SCCWRP

2018 ANNUAL REPORT

Next-generation biology

Advances in biology-based monitoring methods are improving management of aquatic systems

SCCWRP
Established 1969

Southern California Coastal Water Research Project

Applying next-generation science to aquatic ecosystems management

Welcome to the interactive version of SCCWRP's 2018 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.

Contents

SCCWRP 2018 ANNUAL REPORT

INTRODUCTION

2 | EXECUTIVE SUMMARY: Snapshot of success

4 | DIRECTOR'S MESSAGE: An exciting time to be a biologist

FEATURE ARTICLES

5 | INTRODUCTION: Next-generation biology

7 | Maximizing insights from biology-based monitoring

15 | Pinpointing sources of fecal contamination

21 | Screening for more chemical contaminants

A SCCWRP field crew uses a kick net to collect samples of aquatic insects and other benthic invertebrates from a Southern California streambed. Scientists are using DNA-based technologies to unlock the full potential of biological condition assessments, or bioassessment. **Page 7**

Southern California Coastal Water Research Project 2018 Annual Report

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Cover Illustration
Next-generation biology-based approaches are dramatically enhancing the efficiency, precision and reach of environmental management strategies and tools. Photo courtesy of Occidental College Vantuna Research Group.

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ACCOMPLISHMENTS WITH JOURNAL ABSTRACTS

27 | Overview

28 | Bioassessment

32 | Ecohydrology

36 | Eutrophication

41 | Climate Change

47 | Sediment Quality

51 | Contaminants of Emerging Concern

55 | Microbial Water Quality

58 | Regional Monitoring

61 | Scientific Leadership

PEOPLE

64 | SCCWRP Commissioners and CTAG Representatives

66 | SCCWRP staff

Snapshot of Success

Steps taken by SCCWRP to improve aquatic science research and water-quality management in 2018

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

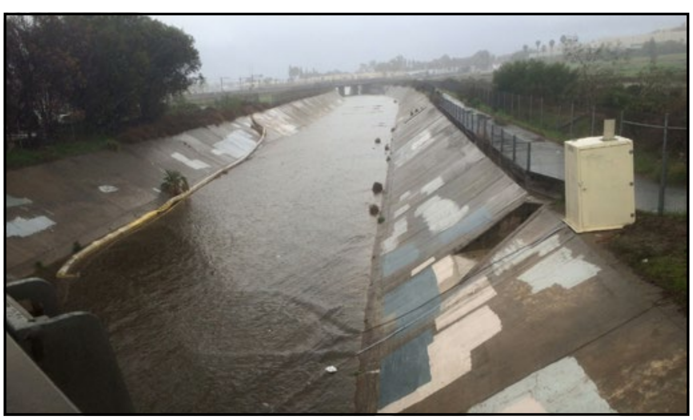
SCCWRP scientific staff published an average of **3.1** journal articles each per year over the past three years. This compares favorably with the **2** publications per year minimum that SCCWRP's partners at academic research institutions generally seek to achieve when being considered for promotion. **Page 27**

» 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 scientists. SCCWRP's goal is for other scientists to reference SCCWRP's work when publishing their own.

Accomplishment

SCCWRP publications were cited **1,702** times in 2018, according to Web of Science statistics, which represents a **12%** increase in the number of citations compared to the previous year.



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 scientists 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 **110** leadership roles with professional societies, advisory committees, and scientific journals in 2018. **Page 61**

» 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 **114** different institutions in 2018. **Page 27**

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

Return to Table of Contents

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 chronicle SCCWRP's efforts to help the region's environmental managers use next-generation biology to better protect the integrity of aquatic systems.

» Developing strategies and tools

SCCWRP is advancing development of next-generation, science-informed strategies, tools and other solutions for monitoring aquatic systems.

» Characterizing the issues

SCCWRP is helping environmental managers apply the latest science to understand the condition of aquatic systems and how they're changing over time.

» Improving management responses

SCCWRP is helping environmental managers use biology-based monitoring data to inform optimal management interventions.

Accomplishment

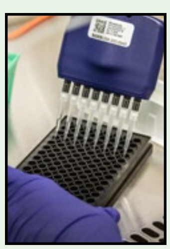
To maximize the insights that biological condition assessments – or bioassessment – can provide, SCCWRP is turning to DNA-based approaches to discern more subtle differences in ecological health. **Page 7**

Accomplishment

To help public health managers more precisely pinpoint the sources and origins of fecal contamination, SCCWRP is using advances in molecular microbiology to advance the science of microbial source tracking. **Page 15**

Accomplishment

To more comprehensively monitor the universe of chemical contaminants in aquatic systems, SCCWRP is investigating how to use bioanalytical screening technology to detect contaminants that pose potential health risks to humans and wildlife. **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 its member agencies.

Accomplishment

SCCWRP staff spent more than **3,000** person-hours in 2018 providing implementation support to member agencies.

Director's Message

An exciting time to be a biologist

At a fundamental level, SCCWRP research is driven by a set of rudimentary questions derived from the federal Clean Water Act of 1972: Is it safe to swim? Is it safe to eat the fish? Is the ecosystem protected?

The glue that holds these research questions together is biology. Whether the goal is protecting human health or ecosystem integrity, biological response is the relevant endpoint for gauging the effectiveness of environmental management actions. This was true 50 years ago at the time of SCCWRP's inception, and it's still true today.

At the same time, there have been substantial transformations over the past five decades in the nature of the biological responses we measure and how we make those measurements. Our focus historically was on overt responses, such as the percentage of fish with tumors, or monitoring fish so contaminated with chemicals that they were unsafe to eat. But as water quality treatment investments by our member agencies have led to environmental improvements, measuring acute biological effects has fallen by the wayside. Instead, our research has increasingly focused on more subtle biological responses, such as sublethal effects and the collective responses of biological communities in aggregate.

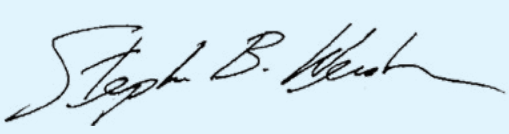
Propelling our ability to track these more subtle biological responses have been advances in molecular technology. While scientists have known since the 1950s that genes are the fundamental biological building block, it is only over the past decade or so that molecular biological approaches for aquatic monitoring have evolved from research methods to standardized, routinely used methods for monitoring and assessment. Significantly, these methods boast a cost-reduction trajectory that is increasingly making them feasible for everyday management application.

The feature articles in this year's Annual Report focus on how technological advances are improving how we measure biological responses. The article on Page 21 illustrates how we are developing cell-line assays to monitor the biological effects of a vast array of new chemicals that are being introduced faster than we can develop traditional methods to reliably measure them. These cell assays provide an effective means for looking at sublethal effects of interest, such as estrogenicity or mutagenicity, rather than the mortality or growth responses typical of traditional toxicity tests. With bioanalytical screening, we have the means to rapidly and cost-effectively screen for chemicals that potentially affect biological health.

Similarly, the article on Page 7 illustrates how genetic measurements are allowing us to more rapidly and more accurately measure whole communities – particularly invertebrates and other biological communities that respond to a wide range of environmental perturbations, including flow and temperature alteration. Genomic methods also are allowing us to measure biological communities for which there is limited taxonomic capacity.

Finally, the article on Page 15 describes how we are using genetic signatures to determine the origin of fecal contamination sources, enabling public health managers to more effectively mitigate public health threats. This is especially important because our member agencies have long emphasized that they need help not only in identifying where problems exist, but in determining the causal agents – something we could not do without the help of molecular tools.

I hope you share in my excitement about how these new biology-based approaches are allowing us to better assess the condition of – and develop solutions that improve – our aquatic environment.



Stephen B. Weisberg, Ph.D.
Executive Director

Return to Table of Contents

NEXT-GENERATION BIOLOGY

SCCWRP and its research partners are using advances in biology to improve management of aquatic systems – and better protect humans and wildlife

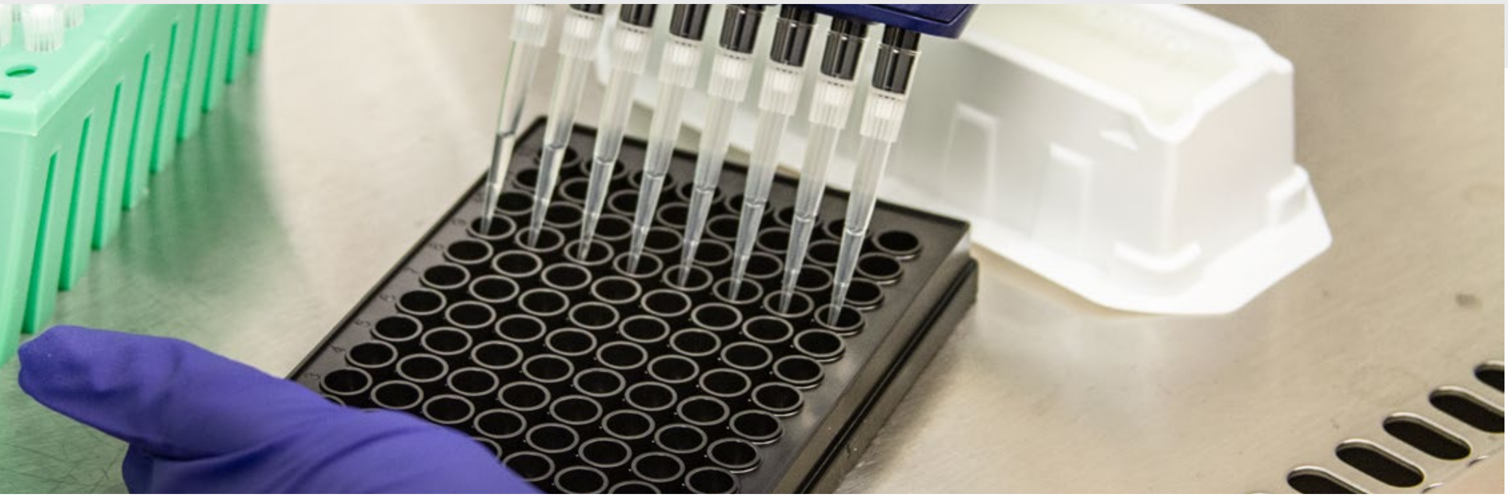
In recent decades, advances in molecular biology have revolutionized numerous fields and industries, from medicine and forensic science to agriculture and conservation biology.

By focusing on DNA and cellular-level processes, scientists have discovered powerful new pharmaceutical drugs and gene therapies, boosted crop and fisheries yields, solved crimes and absolved the innocent, and prevented species from going extinct.

In this same vein, biology-based approaches have revolutionized the aquatic sciences. Over the past two decades, the seamless infusion of next-generation biology into the environmental sciences has dramatically enhanced the efficiency, precision and reach of water-quality management strategies and tools.

Today, environmental managers rely on biology-based approaches to better protect the integrity of a full range of aquatic systems, from drinking water supplies to urban watersheds to coastal recreational waters.

SCCWRP works at the forefront of next-generation biological science, utilizing its deep connections to the



Laboratory-grown cells are placed into assay wells for bioanalytical screening, an approach that has the potential to help environmental managers monitor hundreds and perhaps thousands of chemical contaminants in aquatic systems.

water-quality management community to develop more effective, rapid approaches for routine monitoring and diagnostic applications.

For nearly 50 years, SCCWRP and an international network of research partners have been providing water-quality managers with a wide range of management solutions directly responsive to pressing environmental challenges.

"All of our research at SCCWRP is guided by how it improves and enhances the work of our member agencies and, indeed, the entire end-user management community," said Dr. Stephen Weisberg, SCCWRP's Executive Director and an aquatic biologist. "As scientists, we've long prided ourselves on investigating the potential of biology to better protect our aquatic resources."

At SCCWRP, next-generation biology cuts across virtually all of the agency's research lines. The three feature articles in this Annual Report chronicle multiple decades of accomplishments across three of SCCWRP's signature research lines.

Each article focuses on how biological approaches have transformed routine water-quality management practices – and how biology is continuing to push the boundaries of what is possible.

» In **Maximizing insights from biology-based monitoring**, SCCWRP explores how DNA-based technology is unlocking the full potential of bioassessment-based approaches for monitoring water body health, transforming bioassessment from a core diagnostic management tool to an invaluable and uniquely insightful one. **Page 7**

» In **Pinpointing sources of fecal contamination**, SCCWRP examines how advances in molecular microbiology have dramatically improved the specificity with which fecal contamination can be tracked in aquatic systems, enabling public health managers to move with far greater speed and effectiveness in remediating public health threats. **Page 15**

» In **Screening for more chemical contaminants**, SCCWRP chronicles how a cell biology-based approach to monitoring waterborne chemical contaminants is helping the management community rethink its strategy for monitoring the wide universe of chemicals that potentially threaten human and wildlife health. **Page 21**

SCCWRP's Dr. John Griffith collects flowing stormwater as part of an effort to pinpoint the origins of human fecal contamination, which is widespread at Southern California beaches and other coastal recreational areas after rainfall. Microbial source tracking is helping public health managers track microbial contamination with increasing specificity.

Return to Table of Contents

MAXIMIZING INSIGHTS FROM BIOLOGY-BASED MONITORING

DNA-based approaches are unlocking the full potential of bioassessment

Biological communities that live in aquatic environments offer some of the most revealing, relevant insights about overall ecological condition.

By collecting a wealth of data on the composition of these sentinel organisms, scientists can use assessments of biological condition – or bioassessment – to discern even very subtle differences in water body health.

But raw biological data also can be very complex to understand and reliably interpret.

For generations, scientists have been learning how to make

A SCCWRP field crew uses kick nets to collect samples of aquatic insects and other benthic invertebrates from a Southern California streambed. The composition of these biological communities serves as a reliable indicator of overall ecological health.

bioassessment more insightful and more relevant for routine aquatic monitoring.

Today, bioassessment is a foundational line of evidence used in a wide variety of aquatic monitoring programs, from California's Sediment Quality Objectives program for monitoring the ecosystem impacts of contaminated coastal seafloor sediment, to a statewide freshwater monitoring program run by the Surface Water Ambient Monitoring Program that targets thousands of miles of California's perennially flowing streams.

Driving the environmental management community's commitment to bioassessment-based monitoring is its invaluable advantage: Unlike chemical and physical measures of ecological health, bioassessment directly measures a water body's ability to support aquatic life – a defining metric of success for water-quality management programs.

