BMP Monitoring Network Work Plan 2022-2023 - Version 1.0. Technical Report 1270. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1270
Full text available online: www.sccwrp.org/publications

Monitoring guidance to support adaptive watershed management

Kenneth Schiff[1], Emily Darin[1], Elizabeth Fassman-Beck[1], Gemma Shusterman[2], Lorenzo Flores[2], Tony Hale[2], Chris Beegan[3]

[1]Southern California Coastal Water Research Project, Costa Mesa, CA
[2]San Francisco Estuary Institute, Richmond, CA
[3]State Water Resources Control Board, Sacramento, CA

CITATION

Schiff, K.C., E. Darin, E. Fassman-Beck, G. Shusterman, L. Flores, T. Hale, C. Beegan. 2022. Monitoring Guidance To Support Adaptive Watershed Management. Technical Report 1257. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1257
Full text available online: www.sccwrp.org/publications

Assessing the state of knowledge and research needs for stormwater harvesting

James Rasmus[1], Elisa Garvey[1], Seth Brown[2], Elizabeth Fassman-Beck[3], Eric Stein[3]

[1]Carollo Engineers, Inc., Walnut Creek, CA
[2]Storm & Stream Solutions, LLC/National Municipal Stormwater Alliance, Springfield, VA
[3]Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Ramus, J., E. Garvey, S. Brown, E. Fassman-Beck, E. Stein. 2022. Assessing the State of Knowledge and Research Needs for Stormwater Harvesting. Technical Report 1305. The Water Research Foundation. Alexandria, VA.

SCCWRP Technical Report #1305
Full text available by request: pubrequest@sccwrp.org

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Framework finalized for monitoring California estuaries

SCCWRP and its partners have finalized and published a statewide monitoring framework intended to bring consistency to how California assesses the health of its coastal estuaries.

The standardized framework, whose development was completed in 2022, is expected to be immediately incorporated into at least four estuarine monitoring assessment efforts in California: the California Ocean Protection Council's upcoming 2024 assessment of the health of California's estuarine Marine Protected Areas (MPAs), the Southern California Bight 2023 Regional Monitoring Program, coastal resiliency monitoring by the U.S. Environmental Protection Agency, and monitoring of smaller estuaries in Santa Monica Bay.

The estuary monitoring framework focuses on evaluating ecological functioning of estuaries by looking at multiple aspects of estuarine health, including benthic infauna, fish and marsh vegetation.

This approach allows for greater flexibility and comparability across California's highly heterogenous estuaries. Ecological function-based assessments also are directly tied to the beneficial-use goals that environmental managers are working to protect.

Although monitoring programs have already been developed for estuary sites across California, these programs have never been coordinated, limiting data comparability and managers' ability to track the overall health of estuaries statewide.

Courtesy of Wood Environment and Infrastructure

SCCWRP and its partners have developed and field-tested a standardized monitoring framework for assessing the condition of California's coastal estuaries, including Upper Newport Bay in Orange County, above, one of the State's estuarine Marine Protected Areas (MPAs).

Bight '18 publishes synthesis report summarizing Sediment Quality studies

The Southern California Bight 2018 Regional Monitoring Program has published its final assessment report summarizing how sediment contamination in Southern California has impacted the overall health of coastal marine ecosystems.

The Bight '18 Sediment Quality Executive Synthesis report, which synthesizes five lines of evidence and was published in 2022, found that sediment contamination levels remain low across the vast majority of the coastal seafloor.

Coastal embayments, particularly estuaries, remain disproportionately impacted by sediment contamination, with 67% of the assessed area of Southern California's brackish estuary seafloors and 56% of marine estuary seafloors possibly or likely impacted.

New to the Bight '18 sediment quality synthesis report are brief summaries of studies examining the persistence of harmful algal toxins and the spread of trash across the coastal seafloor; both studies are closely linked to sediment quality.

SMC develops workplan for regional BMP performance monitoring

The Southern California Stormwater Monitoring Coalition (SMC) has finalized the design of a new regional monitoring network that will investigate the performance of a wide variety of structural stormwater BMPs (best management practices).

The SMC Regional BMP Monitoring Network, described in a study workplan developed by SCCWRP in 2022, will enable the SMC to investigate a prioritized set of research questions intended to shed light on the effectiveness of structural BMPs in treating and managing contamination in runoff.

SMC member agencies launched a pilot phase in late 2022 focused on investigating two key aspects of BMP performance: (1) what levels and types of pollutants are being removed by flow-through bioretention/biofiltration BMPs, and (2) the rates at which sediment loading into multiple types of BMPs decreases the infiltration rates of runoff.

Results from the pilot monitoring are expected to be available in 2023.

The Southern California Stormwater Monitoring Coalition (SMC) has finalized the design of a regional monitoring network being built to investigate the performance of a range of structural stormwater BMPs, including bioretention planters, above.

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Southern California Bight 2018 Regional Monitoring Program sediment quality assessment synthesis report

Southern California Bight 2018 Regional Monitoring Program Sediment Quality Assessment Planning Committee[1]

[1]*Southern California Bight Regional Monitoring Program, Costa Mesa, CA*

Citation

Southern California Bight 2018 Regional Monitoring Program Sediment Quality Assessment Planning Committee. 2022. Southern California Bight 2018 Regional Monitoring Program Sediment Quality Assessment Synthesis Report. Technical Report 1248. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1248
Full text available online: www.sccwrp.org/publications

Southern California Bight 2018 Regional Monitoring Program: Volume III. Benthic infauna

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[2]*City of San Diego Ocean Monitoring Program, San Diego, CA*

Citation

Gillett, D.J., W. Enright, J.B. Walker. 2022. Southern California Bight 2018 Regional Monitoring Program: Volume III. Benthic Infauna. Technical Report 1289. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1289
Full text available online: www.sccwrp.org/publications

Southern California Bight 2018 Regional Monitoring Program: Volume IX. Trash and marine debris

Karen McLaughlin[1], Raphael Mazor[1] Kenneth Schiff[1], Leah Thornton Hampton[1]

[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*

Citation

McLaughlin, K., R.D. Mazor, K.C. Schiff, L.M. Thornton Hampton. 2022. Southern California Bight 2018 Regional Monitoring Program: Volume IX. Trash and Marine Debris. Technical Report 1263. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1263
Full text available online: www.sccwrp.org/publications

Bioassessment survey of the Stormwater Monitoring Coalition: Workplan for the years 2021 to 2025 – Version 2.0

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[1]*Southern California Coastal Water Research Project, Costa Mesa, CA*

Citation

Mazor, R.D. 2022. Bioassessment Survey of the Stormwater Monitoring Coalition: Workplan for the Years 2021 to 2025 Version 2.0 (2022). Technical Report 1174. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1174
Full text available online: www.sccwrp.org/publications

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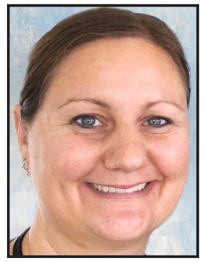

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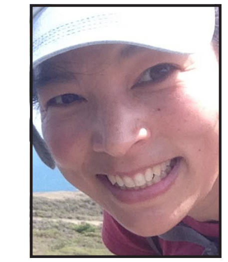

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