"With bioassessment, we are directly measuring how various potential stresses that organisms have been exposed to during their lifetimes has impacted them," said Dr. Andrew Rehn, an Environmental Scientist for the California Department of Fish and Wildlife's Aquatic Bioassessment Laboratory. "By contrast, chemical measures of ecosystem condition are designed to capture snapshots in time, at the moments someone happens to be collecting the data."

Even with these advances, scientists recognize that the bioassessment approaches in use today are just beginning to tap into the full range of insights that data on biological community composition can offer.

To unlock bioassessment's full potential, scientists are turning to advances in molecular biology.

Indeed, DNA-based technologies are at the heart of an ongoing, multi-pronged strategy to enable environmental managers to generate more bioassessment data faster and more cost-effectively for more water bodies.

Scientists also are working to use DNA-based technologies to boost the resolution of bioassessment data, increase management confidence in bioassessment findings, and more comprehensively understand how an ecosystem

Aquatic insects like the larval dragonfly, above, are sensitive to human-triggered environmental impacts, making them sentinel organisms for evaluating the overall health of water bodies.

Return to Table of Contents

is functioning – all the way down to the bacterial communities at the bottom of aquatic food webs.

"DNA-based technology could propel the next generation of bioassessment," said Dr. Raphael Mazor, an aquatic biologist at SCCWRP. "We see tremendous potential to answer new types of management questions with bioassessment, and ultimately expand what monitoring can reveal about ecosystem condition – and in more water body types than we currently assess."

Learning to interpret biology

At its most basic level, bioassessment typically involves counting the numbers and types of organisms in an aquatic environment to understand overall ecological health.

For more than a century, scientists have recognized the value of tracking this information for certain types of organisms.

The challenge has long been finding a reliable, systematic approach for interpreting raw biological data to quantify ecological condition.

To be useful in aquatic monitoring programs, bioassessment interpretation tools – known as indices of biotic integrity – must be able to discern relatively subtle, human-triggered ecological impacts from environmental changes that occur naturally.

In other words, bioassessment interpretation tools need to reliably assign lower condition scores to water bodies where human-induced stresses have impacted the composition of the biological community, and higher scores to water bodies where changes in biological community composition are the result of natural environmental variability.

Scientists have spent much of the 20th century exploring more precise, reliable approaches for building these interpretation tools.

The biggest breakthroughs for bioassessment came in the 1980s, when scientists learned how to build more comprehensive interpretation tools that use statistical analysis to synthesize multiple marquee aspects of ecological health, including pollutant tolerance and feeding behavior.

Courtesy of Joseph Slusark Jr.

Insects and other benthic macroinvertebrates are removed individually with tweezers from a streambed sample so they can be counted and identified under a microscope. Scientists are exploring ways to identify these organisms using DNA sequencing methods.

Thus, as the federal Clean Water Act and other legislation ushered in the modern era of routine water-quality monitoring in the 1970s, bioassessment did not initially get incorporated into monitoring programs.

Today, however, water-quality managers rely on bioassessment-based scoring tools to quantify the ecological condition of water bodies across California and beyond.

In Southern California, the Benthic Response Index – developed by SCCWRP and its member agencies in the mid-1990s – is a widely used bioassessment tool for evaluating how coastal marine communities are being impacted by chemical contamination in seafloor sediment.

In freshwater environments, a pair of statewide bioassessment tools co-developed by SCCWRP – the California Stream Condition Index and the Algal Stream Condition Index – are serving as a key part of the scientific

Courtesy of Joseph Slusark Jr.

Bioassessment traditionally is dependent on manual taxonomic identifications. Above, organisms collected from a stream are identified and counted under a microscope.

Sediment-laden water flows through Switzer Canyon in the San Gabriel Mountains after a wildfire. While toxic burn products quickly flow through streams, the disruption these contaminants cause to biological communities lingers, making bioassessment a particularly useful tool for evaluating long-term ecological health.

foundation for proposed policies intended to better protect California's rivers, creeks and other streams.

"The central value of these biotic indices is that they offer quantitative, comparable scores of the baseline biological condition for wadeable streams across California, which allows us to directly measure beneficial use attainment or impairment," said Chad Loflen, a Senior Environmental Scientist for the San Diego Regional Water Quality Control Board. "We depend on these tools to serve as our scientific foundation for crafting biointegrity policies that better protect and restore our streams and other water bodies."

Turning to DNA technology

For the vast majority of water bodies where bioassessment tools have been built, existing tools provide more than adequate insights into overall ecosystem functioning.

But existing bioassessment tools are focused on tracking just a handful of types of sentinel organisms, meaning they do not directly evaluate an ecosystem's full biological diversity.

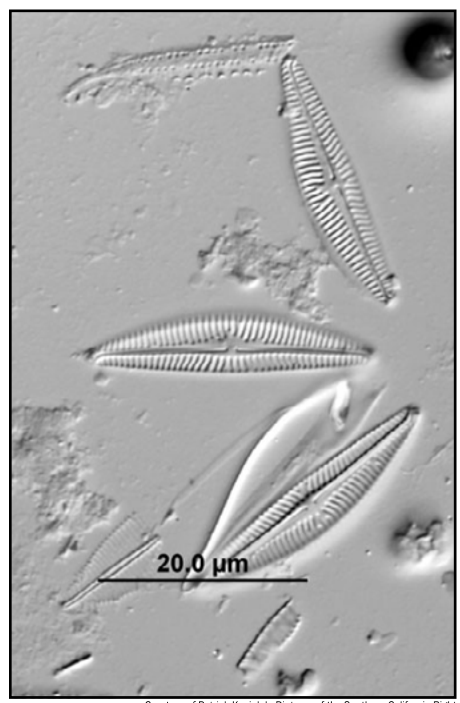
Although creating more bioassessment tools based on more types of organisms could boost resolution and increase confidence in findings, this work is not a simple proposition.

For every bioassessment tool developed, scientists need to construct a robust taxonomic library that is used to identify organisms collected in the field.

The quality of these taxonomic libraries varies by organism. For example, insect and crustacean libraries are generally adequate to identify organisms, but many other libraries are comparatively incomplete.

Thus, scientists view advances in molecular biology – specifically, DNA-based technology – as essential to extending the applicability and reach of bioassessment.

Not only do scientists anticipate that DNA technology will enable routine bioassessment work to be conducted faster and more cost-effectively, but scientists also believe DNA-based technologies will be able to discern more subtle differences in ecosystem condition and



Courtesy of Patrick Kociolek, Diatoms of the Southern California Bight

Diatoms, above, and soft-bodied algae communities are used as sentinel indicators of the ecological condition of water bodies, but these single-celled organisms can be prohibitively costly, time-consuming and difficult to identify under a microscope. DNA barcoding is being explored as an alternative for identifying these organisms.

Return to Table of Contents

boost confidence in the precision of bioassessment results.

At the heart of this DNA-based approach to bioassessment is a molecular biology technique known as DNA barcoding.

Named after the scannable black-striped barcodes on consumer products and packaging, DNA barcoding represents a fundamentally different approach to identifying organisms. With DNA barcoding, organisms are identified based on characteristic, short DNA sequences that are unique to a particular species or taxonomic class.

Traditional bioassessment analyses, by contrast, depend on manual identification and counting of organisms by a trained taxonomist. Biological samples are collected from a water body, processed and then analyzed under a microscope – a process that can take months or even years.

DNA barcoding enables scientists to extract and sequence DNA from the organisms they collect, then use customized computational processes known as bioinformatics pipelines to group and sort DNA barcode sequences and taxonomically identify them. The process can be completed in a matter of weeks and sometimes even days.

"By side-stepping manual identification, DNA barcoding has the potential to make bioassessment more rapid and lead to quicker management responses," said Ali Dunn, Coordinator for the Surface Water Ambient Monitoring Program at the California State Water Resources Control Board. "As the number of taxonomists available to conduct this specialized work declines, we're facing months-long backlogs that can compromise our ability to get bioassessment results back in a timely manner."

Expanding DNA barcoding's utility

In recent years, SCCWRP has been working with an international network of partners to test, validate and standardize DNA barcoding methods for bioassessment applications.

For example, during recent development of the Algal Stream Condition

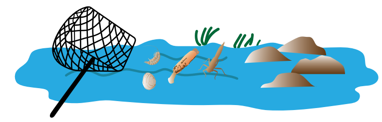
Two approaches to DNA-based bioassessments

SCCWRP and its partners are exploring two potential pathways for using DNA barcoding data to conduct bioassessments: a molecular taxonomic approach and a taxonomy-free approach.

	Molecular taxonomy	Taxonomy-free
Approach	Identify organisms by comparing DNA barcoding sequences to a reference library	Directly analyze patterns in the occurrence of DNA barcodes to draw conclusions about stressors on organisms
Status	Ongoing R&D for about a decade	Ongoing R&D for the past few years
Advantage	Incorporates knowledge about organisms' life history and relationship with stressors	Avoids taxonomic identifications of organisms and the need for a DNA reference library
Disadvantage	Depends on access to extensive, high-quality DNA reference libraries	Does not incorporate insights about organisms' life history and relationships with stressors

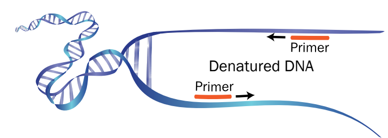
How DNA barcoding works

1 Samples are collected in the field.

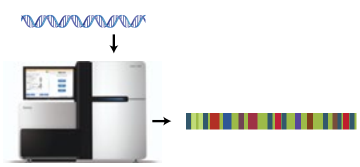


2 Sample are processed, and DNA is extracted from cells.

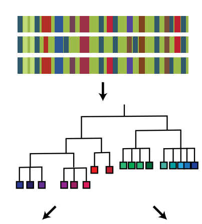
3 A DNA barcode is isolated and amplified by PCR, creating a short DNA sequence a few hundred base pairs in length.



4 The DNA barcode is sequenced.

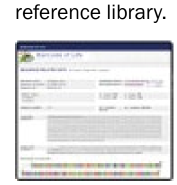


5 DNA barcoding sequences are grouped and sorted.



Option A
Molecular taxonomy

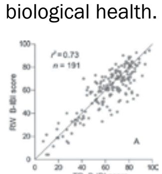
Organisms are identified by comparing DNA barcodes to a reference library.



Taxonomic identification information is fed into a bioassessment tool to score ecological condition.

Option B
Taxonomy-free approach

Patterns in the occurrence of DNA barcodes are analyzed to draw conclusions about which stressors are affecting biological health.

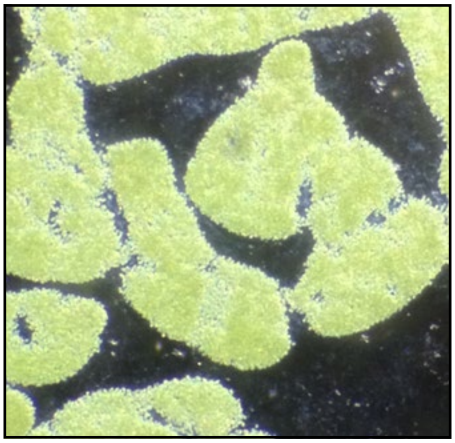


Stressor information is used to score ecological condition.

Return to Table of Contents

Index scoring tool, SCCWRP and its partners tested DNA-based algae identification methods alongside traditional identification methods. Researchers showed that DNA barcoding could generate results in a matter of weeks, instead of months, as is common with traditional taxonomic identification of algae samples.

More significantly, SCCWRP and its partners showed that the DNA-based algae identifications are as reliable as – and in some cases more reliable than – identifications made by taxonomy experts using a microscope.



Harmful algal blooms, above, as seen under a microscope, are among the types of stream algae that scientists are hoping can be identified using DNA-based methods. The composition of aquatic algae communities serves as a key indicator of water body health.

Today, DNA barcoding is envisioned as a complementary or alternative method to traditional taxonomic identifications, with scientists exploring the feasibility of identifying multiple types of organisms using DNA barcoding.

In particular, DNA barcoding could be useful for identifying organisms for which taxonomic knowledge remains underdeveloped – an ongoing limitation that hampers the ability to identify these organisms under a microscope.

For example, SCCWRP and its partners have begun exploring how to use DNA barcoding to identify tiny organisms known as meiofauna that live in coastal sediment. Meiofauna have traditionally been ignored as bioassessment-based scoring tools were developed for evaluating the ecological impacts of seafloor sediment contamination; instead, bioassessment tools were built around their larger brethren, known as macrofauna.

Meanwhile, in developing a bioassessment tool for monitoring streams that run dry for much of the year, SCCWRP and its partners are exploring the feasibility of identifying the composition of the bryophyte community in streambeds using DNA barcoding – perhaps as a complement to traditional identification methods.

"A decade ago, the question for the end-user management community was if DNA barcoding was viable as a complement or replacement for traditional taxonomic identification," said Dr. Eric Stein, head of SCCWRP's Biology Department. "Now, the question is how fast we can incorporate DNA barcoding into routine bioassessment monitoring."

Mining DNA for more insights

To date, scientists have largely focused on using DNA-based approaches to

A SCCWRP field crew collects algae samples from the Santa Margarita River, which spans Riverside and San Diego Counties. SCCWRP and its partners have shown that DNA-based methods for identifying stream algae can be as reliable as – and in some cases more reliable than – identifications made by taxonomists using a microscope.

California's molecular methods workgroup

In 2018, California formed a molecular methods workgroup to begin developing standardized DNA-based approaches for conducting bioassessments in California and beyond.

The DNA Barcoding and eDNA Workgroup, formed by the California Water Quality Monitoring Council and co-chaired by SCCWRP, is an effort to ensure DNA-based methods can be successfully transitioned to widespread use by the environmental management community.

The workgroup is examining how to develop best-practices standardizations for using molecular methods in routine bioassessment work and similar applications.

A comparable workgroup known as DNAqua-Net exists in Europe, but there is not a comparable level of coordination in the U.S. at the national level.

Return to Table of Contents

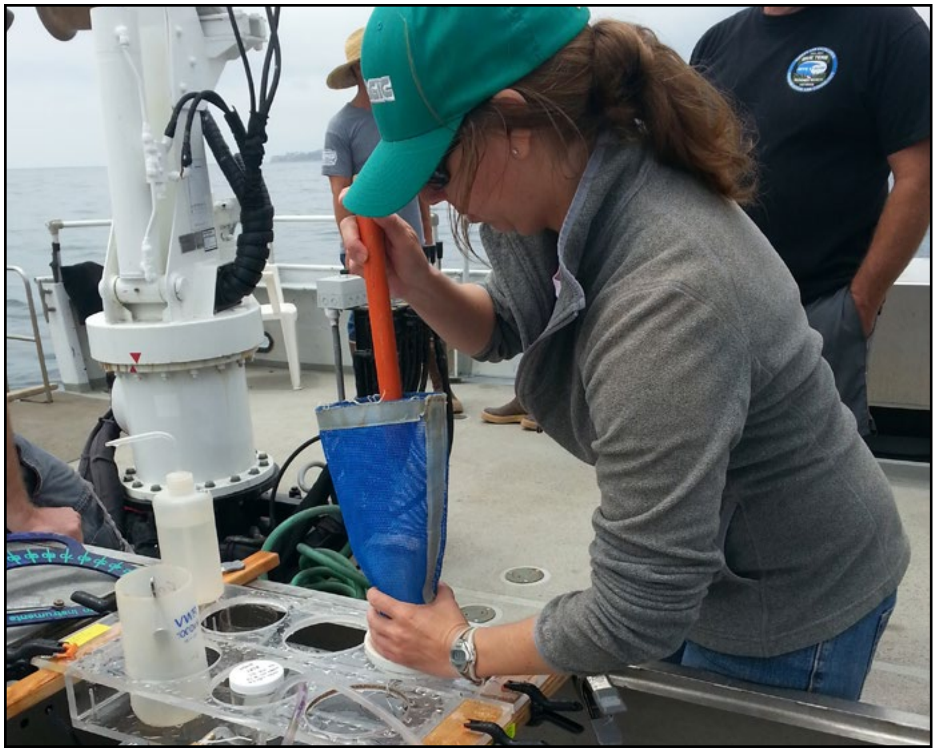
Weighing the size of the bioassessment toolbox

In general, multiple lines of evidence improve confidence in bioassessment findings, but what is less clear is how many lines of evidence are necessary to diagnose the biological health of water bodies.

In the European Union, the Water Framework Directive recommends that perennially flowing streams be evaluated using at least three types of stream biological communities, including the interactions among these communities.

California is weighing incorporating two biological indicators – benthic invertebrates and algae – into a proposed statewide policy intended to protect the health of perennial streams.

SCCWRP and its partners believe these two biological indicators provide a strong foundation for assessing stream condition. However, this does not preclude the possibility of developing additional lines of evidence for certain water body types and/or scenarios. Such a decision would involve careful deliberation and thought by all management and scientific stakeholders.



The eggs and larvae of fish, known as ichthyoplankton, are extracted from a collection bag that has been towed through Southern California coastal waters. Researchers are exploring how to use DNA barcoding methods to identify ichthyoplankton.

enhance the utility and applicability of existing bioassessment tools.

But increasingly, scientists are exploring how to harness the vast treasure trove of information from DNA barcoding to do far more sophisticated analyses.

SCCWRP and its partners launched a multi-year study in 2018 to analyze overall DNA patterns in the aquatic bacteria and algae communities that live in perennial streams. The goal is to use an advanced statistical approach known as network analysis to gain more precise insights into how an ecosystem is functioning.

By collectively analyzing DNA patterns for multiple types of biological communities, network analysis is enabling scientists to move away from assessing one type of organism at a time – and toward understanding higher-level, interconnected functioning of aquatic ecosystems.

Also by moving away from the single-indicator approach to bioassessment, network analysis avoids the long-standing challenge of how to interpret conflicting results when using multiple bioassessment tools to score a water body.

"With network analysis, we're learning how to assess higher-level functioning," said Dr. Sergey Nuzhdin, a Professor of Biological Sciences at the University of Southern California. "This really is cutting-edge science. For example, bacterial communities are at the foundation of aquatic food webs, and yet it wasn't until we started down this route that we've been able to meaningfully incorporate bacteria into bioassessments."

Turning to environmental DNA

All traditional bioassessment tools developed to date – whether for insects or algae or the eggs and larvae of fish – are dependent on physically collecting whole organisms and bringing them to a laboratory for identification.

This step has limited the numbers and types of organisms that can be used in bioassessment analyses.

Thus, scientists in recent years have been exploring how to collect and analyze the DNA that aquatic organisms have shed into their environment – known as environmental DNA, or eDNA.

With an eDNA-based approach, researchers collect water and extract any DNA that has been shed into it. Then, the eDNA is analyzed to determine what organisms are present in the sample – in effect, rendering direct collection of organisms unnecessary.

SCCWRP and its partners have been conducting proof-of-concept studies to understand how far and for how long eDNA signals persist in aquatic environments.

In one recent study, researchers temporarily placed caged mussels into freshwater streams to track the mussels' eDNA signal downstream. Mussels are not native to freshwater environments, allowing scientists to determine how quickly after introduction their presence is detectable via eDNA and how far downstream the eDNA can be detected. Similarly, once the mussels are removed, scientists can track how long signals from remnant eDNA remain in the system.

If eDNA is shown to provide information about biological communities that are just as relevant and insightful as sampling the organisms themselves, eDNA could open up multiple new opportunities for collecting bioassessment data.

First, bioassessments would not need to be based solely on organisms that can be directly sampled in the environment.

Second, eDNA would capture all of the organisms that passed through a particular spot – not just the ones that happened to be present at the moment of sampling. For example, eDNA could potentially detect spawning fish that might pass rapidly through a water body.

Finally, eDNA-based bioassessments have the potential to be even more scalable than DNA barcoding, as collecting water samples is much simpler and more straightforward than sampling specific types of organisms in a water body.

"eDNA-based bioassessments have the potential to dramatically increase the amount of bioassessment work that is feasible to conduct," said Dr. Steve Weisberg, SCCWRP's Executive Director and an aquatic biologist. "We're getting to a point where a tricorder – the handheld scanner made famous in *Star Trek* – is less of a sci-fi dream and closer to reality."

SCCWRP's Dana Shultz collects a water sample in Upper San Juan Creek in San Diego County just a few feet from where mussels in metal cages have been temporarily placed into the stream. Researchers are investigating the feasibility of identifying organisms by the DNA they shed into their environment, known as environmental DNA.

Mussels are placed into a metal cage in preparation for a study seeking to better understand how far and for how long the DNA they shed into their environment can be detected in the system.

Other applications for eDNA-based monitoring

Analyzing the DNA that aquatic organisms have shed into their environment is not only being adapted to enhance water-quality monitoring. Researchers also are working to use eDNA to track certain high-priority organisms, including:

- **Threatened and endangered species:** Animals with protected legal status cannot be sampled directly in their environment, but scientists are exploring how to use eDNA to identify them and to quantify their presence in water bodies.
- **Invasive and nuisance species:** From harmful algal blooms to invasive fish species, unwanted and non-native species can trigger rapid disruptions to aquatic ecosystems, underscoring the value of developing a cost-effective, eDNA-based early-warning system.
- **Elusive species:** Certain types of fish or other vertebrates can be hard to sample with accuracy because of their large home ranges and/or reclusive behavior. eDNA represents a promising solution for identifying them and quantifying their presence.

The DNA that organisms shed into their environment could be used to help detect the presence of threatened and endangered species such as the California newt, above, a species of special concern.

Return to Table of Contents

PINPOINTING SOURCES OF FECAL CONTAMINATION

Advances in molecular microbiology are enabling microbial contamination to be tracked with increasing specificity

When fecal contamination is detected in waterways and the coastal ocean, specificity reigns supreme.

Public health officials need as much information as possible about specifically which types of animals are contributing to the contamination and specifically which route it's taking to reach aquatic environments. These insights are critical to stopping fecal contamination at its source and ascertaining potential risks to public health.

But in densely populated environments like Southern California, fecal contamination can originate from a wide variety of geographically distant sources, quickly complicating source tracking efforts.

Human waste flows through hundreds of miles of underground sewer pipes. Sewer pipes often run adjacent to storm drain pipes. Individual property owners are responsible for maintaining septic tanks and private lateral lines that feed into publicly maintained sewer lines.

Meanwhile, wildlife and domestic animals can deposit droppings in and near waterways. Waste from farms and livestock operations can get washed into rivers and streams. Homeless populations living in or near storm drain channels can defecate directly into water.

"Flowing water – whether above or below ground – is highly efficient at transporting fecal contamination to our coastal beaches and other recreational areas," said Dr. Joshua Steele, an aquatic microbiologist at SCCWRP. "And fecal contamination – even very small amounts of it – can make humans sick upon contact."

Until about 15 years ago, the environmental management community lacked the tools to track fecal contamination back to upstream sources and origin points.

In particular, managers struggled to ascertain whether the contamination was coming from human vs. non-human feces. Fecal matter from animals like dogs and birds is far less likely than human feces to contain pathogens that make humans sick.

However, advances in molecular microbiology have dramatically improved the level of specificity that managers can glean from fecal source tracking in aquatic systems.

By focusing on the DNA of fecal microbes, scientists are unlocking new insights that are helping to more precisely narrow down and pinpoint the origins of waterborne fecal contamination.

Not only can human health managers distinguish human sources of contamination from their non-human counterparts, but scientists also are learning how to help managers ascertain whether human contamination originated from sewer pipes, faulty septic systems or another specific source.

"Thanks to the rapid development of molecular microbiology techniques and modeling methods, now we are able to move toward spending our limited resources on the

Surfers paddle away from shore at Ocean Beach in San Diego shortly after rainfall. Microbial source tracking is enabling environmental managers to track fecal contamination in coastal waters to upstream sources and points of origin.

right targets, reducing the type of fecal waste sources in the environment that are the true risk drivers," said Dr. Helen Yu, a Water Resources Control Engineer for the San Diego Regional Water Quality Control Board.

Incorporating source tracking

Microbial source tracking (MST), also known as microbial source identification, refers to the science of identifying where waterborne fecal contamination originated – both what type of animal it originated from and where it entered water.

Through MST technology, scientists can trace fecal signals back to their upstream source and evaluate whether the contamination has a human signature. MST tests also are available for multiple other animals, including dogs, cattle and birds.

Already, MST technology has been used at multiple California beaches to understand whether persistent fecal contamination signals were coming from wildlife such as seabirds, from dogs and other domestic pets, or from leaks in sewer pipes or other infrastructure.

Similarly, scientists have used MST technology to show that fecal contamination – widespread in Southern California waterways during wet weather – has a consistently strong human signature.

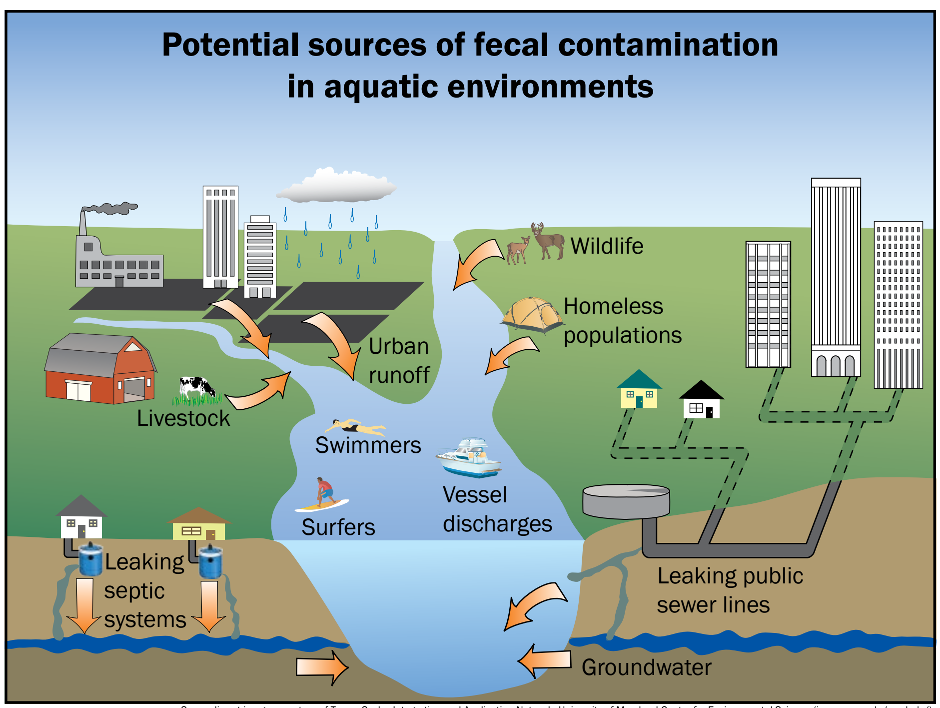
The evolution of MST as a core water-quality management tool is a reflection of the technology's essential advantage: MST moves management of fecal contamination beyond simply detecting the contamination in aquatic environments.

Since the late 1800s, scientists have been able to reliably detect waterborne fecal contamination by monitoring fecal indicator bacteria, a type of bacterium that is abundant in the digestive systems of warm-blooded animals and easily measured in aquatic environments.

Although these bacteria continue to serve as the definitive indicator for waterborne fecal contamination, fecal indicator bacteria cannot shed light on where the contamination originated – a consequential shortcoming that historically has limited public health managers' ability to effectively intervene.

In particular, fecal indicator

By collecting samples of stormwater runoff, researchers can investigate the specific sources and origins of human fecal contamination, which is widespread in Southern California during wet weather.



Some clip art images courtesy of Tracey Saxby, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/symbols/)

Return to Table of Contents

Courtesy of Heal the Bay

Warning signs are routinely posted at Southern California beaches after rainfall because of an elevated risk of aquatic fecal contamination.

bacteria-based monitoring treats all fecal contamination as if it were human, even though contamination from non-human sources such as bird droppings is much less likely to contain the viruses, bacteria and other protistan microbes that can sicken humans. In this way, fecal indicator bacteria-based monitoring can over-estimate the actual risks to public health.

Furthermore, fecal indicator bacteria like *E. coli* and *Enterococcus* can grow on their own in aquatic environments, which also can lead to false positive detection of fecal contamination.

Consequently, until the development of MST approaches, managers struggled to effectively target their limited resources toward the sites and sources that pose the greatest risks to public health.

"The ability to identify the source of bacterial contamination is a huge advantage," said Dr. Jian Peng, North Orange County Monitoring Manager for OC Public Works. "MST markers make it both practical and feasible to find and remediate sources of fecal pollution.'"

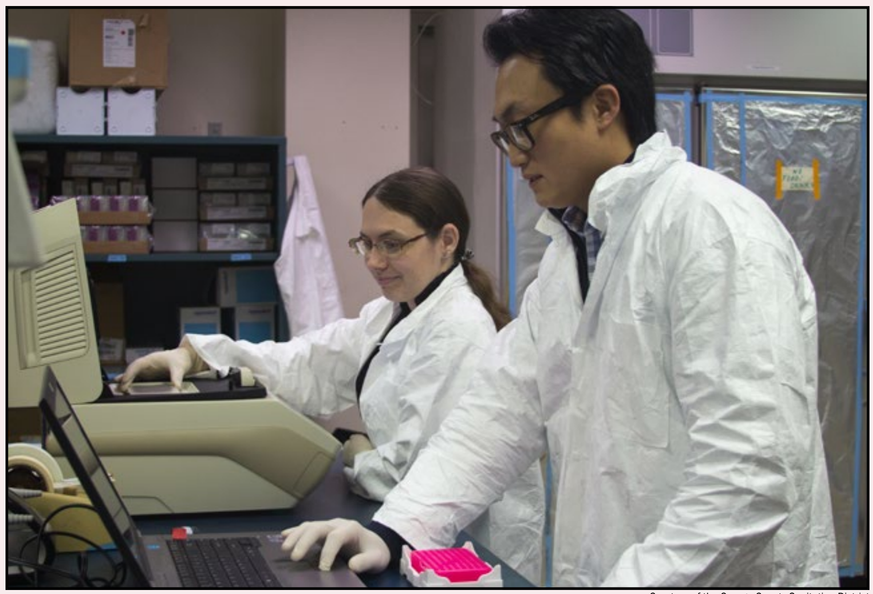
Evolving DNA-based methods for detecting human fecal contamination

A DNA-based technology known as the polymerase chain reaction (PCR) was initially used in the mid-2000s to detect human contamination. By focusing on a genetic marker known as HF183 that is uniquely associated with humans, scientists could reliably identify water bodies contaminated with human fecal matter.

But traditional PCR cannot quantify the amount of HF183 present. In the mid-2000s, SCCWRP and its partners examined a next-generation PCR approach known as quantitative PCR (qPCR), which uses a fluorescent genetic probe to quantify the amount of the HF183 genetic marker present in a given sample.

Today, qPCR and an even more advanced quantitative form of PCR known as droplet digital PCR (ddPCR) have enabled HF183 to be widely adopted as the human fecal source tracking method of choice by the end-user public-health management community.

SCCWRP has played a key role in standarizing these DNA-based methods for routine use by its member agencies and other public health managers.



Courtesy of the Orange County Sanitation District

The Orange County Sanitation District's Jessica Roussos, left, and Dr. Samuel Choi use a DNA-based approach known as quantitative PCR to analyze water samples for fecal contamination. SCCWRP has played a key role in getting DNA-based technologies into the hands of its member agencies.

Evaluating source tracking methods

As the environmental management community learned how to use MST to pinpoint the origins and extent of waterborne fecal contamination, scientists turned their attention to how managers could reliably distinguish human from non-human fecal sources.

By the 1990s, researchers had developed multiple experimental methods for ascertaining whether fecal contamination includes a human signature. Most of these methods focused on studying specific characteristics of individual fecal bacterial isolates, including developing a reference library for these traits.

Although public health managers immediately started implementing these methods, the methods were largely still investigator-specific and had not yet been subjected to rigorous, independent testing.

The most widely used method was multiple antibiotic resistance profiling, based on the premise that animals, including humans, develop resistance to various antibiotics they've ingested over time. By profiling the antibiotic resistance characteristics of a fecal bacteria sample, researchers sought to identify the type of animal the fecal bacteria came from.

Other methods focused on carbon utilization profiling – based on the premise that fecal bacteria will evolve to possess metabolic characteristics unique to the gut of a particular type of animal.

Scientists also explored ways to use the DNA of the fecal bacteria to distinguish human from non-human sources of fecal contamination.

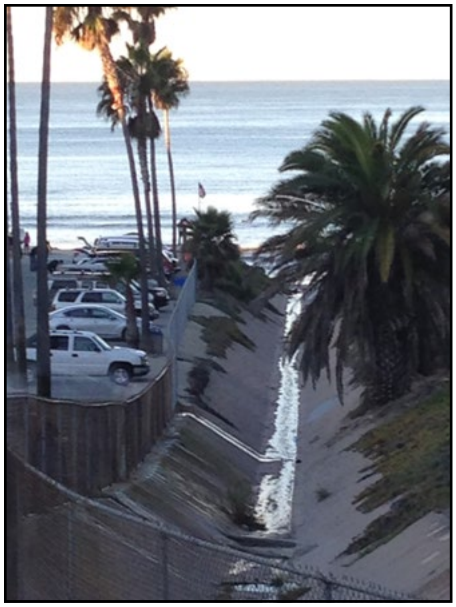
As the number of MST methods proliferated into the early 2000s, scientists recognize the need to subject these methods to rigorous, independent evaluation.

In 2003, SCCWRP and its partners published a landmark study showing that most MST methods in use at the time could not reliably distinguish among fecal sources, including human vs. non-human sources. However, a particular type of DNA-based method – known as a non-library-based genotypic approach – was shown to be highly effective.

As a result of the SCCWRP-facilitated study, there was almost immediately a dramatic consolidation of MST-focused research. All of the experimental library-based source tracking methods fell by the wayside as scientists focused on further vetting and improving non-library-based genotypic methods.

Ultimately, scientists zeroed in on a gene fragment believed to come from a type of fecal bacteria known as *Bacteriodes dorei* that is found predominantly inside human digestive systems. Known as HF183, this gene fragment has been repeatedly shown to be particularly reliable for distinguishing human from non-human fecal contamination.

Later, SCCWRP and its partners validated HF183's ability to quantify human fecal contamination levels.



Beaches and other coastal recreational areas at the receiving end of storm drain channels can be contaminated with bacteria and other microbes that pose a public health risk. Advances in microbial source tracking technology have enabled researchers to show that fecal contamination during wet weather includes a human signature.

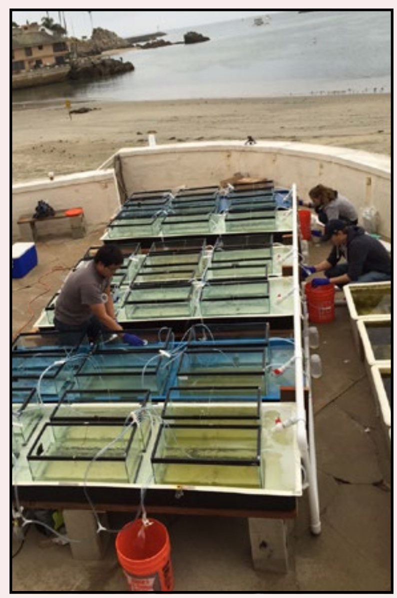
Seagulls and other wildlife deposit their droppings in and near coastal waters, which can complicate efforts to understand health risks associated with fecal contamination at beaches and other recreational areas. Non-human fecal sources are much less likely to sicken humans upon contact.

Limitations of source tracking

Scientists and environmental managers initially hoped that source tracking technology would make it possible for users to create simple pie charts that reveal which portion of observed fecal contamination came from which animal source.

In recent years, SCCWRP and its partners have conducted studies exploring the feasibility of taking such an approach, but have concluded that a simple pie chart is not possible in most cases.

The problem is that fecal contamination often enters the environment at multiple locations and times, and the various microbes associated with specific fecal sources start to degrade at different rates in response to sunlight, water temperature and other environmental factors. Thus, the pie chart approach could only be used when contamination enters the environment at the same time from the same source.



A mesocosm experiment is set up near the beach to examine the relative rates at which pathogens, fecal indicator bacteria and other microbes degrade in the environment. SCCWRP and its partners have shown that site-specific environmental factors can influence the rate at which different fecal microbes degrade.

Return to Table of Contents

Researchers also validated non-library-based genotypic MST methods for cattle, dogs and birds. These methods are now widely used across California and beyond.

"Microbial source tracking has progressed significantly within the last decade, allowing investigators to more confidently identify the source or sources of fecal contamination," said Dr. Samuel Choi, Environmental Laboratory Supervisor for the Orange County Sanitation District. "These types of tools are important because they can augment current monitoring by fecal indicator bacteria, which do not identify the source beyond warm-blooded animals."

Community fingerprinting

Although public health managers depend on HF183 to reliably distinguish human fecal contamination from livestock manure, bird droppings and other non-human sources, even the specificity offered by HF183 is not necessarily sufficient to inform management interventions.

When managers find widespread human fecal contamination during wet weather, they also need to know specifically where the contamination originated – that is, the specific location and/or

A SCCWRP field crew wades into beach water shortly after rainfall to collect samples. Public health managers rely on microbial source tracking to help eliminate fecal contamination in public recreational areas.

Courtesy of the Port of Los Angeles

At Inner Cabrillo Beach in Los Angeles County, where aquatic fecal contamination exceeds permissible levels even during dry weather, metal cables have been suspended in a grid pattern over the heads of beachgoers to deter birds from depositing their droppings in the water. Source tracking technology has enabled scientists to identify avian sources of fecal contamination in beach water.

Making source tracking field-deployable

Scientists are exploring ways to detect fecal contamination in the field – without having to transport samples to a lab for analysis. One prototype instrument that SCCWRP and its member agencies tested in 2018 is a suitcase-sized device that consists of a droplet digital PCR (polymerase chain reaction) machine paired to a system that can process raw water samples. Such field-deployable technology is still a work in progress, but scientists envision eventually being able to feed raw water samples into the device and getting results about two hours later.

SCCWRP's member agencies test a suitcase-sized, portable instrument that could help track fecal contamination to upstream points of origin. The device was tested in a SCCWRP mobile laboratory.

infrastructure type.

In highly urban environments like Southern California, this widespread contamination is hypothesized to be coming from one or more of three main potential sources: leaking sanitation infrastructure, faulty private lateral lines and septic tanks, and direct deposition of human fecal matter in and near waterways.

To distinguish among these three potential sources of wet-weather contamination, scientists are turning to an entirely new MST approach known as bacterial community-based source tracking, or community fingerprinting.

With community fingerprinting, researchers are moving beyond relying on a single, custom-tailored molecular marker like HF183. Instead, they're looking at differences in the DNA sequencing patterns of the microbial community as a whole.

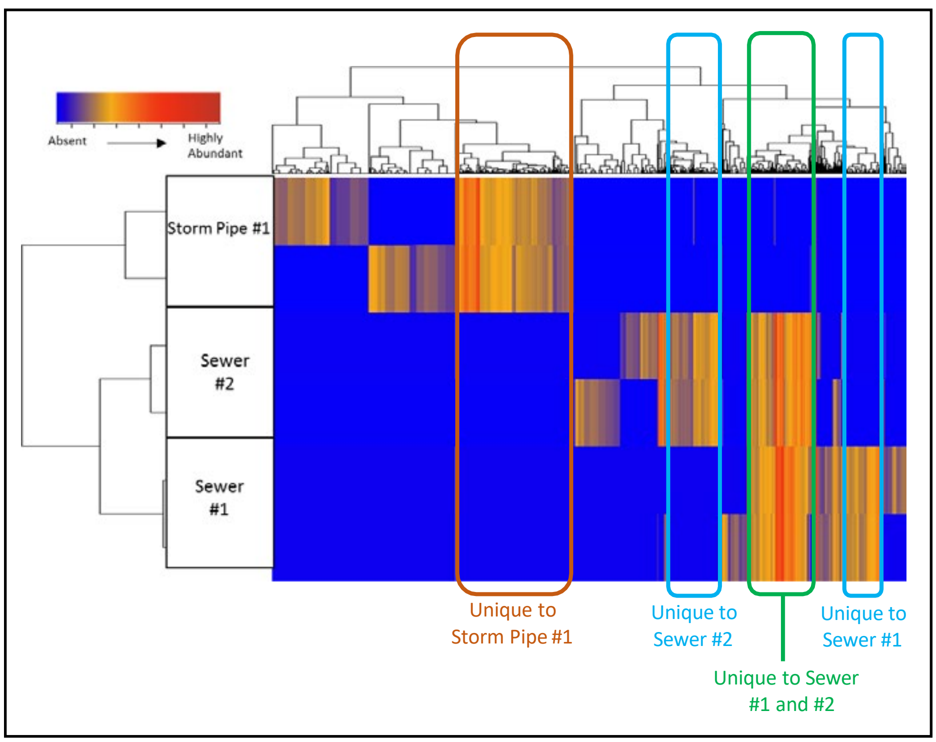
In 2018, SCCWRP launched a multi-year initiative to examine whether the microbial community that lives on the insides of sewer pipes – known as biofilm – is different from the biofilm community that lives inside storm drain pipes. Researchers' goal is to show that this biofilm community can reliably ascertain whether aquatic fecal contamination is coming from a sewer vs. storm drain pipe.

In parallel with this exploratory work on community fingerprinting, SCCWRP and its partners also are examining whether the microbial community in sewer pipes contains marquee chemical differences that distinguish it from the water flowing through storm drain pipes. This approach is referred to as chemical fingerprinting.

Initial results from community fingerprinting and chemical fingerprinting indicate that both MST methods have the potential to distinguish among multiple discrete sources of human fecal contamination.

"Every year, we're getting more and more specific in terms of the source-tracking insights we can offer to managers," said Dr. John Griffith, head of SCCWRP's Microbiology Department. "That means every year we're getting better at protecting public health."

SCCWRP's Dr. John Griffith uses a peristaltic pump to vacuum contents from an underground sewer pipe in San Diego County. Researchers are investigating whether the microbial community that lives inside the pipes – known as biofilm – is distinguishable from the biofilm in storm drain pipes, which could help narrow down the origins of widespread fecal contamination in Southern California waterways during wet weather.



Researchers are using microbial source tracking technology to identify marquee differences in the composition of bacterial communities living on the insides of sewer pipes and storm drain pipes. Above, a SCCWRP-created heat map shows that certain types of bacteria are unique to specific types of infrastructure.

Return to Table of Contents

SCREENING FOR MORE CHEMICAL CONTAMINANTS

Bioanalytical tools are transforming monitoring of the thousands of chemicals in aquatic systems

For generations, the environmental management community has protected humans and wildlife from waterborne chemical contamination by developing defined lists of priority pollutants to monitor.

These lists have largely been centered around chemicals commonly found in aquatic systems that trigger high-profile biological impacts, including acute poisoning in humans, lesions in fish, and reductions in the thickness of seabird egg shells.

To monitor the chemicals

SCCWRP's Dr. Alvina Mehinto transfers small aliquots of cells into assay wells for a bioanalytical screening test that involves exposing the cells to a water extract sample, then tracking how they respond. Bioanalytical screening has the potential to enable water bodies to be screened for hundreds and perhaps thousands of chemical contaminants.

responsible for these impacts, environmental managers traditionally have relied on chemical analyses that target one specific priority pollutant at a time, plus toxicity tests that expose living organisms to chemical contaminants.

From lead in drinking water to now-banned polychlorinated biphenyls (PCBs) in the coastal ocean environment, this traditional approach to aquatic monitoring is credited with extending vital protections to humans and wildlife.

But in recent decades, scientists have learned that aquatic systems are contaminated with tens of thousands of other chemicals that have the potential to present health risks – albeit via more subtle, non-acute biological pathways.

These contaminants of emerging concern (CECs) encompass a wide array of biologically active chemicals, including endocrine disruptors, carcinogens, immunosuppressants and neurotoxins.

Even at very low concentrations, some of these CECs can trigger adverse biological impacts in vulnerable aquatic life, including interfering with metabolic functions, reproduction and tissue integrity. And existing toxicity tests are not necessarily sensitive enough to detect the sublethal biological impacts of CECs.

These chemical contaminants also can break down and be transformed in ways that potentially pose equal or greater risks – and be present in combinations and concentrations that trigger synergistic biological impacts.

"Trying to develop individual tests for CECs would be like playing a game of whack-a-mole," said Dr. Alvina Mehinto, a molecular toxicologist at SCCWRP. "Not only is the universe of CECs huge, but it's constantly changing as new chemicals enter production while others are phased out."

Increasingly, scientists are recognizing that next-generation, biology-based screening tests are needed to more comprehensively monitoring the universe of CECs in aquatic systems.

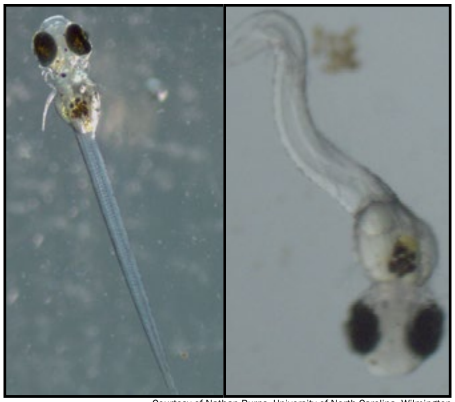
Under a monitoring paradigm proposed by SCCWRP and its partners, this effects-directed approach would rely on a laboratory technique known as bioanalytical screening.

Bioanalytical screening involves exposing laboratory-grown cells to water samples and then tracking their cellular-level responses. Using a small suite of bioanalytical tests, water bodies can be screened for hundreds and perhaps thousands of chemicals, including breakdown derivatives and transformation products.

"Bioanalytical screening is the most promising technology we have right now to be able to get a comprehensive handle on the potential health risks posed by CECs," said Dr. Daniel Schlenk, a Professor of

A wide variety of common household drugs, fragrances and personal hygeine products contain chemicals that can contaminate aquatic systems. Bioanalytical screening has the potential to improve scientists' ability to track the biological impacts of these chemicals on wildlife that might be exposed to them.

Return to Table of Contents



Courtesy of Nathan Burns, University of North Carolina, Wilmington

A healthy fish larva, left, with a straight spine contrasts visibly with a larva with a curved spine, right. The spinal deformity, which is permanent and potentially lethal, was triggered by exposure to biologically active CECs commonly found in aquatic systems.

Aquatic Ecotoxicology at the University of California, Riverside and a member of multiple CEC expert advisory panels facilitated by SCCWRP. "If we can get managers to a place where bioanalytical screening becomes a routine part of water-quality monitoring, we'll no longer be ignoring the majority of the biologically active chemical contaminants in our aquatic systems."

Adapting bioanalytical technology

Bioanalytical screening is an approach adapted from the pharmaceutical and food-safety industries to understand how waterborne contamination affects living systems.

During bioanalytical screening, small aliquots of cells are exposed to a water sample in a laboratory for up to 24 hours. Then, scientists track the way that the cells respond – specifically, initiation of a particular sequence of cellular-level events that, in living organisms, would trigger an adverse biological change.

Courtesy of Shawn Thompson, Sanitation Districts of Los Angeles County

During traditional toxicity testing, organisms such as fish are exposed to water samples in a laboratory. Bioanalytical screening has the potential to reduce reliance on whole-organism toxicity tests.

The cells, which are engineered so that researchers can track their responses, serve as a proxy for how wildlife could potentially be impacted by exposure to this same water.

Based on the degree of biological activity, water bodies can be flagged for follow-up testing to identify the chemicals responsible for the cellular-level response.

SCCWRP and other experts have proposed using bioanalytical screening as a cost-effective first line of defense for monitoring California water bodies for bioactive contaminants.

Under this proposed CEC monitoring paradigm, water-quality managers would complete the bioanalytical screening step in parallel with existing chemistry-based screening methods, then deploy more labor-intensive, tailored tests to validate and confirm the screening's findings.

In particular, bioanalytical screening is cheaper and less labor-intensive than traditional toxicity testing, which requires the use of live organisms.

"What we envision is that bioanalytical screening would serve as a sort of an early-warning sign: 'Hey, water quality might be compromised in this particular water body. You need to keep investigating,'" says Dr. Keith Maruya, head of SCCWRP's Chemistry Department.

In 2018, the California State Water Resources Control Board took the first step toward implementing this CEC monitoring framework on a statewide basis.

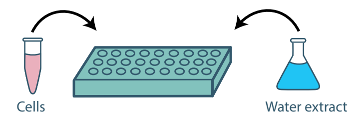
As part of a four-year trial, the State Water Board is requiring recycled water for potable reuse to be screened using two types of bioanalytical assays – the estrogen receptor assay and the aryl hydrocarbon receptor assay. The assays, which SCCWRP and its partners adapted for aquatic screening applications, screen for dozens and perhaps hundreds of chemicals that trigger a common cellular-level response.

At the end of the trial, the State Water Board will evaluate whether to set bioanalytical screening thresholds that, if exceeded, would require follow-up testing.

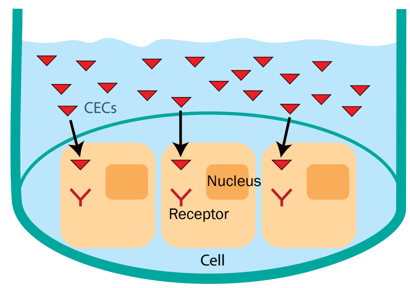
"We need to get these bioanalytical screening in the hands of end users right away to evaluate how well they work," said Karen Mogus, Deputy Director of the Division of Water Quality for the California State Water Resources Control Board. "This is a step toward advancing technology

How bioanalytical screening works

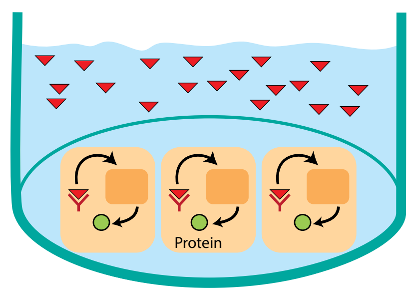
1 Cells are plated with growth media, and the water sample being tested is added.



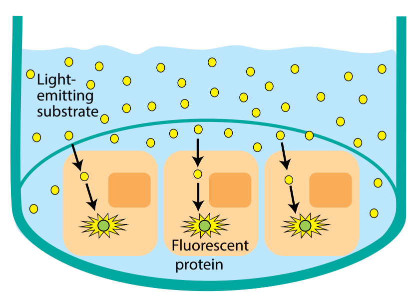
2 CECs that may be present in the sample are given up to 24 hours to enter the cells and bind to a receptor target inside.



3 When a CEC binds to its target receptor, the cell is engineered to respond by producing a special protein.



4 A light-emitting substrate is added that enters the cells and interacts with the protein to produce a fluorescent signal.



The strength of the signal reflects the CEC levels in the water sample.

Return to Table of Contents

Recycled water is sometimes placed into holding ponds, such as this one in Santa Clara County in Northern California, to allow the water to gradually infiltrate into groundwater. A new State Water Board policy requires that this type of recycled water be monitored via bioanalytical screening technology.

that will extend the CEC monitoring we're doing in California, and eventually across the U.S."

Evolving management strategy

The advent of a cell-based screening approach for tracking chemicals in aquatic systems is part of a decades-long evolution in management strategy for optimally protecting the health of humans and wildlife.

In the 1960s and 1970s, the U.S. water-quality management community was just waking up to the health risks posed by toxic chemicals that had been discharged into waterways and the coastal ocean for generations prior.

At the time, researchers focused on zeroing in on dozens of "priority pollutants" believed to pose the most acute, high-profile health threats.

Monitoring protocols were developed to screen water bodies – ranging from wastewater discharges to drinking water to rivers and streams – on a chemical-specific basis. Meanwhile, toxicity testing was used to determine whether exposure resulted in an adverse biological impact.

This combination of traditional chemical and toxicity testing is credited with spurring significant management action in California and beyond, including bans on chemical production and use. For example, the now-banned pesticide dichlorodiphenyltrichloroethane (DDT) – widespread in coastal ocean sediment by the late 20th century – was linked to a decline in seabirds and other predatory bird populations across the region.

Also during this time, environmental managers upgraded water treatment processes and implemented more stringent source-control measures to reduce the discharge of chemicals like mercury and DDT into aquatic environments.

"These aggressive management interventions throughout the 1970s and 1980s are really what has taken care of the most egregious health threats – and simultaneously allowed us to start focusing on the more complex, nuanced ones," said Dr. Stephen Weisberg, SCCWRP's Executive Director and an aquatic biologist.

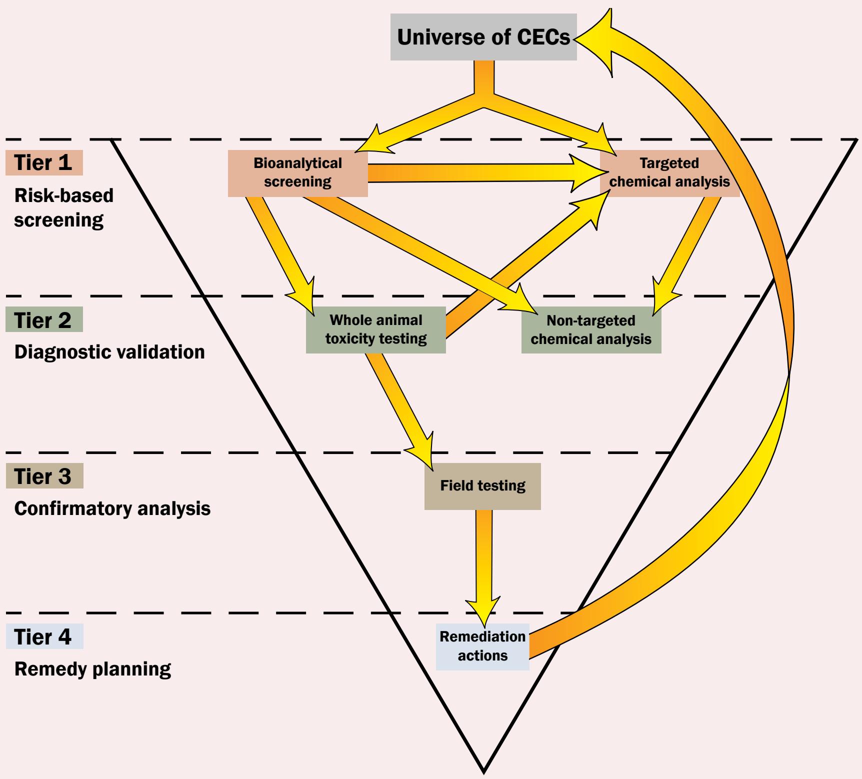
Responding to emerging health risks

By the 1990s, scientists began turning their attention to other chemicals commonly found in aquatic systems.

As the sensitivity and precision of

How bioanalytical screening fits into a broader CEC monitoring framework

SCCWRP and other experts have proposed using bioanalytical screening as a cost-effective first line of defense for screening water bodies for bioactive contaminants, complementing the existing targeted chemical screening analyses that are used today. The framework is designed to give environmental managers an efficient, cost-effective way to zero in on the CECs that pose the greatest potential health risks to humans and wildlife.



Courtesy of Kevin White, Full Frame Productions

The Montrose Chemical Corporation in Torrance, now demolished and a federal Superfund site, is an example of Southern California's legacy of chemical contamination. The plant is believed to have discharged as much as 1,700 tons of the pesticide DDT into coastal waters via a wastewater outfall.

Return to Table of Contents

scientific instruments improved, scientists documented thousands of chemical contaminants that are ubiquitous in aquatic systems.

But because toxicity tests were not designed to detect sublethal biological impacts triggered by prolonged exposure to these chemicals, scientists could not offer a practical way to evaluate which of these CECs might pose health risks to humans and wildlife.

Meanwhile, foundational research in the 1990s showed that a class of biologically active chemicals known as endocrine disruptors can trigger developmental anomalies in fish even at low levels.

Endocrine disruptors – both hormones naturally produced by humans and manmade formulations – are a ubiquitous part of modern life, being flushed down toilets, sinks and storm drains every day.

Compounding the challenge of assessing health risks from CECs is that the universe of CECs is constantly changing as new chemicals enter production and use while others are phased out.

Furthermore, CECs can break down and be transformed in ways that alter the health risks they pose – or be present in mixtures that trigger synergistic biological impacts.

"The more we learned about what chemicals are in our environment, the more we recognized that our existing chemical-by-chemical approach to monitoring was inherently limited," said Dr. Shane Snyder, a Professor of Chemical and Environmental Engineering at the University of Arizona and a member of multiple CEC expert advisory panels facilitated by SCCWRP. "We were discovering so many ubiquitous chemicals we had no way to practically monitor."

Targeting low levels of CECs

As scientists investigated alternative approaches for monitoring CECs in aquatic environments, bioanalytical screening emerged as a promising technology.

Bioanalytical screening already was a mainstay of the pharmaceutical and food-safety industries, so multiple classes of bioanalytical screening tests were commercially available, including for an array of endocrine disruptors.

For aquatic scientists, the challenge was showing that bioanalytical screening could be used effectively and practically to screen for complex mixtures of CECs found at low levels in water bodies.

As early as the mid-1980s, SCCWRP and its member agencies began experimenting with bioanalytical screening.

A cell-based screening test known as the P450 report gene system was used to understand how polycyclic aromatic hydrocarbons (PAHs) in seafloor sediment in coastal Southern California were impacting the health of marine

A SCCWRP field crew collects water samples to screen water bodies for chemical contaminants using multiple laboratory methods, including bioanalytical screening.

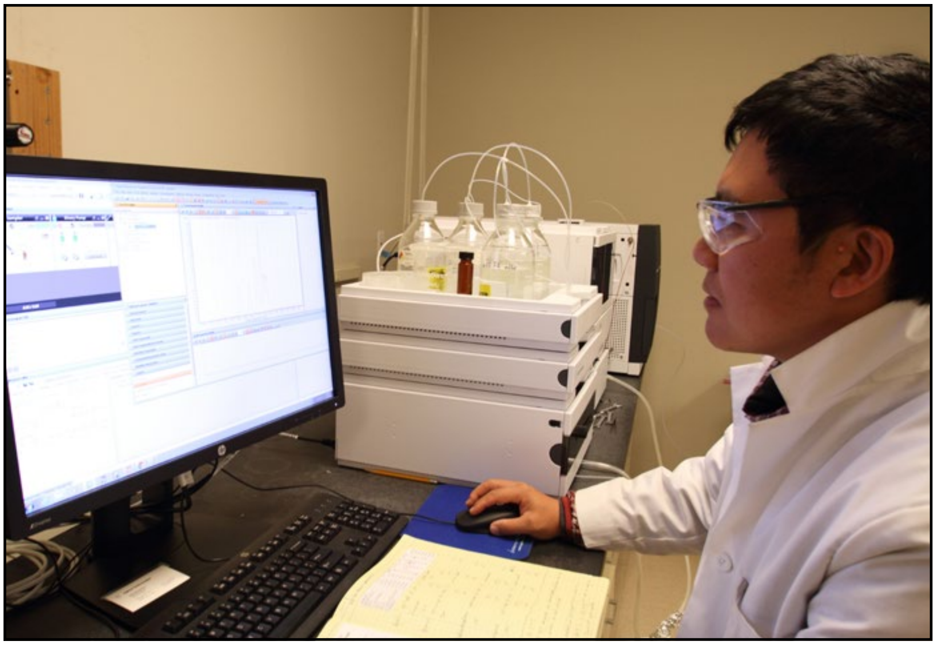
Linking bioanalytical screening data to organism-level biological responses

For bioanalytical screening to be effective as a screening tool, the technology must reliably detect cellular-level changes that would ultimately manifest as tissue damage and other impacts in living organisms.

SCCWRP and its partners are learning how to interpret bioanalytical screening data by documenting the linkage between cellular-level responses in a laboratory and biological impacts to living organisms in the field.

Scientists' goal is to show that bioanalytical screening is more sensitive than whole-animal toxicity testing; this would enable bioanalytical screening to be reliably used as an initial, encompassing screening test, to be followed by toxicity testing and other diagnostic tests.

SCCWRP's Syd Kotar monitors water quality inside a mobile unit that houses fish. The units, set up along the banks of the Los Angeles River, were used to expose the fish to flowing river water in real time, enabling researchers to track potential biological impacts from exposure.



SCCWRP's Dr. Bowen Du analyzes water samples using targeted chemistry analysis. Bioanalytical screening is envisioned as a complement to traditional targeted analysis, enabling water bodies to be screened for a broader universe of chemical contaminants.

communities; PAHs are a carcinogenic byproduct of burning wood and other fuels.

Perhaps the biggest advance for bioanalytical screening came at the turn of the 21st century, when the U.S. Environmental Protection Agency and other federal agencies established that bioanalytical screening is a viable alternative to animal testing for determining the safety of pharmaceuticals and other consumer chemicals.

SCCWRP and its partners began adapting this technology to detect very low levels of potentially harmful chemical contaminants in aquatic environments.

"When we demonstrated that *in vitro* cell assays could help direct further analyses to identify bioactive compounds potentially harmful to wildlife, we realized that this was the path forward for more comprehensive monitoring," Snyder said. "We identified a workflow that would more efficiently address complex mixtures of chemicals in the environment."

Building capacity for bioanalytical screening

Today, bioanalytical screening is viewed as central to a proposed next-generation management strategy in California that would significantly expand the universe of CECs that can be routinely monitored.

SCCWRP and its partners have spent the past decade working with the world's leading experts to lay the scientific foundation for this transition.

In particular, scientists have shown that cell assays are reliable and effective as a routine management monitoring tool for aquatic contaminants, and that standardized laboratory protocols for bioanalytical assays can be developed.

SCCWRP and its partners are now working to ensure this technology can be implemented consistently statewide, as well as increase the number of classes of bioactive chemicals that can be screened with bioanalytical technology.

Already, bioanalytical technology can be used to screen water bodies for three classes of bioactive CECs:

» Estrogen-mimicking chemicals, especially natural and synthetic forms of estradiol that are commonly used for hormone therapy and birth control; these chemicals activate the estrogen receptor.

» Glucocorticoid-mimicking chemicals, which are anti-inflammatory steroids commonly used to treat eczema, skin rashes and arthritis; these chemicals activate the glucocorticoid receptor.

» Polycyclic/halogenated aromatic hydrocarbons, which are generated during combustion of coal and oil; these dioxin-like chemicals and their transformation products activate the aryl hydrocarbon receptor.

Over time, scientists envision bioanalytical screening being developed for perhaps a dozen or more major classes of bioactive contaminants.

Deciding which CEC classes to develop bioanalytical screening for – and the order of this R&D work – will depend on future scientific research that expands knowledge about which chemicals are ubiquitous and most persistent in aquatic systems, as well as the relative health risks they pose.

"Our R&D strategy for bioanalytical screening ultimately will be responsive to what science tells us is going to best protect humans and wildlife," Mehinto said. "That's how we'll ensure we're building the highest-quality monitoring toolbox possible."

Building a bioanalytical screening toolbox

Multiple types of bioanalytical screening assays will be needed to provide comprehensive CEC monitoring for aquatic systems. Already, the estrogen receptor assay and aryl hydrocarbon receptor assay have been codified into screening requirements for some types of recycled water in California. Priority classes of CECs and the toolbox of bioanalytical assays needed to track these CECs include:

Endocrine disruptors

- Estrogen receptor assay
- Glucocorticoid receptor assay
- Progesterone receptor assay

Carcinogens

- Aryl hydrocarbon receptor assay
- Tumor protein P53 response element assay

Immunosuppressants/neurotoxins

- Thyroid receptor assay
- Peroxisome proliferator activated receptor assay
- Acetylcholine receptor assay

Return to Table of Contents

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 watershed resources

Research themes

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

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

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

110 Number of leadership roles that SCCWRP scientists hold with professional societies, advisory committees and editorial boards of scientific journals **Page 61**

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.

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.

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.

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.

Sediment Quality

To help environmental managers extend greater protections to marine communities affected by contaminated seafloor sediment, SCCWRP is working to understand how this contamination enters food webs and bioaccumulates in fish and wildlife, and how to effectively clean up and remediate its toxic effects.

Interactive mapping app helps visualize stream condition

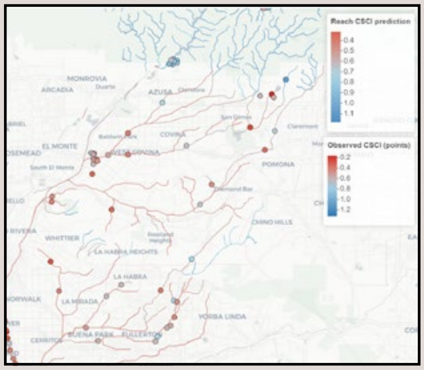
SCCWRP and its partners have developed a web-based interactive mapping program to help stream managers visualize whether they are more vs. less likely to find success in improving stream condition.

The Stream Classification and Priority Explorer (SCAPE) web app, unveiled in 2018 and available online at https://github.com/SCCWRP/SCAPE, maps data generated by a new computer modeling tool that predicts the degree to which stream biointegrity scores are likely to be limited, or "constrained," by urban and agricultural development. This landscape models tool also was co-developed by SCCWRP.

The mapping app was initially developed as a pilot project for the San Gabriel River watershed. The more constrained a site is, the less likely standard management interventions at the site are to result in improved condition scores.

Watershed managers will be able to use the web app to determine where they should direct resources to get the biggest bang for the buck.

Various management scenarios can be run through the mapping app, which then automatically re-calculates how ranges of likely stream biointegrity scores – as assessed through the California



The Stream Classification and Priority Explorer (SCAPE) is a web app that helps stream managers visualize how stream biointegrity scores in a watershed are likely to be limited, or "constrained," by urban and agricultural development. SCCWRP and its partners developed the app initially for use in the San Gabriel River watershed.

Stream Condition Index quantitative scoring tool – are expected to change based on local landscape constraints.

Especially in California's South Coast region, where 15% of stream-miles are considered "likely constrained," managers can benefit from improved understanding of the feasibility of improving biointegrity scores at a given site.

Ephemeral stream scoring tools being transitioned to management use

Watershed managers have begun pilot-testing a new set of scoring tools co-developed by SCCWRP that are designed to evaluate the ecological condition of ephemeral streams when they are dry.

The ephemeral stream assessment tools have the potential to dramatically expand the types of streams that Southern California water-quality managers can monitor via a bioassessment-based approach. Ephemeral streams, which are streams that run dry for much of the year, make up about 60% of all streams in Southern California, but they have traditionally been excluded from watershed monitoring programs, as bioassessment tools were previously designed for application in perennial and intermittent streams only.

In 2018, SCCWRP facilitated pilot testing for more than a dozen federal, state and local agencies. Already, the Los Angeles Regional Water Quality Control Board has launched an ephemeral streams pilot project in the Santa Clara River and Malibu Creek.

New modeling tool to help speed up causal assessment work

SCCWRP and its partners have developed a statistical modeling tool for conducting causal assessments that could help shave a year or more off the time required to narrow down potential causes of degraded ecological condition in streams and estuaries.

Instead of conducting a water body condition assessment first, and then following up with a causal assessment afterward, the Comparator Site Selection tool will enable environmental managers to use data from the condition assessment to simultaneously conduct a rapid, screening-level causal assessment. The tool, completed in 2018, enables each stressor to either rapidly be eliminated from consideration or identified as a possible cause of degradation based on a standard set of evidence types.

SCCWRP and its partners are continuing to work to build the analytical framework for the tool.

A field crew collects biological, habitat and water-quality data from a stream in the Big Bear Lake watershed as part of a stream condition assessment. SCCWRP and its partners have developed a modeling tool that uses data from condition assessments to enable a rapid, screening-level causal assessment of the site.

Adaptation and application of multivariate AMBI (M-AMBI) in US coastal waters

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[3]*TetraTech, Owings Mills, MD*
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Abstract

The multivariate AMBI (M-AMBI) is an extension of the AZTI Marine Biotic Index (AMBI) that has been used extensively in Europe, but not in the United States. In a previous study, we adapted AMBI for use in US coastal waters (US AMBI), but saw biases in salinity and score distribution when compared to locally calibrated indices. In this study we modified M-AMBI for US waters and compared its performance to that of US AMBI. Index performance was evaluated in three ways: 1) concordance with local indices presently being used as management tools in three geographic regions of US coastal waters, 2) classification accuracy for sites defined a priori as good or bad and 3) insensitivity to natural environmental gradients. US M-AMBI was highly correlated with all three local indices and removed the compression in response seen in moderately disturbed sites with US AMBI. US M-AMBI and US AMBI did a similar job correctly classifying sites as good or bad in local validation datasets (83–100% accuracy vs. 84–95%, respectively). US M-AMBI also removed the salinity bias of US AMBI so that lower salinity sites were not more likely to be incorrectly classified as impaired. The US M-AMBI appears to be an acceptable index for comparing condition across broad-scales such as estuarine and coastal waters surveyed by the US EPA's National Coastal Condition Assessment, and may be applicable to areas of the US coast that do not have a locally derived benthic index.

Citation

Pelletier, M.C., D.J. Gillett, A. Hamilton, T. Grayson, V. Hansen, E.W. Leppo, S.B. Weisberg, A. Borja. 2018. Adaptation and application of multivariate AMBI (M-AMBI) in US coastal waters. *Ecological Indicators* 89:818-827.

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Development of a biological condition assessment index for shallow, subtidal rocky reefs in Southern California, USA

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Abstract

Quantitative biological assessment indices overcome many of the challenges faced when trying to convey the status or trends of complex biological communities with large natural variability, particularly when attempting to evaluate the impacts from human influences. In this paper, we developed a biological condition index for shallow (<30 m) rocky reefs of the Southern California Bight, evaluated its ability to distinguish healthy from stressed sites, and then applied the index by examining relative correlations with fishing and water quality as ecosystem stressors. We utilized a multivariate, predictive index based on the ratio of observed- to- expected taxa (O/E). O/E indices are relatively common in freshwater environments, but rarely utilized in marine systems and never before applied to rocky reefs. Based on expectations drawn from region- wide reference reefs with the least fishing or water quality stress, the O/E index predicts expected taxa at a new site based on environmental factors such as sea surface temperature, reef area, and slope, among others. The observed taxa at that site are then compared to the predicted taxa to generate index scores; values near unity indicate intact, reference- like communities. Overall, the accuracy of the index was high, with minimal bias, and precision exceeded the performance of an index based on null models (i.e., indices that did not account for natural gradients). The mean index score was significantly higher among reference sites than stressed sites; however, sensitivity was low, as 84% of stressed sites had scores within the range of reference sites. Ultimately, fishing pressure was more correlated with changes in index scores from the non-reference data set than was water quality pressure. This study demonstrates that a multivariate predictive index is feasible in rocky reef assessment and illuminates additional investigative work to continue to advance index development.

Citation

Coates, J., K.C. Schiff, R.D. Mazor, D.J. Pondella II, R.A. Schaffner, E. Whiteman. 2018. Development of a biological condition assessment index for shallow, subtidal rocky reefs in Southern California, USA. *Marine Ecology* DOI:10.1111/maec.12471.

SCCWRP Journal Article #1062
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1062_BioIndexRockyReefs.pdf

A freshwater conservation blueprint for California: prioritizing watersheds for freshwater biodiversity

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ABSTRACT

Conservation scientists have adapted conservation planning principles designed for protection of habitats ranging from terrestrial to freshwater ecosystems. We applied current approaches in conservation planning to prioritize California watersheds for management of biodiversity. For all watersheds, we compiled data on the presence/absence of herpetofauna and fishes; observations of freshwater-dependent mammals, selected invertebrates, and plants; maps of freshwater habitat types; measures of habitat condition and vulnerability; and current management status. We analyzed species-distribution data to identify areas of high freshwater conservation value that optimized representation of target taxa on the landscape and leveraged existing protected areas. The resulting priority network encompasses 34% of the area of California and includes ≥10% of the geographic range for all target taxa. High-value watersheds supported nontarget freshwater taxa and habitats, and focusing on target taxa may provide broad conservation value. Most of the priority conservation network occurs on public lands (69% by area), and 46% overlaps with protected areas already managed for biodiversity. A significant proportion of the network area is on private land and underscores the value of programs that incentivize landowners to manage freshwater species and habitats. The priority conservation areas encompass more freshwater habitats/ ha than existing protected areas. Land use (agriculture and urbanization), altered fire regimes, nonnative fish communities, and flow impairment are the most important threats to freshwater habitat in the priority network, whereas factors associated with changing climate are the key drivers of habitat vulnerability. Our study is a guide to a comprehensive approach to freshwater conservation currently lacking in California. Conservation resources are often limited, so prioritization tools are valuable assets to land and water managers.

CITATION

Howard, J.K., K.A. Fesenmyer, T.E. Grantham, J.H. Viers, P.R. Odes, P.B. Moyle, S.J. Kupferburg, J.L. Furnish, A. Rehn, J. Slusark, R.D. Mazor, N.R. Santos, R.A. Peek, A.N. Wright. 2018. A Freshwater Blueprint for California: Prioritizing freshwater habitat for conservation in California to maximize biodiversity and leverage existing protected areas. *Freshwater Science* DOI:10.1086/697996.

SCCWRP Journal Article #1036
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1036_FreshwaterConservationBlueprint.pdf

California Rapid Assessment Method for wetlands and riparian areas (CRAM)

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ABSTRACT

The California Rapid Assessment Method (CRAM) for wetlands and riparian areas is an integral part of the Wetland and Riparian Area Monitoring Plan (WRAMP) produced by the Wetland Monitoring Workgroup of the California Water Quality Monitoring Council. WRAMP has two main objectives: to enable local, state, and federal agencies in California to consistently assess (1) the distribution, abundance, diversity, and condition of wetlands in the watershed context, and (2) the performance of public policies, programs, and projects intended to restore and protect California wetlands.

WRAMP is based on the three-level framework for wetland assessment embodied in the US Environmental Protection Agency's (USEPA) Core Elements of an Effective State and Tribal Wetlands Program, where Level 1 consists of map-based inventories, Level 2 consists of field-based rapid assessments of wetland overall health, and Level 3 consists of intensive field-based measures of particular health aspects. CRAM is the state's primary Level 2 tool.

CRAM assumes that the condition of a wetland is a manifestation of many processes that together control the kinds and levels of wetland functions, such that the overall functional capacity of a wetland can be assessed based on its overall condition.

CRAM meets a broadly expressed need in California for a standard, scientifically sound, and affordable way to assess the overall condition or functional capacity of wetlands in a watershed context. The need is amplified by the watershed approach to compensatory mitigation required under the federal Clean Water Act (CWA, Section 404), and the state's intent to take a complimentary watershed approach under CWA Section 401. The state has also recognized that CRAM can help meet its reporting requirements under CWA Sections 303(d) and 305(b) while also helping to evaluate the governor's Wetland Conservation Policy.

 Return to Table of Contents

The state conducted a peer review of CRAM as part of its adoption process, and the USACE also conducted a review of CRAM relative to its use in mitigation planning and evaluation. A key finding of the state's review was that CRAM should be subject to ongoing revision to assure its continued efficacy. The Level 2 Committee of the Wetland Monitoring Workgroup serves this objective while also overseeing a statewide CRAM training program and online database. A key recommendation from the USACE was to quantify the relationship between the age and condition of wetland restoration projects based on CRAM that could be used to forecast future project conditions relative to ambient, reference, or target conditions.

CITATION

Collins, J., E.D. Stein. 2018. California Rapid Assessment Method for Wetlands and Riparian Areas (CRAM). in: J. Dorney, R. Savage, R. Tiner, P. Adamus (eds.), *Wetland and Stream Rapid Assessments: Development, Validation, and Application* pp. 353-362. Elsevier Publishers. London, UK.

SCCWRP Book Chapter #1058
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Assessment of Ichthyoplankton metabarcoding for routing monitoring

Dovi Kacev[1,2], David Gillett[1], Anne Freire de Carvalho[2], Curtis Cash[3], Shelly Walther[4], Cody D. Larsen[3], Andrew Thompson[2], Luke Thompson[2], Noelle Bowlin[2], Kelly Goodwin[5], Eric D. Stein[1]

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CITATION

Kacev, D., D.J. Gillett, A.F. de Carvalho, C. Cash, S. Walther, C.D. Larsen, A. Thompson, L. Thompson, N. Bowlin, K. Goodwin, E.D. Stein. 2018. Assessment of Ichthyoplankton Metabarcoding for Routine Monitoring. Technical Report 1031. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1031
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1031_IchthyoplanktonMetabarcoding.pdf

An index to measure the quality of physical habitat in California wadeable streams

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CITATION

Rehn, A.C., R.D. Mazor, P.R. Ode. 2018. An index to measure the quality of physical habitat in California wadeable streams. Technical Report 1053. Surface Water Ambient Monitoring Program. Sacramento, CA.

SCCWRP Technical Report #1053
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1053_CalifPhysicalHabitatWadeableStreamQualityIndex.pdf

Study to determine impacts of diverting L.A. River discharges

SCCWRP and water-quality managers that work in the Los Angeles River watershed have developed a two-year study to determine the potential ecological and recreational effects of diverting treated wastewater effluent and runoff from the river for water recycling purposes.

The environmental flows study, launched in 2018, marks the first effort by California's water-quality management community to understand how sensitive species, habitats and other beneficial uses will be impacted as land-based discharges to the river are reduced over time.

The study is motivated by changing water use and reuse practices across drought-prone California.

Under State Water Code Section 1211, California wastewater treatment agencies have been filing petitions seeking regulatory approval to begin recycling more of the effluent that they're currently discharging into urban streams. Three wastewater treatment plants discharge into the effluent-dominated L.A. River.

Stormwater management agencies also are capturing more land-based runoff, which is further reducing stream flows.

The study will document how vulnerable species and habitats along the lower L.A. River – as well as human recreation – are expected to be impacted by multiple combinations of potential flow reductions.

Treated wastewater effluent is discharged into the Los Angeles River from the nearby L.A.-Glendale Water Reclamation Plant. Water-quality managers for the effluent-dominated river have initiated a study exploring the potential ecological and recreational effects of diverting effluent and runoff from the river for water recycling purposes.

Study shows tool can distinguish intermittent and ephemeral streams in U.S. Southwest

SCCWRP and its partners have shown in a proof-of-concept study that a flow classification tool that can rapidly distinguish intermittent streams from ephemeral streams in the Pacific Northwest is feasible for application in the U.S. Southwest.

The tool, which determines a stream's flow duration based on easily observed field indicators, was originally developed by the U.S. Environmental Protection Agency.

The study, completed in 2018, paves the way to refine the tool for use across California, Arizona and New Mexico. Researchers also will develop a comparable tool in parallel for use in the adjacent Western Mountains region.

Watershed managers need to be able to distinguish intermittent streams from ephemeral because they are subject to different regulatory requirements in some cases. Intermittent streams are defined as streams that have sustained seasonal flows from snow melt and groundwater, whereas ephemeral streams only experience brief surface flows from runoff.

Sagebrush and other upland vegetation dominate in New Mexico's Arroyo Chamiso, which is classified as an ephemeral stream. Researchers have developed a tool that uses riparian plants and other indicators to distinguish ephemeral streams from intermittent streams in the U.S. Southwest.

Environmental flow targets developed to protect Santa Clara River Estuary

A scientific review panel that included participation by SCCWRP has completed an analysis of the environmental flow needs of the Santa Clara River Estuary.

The flow target analysis, completed in 2018, marked the first time that SCCWRP helped evaluate the flow regime necessary to protect the ecological integrity of an estuarine environment. SCCWRP's previous flow target analyses focused on streams.

The goal of the analysis was to develop recommendations for the maximum ecologically sustainable discharge to the estuary that the City of Ventura should be allowed. All effluent above this level would be available to be diverted for recycling purposes.

The three-member review panel concluded that the City could divert about 95% of its effluent; this conclusion was not the same as the one reached during a previous flow target analysis commissioned by the City of Ventura.

Return to Table of Contents

Tools for managing hydrologic alteration on a regional scale: Setting targets to protect stream health

Raphael Mazor[1], Jason T. May[2], Ashmita Sengupta[1], Kenneth S. McCune[1], Brian P. Bledsoe[3], Eric D. Stein[1]

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[2]*California Water Science Center, United States Geological Survey, Sacramento, CA*
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Abstract

Widespread hydrologic alteration creates a need for tools to assess ecological impacts to streams that can be applied across large geographic scales. A regional framework for biologically based flow management can help catchment managers prioritise streams for protection, evaluate impacts of disturbance or interventions and provide a starting point for causal assessment in degraded streams. However, lack of flow data limit the ability to assess hydrologic conditions across a region.

Hydrologic models can address this problem. Regionally calibrated hydrologic models were used to estimate current and reference flows at 572 bioassessment sites in southern and central coastal California. Flow alteration was characterized as the difference in 39 flow metrics calculated from simulations of present-day and reference flow time-series, calculated under up to four precipitation conditions.

Biological condition was assessed with the California Stream Condition Index (CSCI) and its components. Logistic regressions were used to predict the likelihood of high scores (i.e. ≥10th percentile of the CSCI reference calibration data). Statistically significant relationships between increasing severity of hydrologic alteration and decreasing biological condition were used to set thresholds that reflected tolerance for risk of a stakeholder advisory group.

An index of hydrologic alteration was created by selecting flow metrics based on their importance for predicting biological response variables in boosted regression tree models. Metrics were selected in the order of decreasing importance, and no more than two metrics per metric class were selected (i.e. duration, frequency, magnitude, timing and variability). Seven metrics were selected: HighDur (duration of high-flow events), HighNum (# of high-flow events), NoDisturb (duration between high- or low-flow events), MaxMonthQ (maximum monthly discharge), Q99 (99th percentile of daily streamflow), QmaxIDR (interdecile range of annual maxima) and RBI (Richards–Baker Index).

Applying the index to data from a probabilistic survey, 34% of stream-miles in southern California were estimated to be hydrologically altered. One of four management priorities were assigned to each site based on biological condition and hydrologic status: protection (healthy and unaltered, 52% of stream-miles, monitoring (healthy but altered 4%), evaluation of flow management (unhealthy and altered, 30%) and evaluation of other management (unhealthy but unaltered, 14%).

Regionally derived biologically based targets for flow alteration allow catchment managers to prioritise activities and conduct screenings for causal assessments across large spatial scales. Furthermore, regional tools pave the way for incorporation of hydrologic management in policies and catchment planning designed to support biological integrity in streams. Development of regional tools should be a priority where hydrologic alteration is pervasive or expected to increase in response to climate change or urbanisation.

Citation

Mazor, R.D., J.T. May, A. Sengupta, K. McCune, B.P. Bledsoe, E.D. Stein. 2018. Tools for managing hydrologic alteration on a regional scale: Setting targets to protect stream health. *Freshwater Biology* DOI:10.1111/fwb.13062.

SCCWRP Journal Article #1015
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Tools for managing hydrologic alteration on a regional scale: Estimating changes in flow characteristics at ungauged sites

Ashmita Sengupta[1], Stephen K. Adams[2], Brian P. Bledsoe[3], Eric D. Stein[1], Kenneth S. McCune[1], Raphael D. Mazor[1,4]

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[2]*Colorado State University, Fort Collins, CO*
[3]*University of Georgia, College of Engineering, Athens, GA*
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Abstract

Hydrologic alteration is a predominant stressor for biological resources in streams. This stress is further aggravated by competing human and ecological demands for limited water resources. Understanding flow-ecology relationships and establishing relevant and implementable flow targets are essential to protect biological communities.

Estimating degree of ecologically relevant hydrologic alteration depends on the availability of long-term flow data at sites with biological information. However, measured flow data are seldom available at sufficient density to support largescale analyses of the biological effects of hydrologic alterations. The ability to accurately simulate flows and estimate flow metrics at many ungauged locations across a broad geographical area remains a fundamental challenge.

We address this challenge by applying a novel technique to simulate flow regimes at any stream reach of interest by first developing an ensemble of regionally calibrated and validated hydrological models, and then using a selection tool to match the "best-fit" model to ungauged stream reaches. An ensemble of 26 HEC-HMS rainfall-runoff models were calibrated to represent the range of catchment conditions in the southern California region.

We developed current and historical flow regimes and a suite of flow metrics at 572 ungauged sites in southern California with bioassessment monitoring data. The flow metrics represent hydrograph characteristics of magnitude, timing, frequency, duration and variability. The flow metrics were estimated under three precipitation conditions—dry, wet and average. In addition, we estimated aggregated flow metrics for (dry + wet + average) condition. Hydrologic alteration was estimated as the deviation between the modelled current and historical flow metrics.

Approximately 79% of the region shows some degree of hydrologic alteration, and approximately 40% of the sites are estimated to be severely altered. Magnitude metrics tend to increase in response to urban and agricultural land uses, whereas the timing and duration metrics are mostly unchanged.

This mechanistic modelling approach demonstrates the feasibility of estimating flow alterations for ungauged catchments with relative ease of transferability over a broad geographical region. The continuous granular flow data allow for computation and consideration of metrics that may be applicable to a variety of ecological endpoints and consideration of a range of management trade-offs.

CITATION

Sengupta, A., S.K. Adams, B.P. Bledsoe, E.D. Stein, K. McCune, R.D. Mazor. 2018. Tools for managing hydrologic alteration on a regional scale: Estimating changes in flow characteristics at ungauged sites. *Freshwater Biology* DOI:10.1111/fwb.13074.

SCCWRP Journal Article #1019
Full text available by request: pubrequest@sccwrp.org

Recent advances in environmental flows science and water management—Innovation in the anthropocene

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ABSTRACT

The implementation of environmental flow regimes offers a promising means to protect and restore riverine, wetland and estuarine ecosystems, their critical environmental services and cultural/societal values.

This Special Issue expands the scope of environmental flows and water science in theory and practice, offering 20 papers from academics, agency researchers and non-governmental organisations, each with fresh perspectives on the science and management of environmental water allocations.

Contributions confront the grand challenge for environmental flows and water management in the Anthropocene—the urgent need for innovations that will help to sustain the innate resilience of social–ecological systems under dynamic and uncertain environmental and societal futures.

Basin-scale and regional assessments of flow requirements mark a necessary advance in environmental water science in the face of rapid changes in water resource management activities worldwide (e.g. increases in dams, diversions, retention and reuse). Techniques for regional-scale hydrological and ecohydrological modelling support ecological risk assessment and identification of priority flow management and river restoration actions.

Changing flood–drought cycles, long-term climatic shifts and associated effects on hydrological, thermal and water quality regimes add enormous uncertainty to the prediction of future ecological outcomes, regardless of environmental water allocations. An improved capacity to predict the trajectories of ecological change in rivers degraded by legacies of past impact interacting with current conditions and future climate change is essential. Otherwise, we risk unrealistic expectations from restoration of river and estuarine flow regimes.

A more robust, dynamic and predictive approach to environmental water science is emerging. It encourages the measurement of process rates (e.g. birth rate, colonisation rate) and species traits (e.g. physiological requirements, morphological adaptations) as well as ecosystem states (e.g. species richness, assemblage structure), as the variables representing ecological responses to flow variability and environmental water allocations. Another necessary development is the incorporation of other environmental variables such as water temperature and sedimentary processes in flow–ecological response models.

Based on contributions to this Special Issue, several recent compilations and the wider literature, we identify six major scientific challenges for further exploration.

CITATION

Arthington, A.H., J.G. Kennen, E.D. Stein, J.A. Webb. 2018. Recent advances in environmental flows science and water management – Innovation in the Anthropocene. *Freshwater Biology* DOI:10.1111/fwb.13108.

SCCWRP Journal Article #1033
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Evaluating and managing environmental water regimes in a water-scarce and uncertain future

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ABSTRACT

While the number of environmental flows and water science programmes continues to grow across the globe, there remains a critical need to better balance water availability in support of human and ecological needs and to recognise the environment as a legitimate user of water. In water-stressed areas, this recognition has resulted in friction between water users in the public and private sectors. An opportunity exists for practitioners to be on the forefront of the science determining best practices for supporting environmental water regimes.

This Special Issue brings together a collection of environmental flows science and water management papers organised around three major themes: (1) method development and testing; (2) application case studies; and (3) efficacy evaluation. Contents of this Special Issue are intended to foster collaboration and broaden transferability of the information, technical tools, models and methods needed to support environmental water management programmes.

The technical sophistication of methods and modelling tools, while important to the advancement of environmental water science, may come at the expense of easily interpretable outcomes that positively influence management decisions. Researchers need to be more proactive in translating the results of advanced modelling methodologies into user-friendly tools and methods. This will allow stakeholders and water managers to proactively test alternative water allocation scenarios to help address growing human water demands in the face of droughts and changes in climatic patterns.

The application of environmental flows science and water management strategies cannot be done in isolation. Implementation involves a complex decision-making process that integrates ecological, hydrologic and social science across diverse multifaceted governance systems and requires active stakeholder involvement. Scientists and managers must strengthen partnerships at multiple scales to develop sensible science investment strategies so that collective knowledge can be translated into wise environmental water management decisions.

CITATION

Kennen, J.G., E.D. Stein, J.A. Webb. 2018. Evaluating and managing environmental water regimes in a water-scarce and uncertain future. *Freshwater Biology* DOI:10.1111/fwb.13104.

SCCWRP Journal Article #1035
Full text available by request: pubrequest@sccwrp.org

Beyond metrics? The role of hydrologic baseline archetypes in environmental water management

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ABSTRACT

Balancing ecological and human water needs often requires characterizing key aspects of the natural flow regime and then predicting ecological response to flow alterations. Flow metrics are generally relied upon to characterize long-term average statistical properties of the natural flow regime (hydrologic baseline conditions). However, some key aspects of hydrologic baseline conditions may be better understood through more complete consideration of continuous patterns of daily, seasonal, and inter-annual variability than through summary metrics. Here we propose the additional use of high-resolution dimensionless archetypes of regional stream classes to improve understanding of baseline hydrologic conditions and inform regional environmental flows assessments. In an application to California, we describe the development and analysis of hydrologic baseline archetypes to characterize patterns of flow variability within and between stream classes. We then assess the utility of archetypes to provide context for common flow metrics and improve understanding of linkages between aquatic patterns and processes and their hydrologic controls. Results indicate that these archetypes may offer a distinct and complementary tool for researching mechanistic flow-ecology relationships, assessing regional patterns for streamflow management, or understanding impacts of changing climate.

CITATION

Lane, B.A., S. Sandoval-Solis, E.D. Stein, S.M. Yarnell, G.B. Pasternack, H.E. Dahlke. 2018. Beyond Metrics? The role of hydrologic baseline archetypes in environmental water management. *Environmental Management* DOI:10.1007/s00267-018-1077-7.

SCCWRP Journal Article #1060
Full text available by request: pubrequest@sccwrp.org

Review of flow duration methods and indicators of flow duration in the scientific literature: Arid Southwest

Kenneth McCune, Raphael Mazor

Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

McCune, K., R. Mazor. 2019. Review of flow duration methods and indicators of flow duration in the scientific literature: Arid Southwest. SCCWRP Technical Report 1063. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1063
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1063_FlowMethodsReview.pdf

Tools for proposed stream policy released in draft form

The State Water Board has published draft versions of a suite of technical reports, journal manuscripts and tools co-authored by SCCWRP that will serve as the technical foundation for the State in developing a policy that protects the biological integrity of wadeable streams from the impacts of eutrophication and other stressors.

The draft science products, released in 2018, will support State Water Board staff in crafting a combined biointegrity-biostimulatory policy that includes programs both for assessing stream biointegrity and for limiting excess loading of biostimulatory substances (i.e., nutrients).

The State Water Board could release a draft of the policy as early as 2020.

The combined biointegrity-biostimulatory policy is expected to include numeric guidance on how to reduce the biostimulatory impacts of eutrophication and other stressors on wadeable streams. The science products developed by SCCWRP and its partners fall into two main categories:

» The biointegrity products explain how quantitative measures of a wadeable stream's biological condition relate to the stream's overall ecological health. The State Water Board and other water-quality regulators will consider using this information to establish procedures for sufficiently protecting stream health.

» The biostimulatory products identify a suite of eutrophication indicators (e.g., algal biomass, total nitrogen and phosphorus) for quantifying biostimulatory impacts to wadeable streams. They also summarize the scientific basis for setting numeric targets for these eutrophication indicators that guard against biostimulatory impacts.

Draft science products co-developed by SCCWRP will support a State Water Board effort to craft a policy for protecting California wadeable streams like the Santa Clara River, above.

Set of models built for establishing nutrient loading targets

SCCWRP and its partners have finished assembling an integrated toolkit of mechanistic computer models and empirical statistical models that water-quality managers can use to optimally protect biological integrity and human uses in the lower mainstem of the Santa Margarita River.

The work, completed in 2018, is part of a three-year project to develop scientifically defensible nutrient loading targets for reducing eutrophication in the lower Santa Margarita River watershed.

The Santa Margarita River watershed, which spans Riverside and northern San Diego Counties, has been grappling with algal proliferation and low dissolved oxygen as a result of excess nutrient and organic matter inputs.

Already, researchers have begun developing receiving-water models for the river's upper mainstem that will be connected to the lower mainstem models.

This work serves as a key California case study for test-driving technical elements of a proposed State Water Board biointegrity-biostimulatory policy to govern the health of wadeable streams statewide.

A field crew collects algae samples in the Santa Margarita River, which spans Riverside and northern San Diego Counties. SCCWRP and its partners are developing models for the watershed to test-drive elements of a proposed biointegrity-biostimulatory policy for wadeable streams.

Study seeking to develop field methods for monitoring freshwater cyanotoxins

SCCWRP and its partners have completed Year 1 field sampling for a study that will develop more robust field methods for monitoring cyanotoxins in freshwater aquatic environments.

The three-year study, launched in 2018, involves deploying passive sampling devices for several days to weeks to measure the integrative, average concentration of toxins present. Passive samplers are simple, easy-to-deploy devices that absorb organic contaminants over time, enabling them to capture evidence of toxic cyanobacterial blooms that may be quickly flushed out of water bodies.

Researchers are evaluating the performance of two types of passive sampling devices – resin-based Solid Phase Adsorption Toxin Tracking (SPATT) devices and film-based devices.

Researchers are interested in using passive sampling devices to provide additional insights into the dynamic nature of cyanotoxin-producing bloom events.

Return to Table of Contents

A decade and a half of *Pseudo-nitzschia* spp. and domoic acid along the coast of Southern California

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Abstract

Blooms of the marine diatom genus *Pseudo-nitzschia* that produce the neurotoxin domoic acid have been documented with regularity along the coast of southern California since 2003, with the occurrence of the toxin in shellfish tissue predating information on domoic acid in the particulate fraction in this region. Domoic acid concentrations in the phytoplankton inhabiting waters off southern California during 2003, 2006, 2007, 2011 and 2017 were comparable to some of the highest values that have been recorded in the literature. Blooms of *Pseudo-nitzschia* have exhibited strong seasonality, with toxin appearing predominantly in the spring. Year-to year variability of particulate toxin has been considerable, and observations during 2003, 2006, 2007, 2011 and again in 2017 linked domoic acid in the diets of marine mammals and seabirds to mass mortality events among these animals. This work reviews information collected during the past 15 years documenting the phenology and magnitude of *Pseudo-nitzschia* abundances and domoic acid within the Southern California Bight. The general oceanographic factors leading to blooms of *Pseudo-nitzschia* and outbreaks of domoic acid in this region are clear, but subtle factors controlling spatial and interannual variability in bloom magnitude and toxin production remain elusive.

Citation

Smith, J., P. Connell, R.H. Evans, A.G. Gellene, M.D.A. Howard, B.H. Jones, S. Kaveggia, L. Palmer, A. Schnetzer, B.N. Seegers, E.L. Seubert, A.O. Tatters, D.A. Caron. 2018. A decade and a half of Pseudo-nitzschia spp. and domoic acid along the coast of southern California. *Harmful Algae* DOI:10.1016/j.hal.2018.07.007.

SCCWRP Journal Article #1049
Full text available by request: pubrequest@sccwrp.org

A tale of two algal blooms: Negative and predictable effects of two common bloom-forming microalgae on seagrass and epiphytes

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Abstract

Recent evidence suggests macroalgal blooms may play a role in the worldwide decline in seagrass, but the shape of the functional relationship between seagrass health and dominant bloom-forming macroalgae is poorly characterized. We tested whether the impact of varying abundances of two cosmopolitan bloom-forming macroalgal genera caused linear/quasi-linear or sudden threshold changes in measures of eelgrass, *Zostera marina*, meadow health. We conducted two caging experiments in a shallow *Z. marina* bed (~1 m depth) in Bodega Harbor, California, USA where we maintained six densities within the range of natural abundances of macroalgae, *Ulva* (0–4.0 kg m^{-2}) and *Gracilariopsis* (0–2.0 kg m^{-2}), as well as uncaged controls over a 10-week period. Shoot density, blade growth, and epiphyte load were measured every two weeks and algal treatments reset. We did not find support for threshold transitions between algal abundance and measures of seagrass bed health using sigmoidal and broken-stick regression analyses for each data set; these models are commonly used to identify threshold patterns in ecological shifts. Instead, final measurements of shoot density and epiphyte load were best modelled as linear or slightly non-linear declines with increasing *Ulva* abundance. A negative linear relationship also existed between shoot density and *Gracilariopsis* abundance and a trend towards linear negative effects on epiphyte load. The similar shape of these functional relationships across different types of algae suggests the relationship may be generalizable. At algal abundances that are commonly observed, we found smooth and predictable negative impacts to *Z. marina* by decline in shoot density and potential impacts to food webs by loss of epiphytes rather than sudden threshold shifts or "ecological surprises". Our work contrasts with the growing body of literature suggesting highly non-linear shifts in response to human impact; thus, it is important to broaden understanding of shifts to more than just pattern but to the processes that drive different patterns of shifts.

Citation

Bittick, S.J., M. Sultula, P. Fong. 2018. A tale of two algal blooms: negative and predictable effects of two common macroalgae on seagrass health. *Marine Environmental Research* 140:1-9

SCCWRP Journal Article #1064
Full text available by request: pubrequest@sccwrp.org

Four decades of water quality change in the upper San Francisco Estuary

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[3]*San Francisco Estuary Institute, Richmond, CA*

ABSTRACT

Quantitative descriptions of chemical, physical, and biological characteristics of estuaries are critical for developing an ecological understanding of drivers of change. Historical trends and relationships between key species of dissolved inorganic nitrogen (ammonium, nitrate/nitrite, total) from the Delta region of the San Francisco Estuary were modelled with an estuarine adaptation of the Weighted Regressions on Time, Discharge, and Season (WRTDS). Analysis of flow-normalized data revealed trends that were different from those in the observed time-series. Flow-normalized data exhibited changes in magnitude and even reversal of trends relative to the observed data. Modelled trends demonstrated that nutrient concentrations were on average higher in the last twenty years relative to the earlier periods of observation, although concentrations have been slowly declining since the mid-1990s and early 2000s. We further describe mechanisms of change with two case studies that evaluated 1) downstream changes in nitrogen following upgrades at a wastewater treatment plant, and 2) interactions between biological invaders, chlorophyll, macro-nutrients (nitrogen and silica), and flow in Suisun Bay. WRTDS results for ammonium trends showed a distinct signal as a result of upstream wastewater treatment plant upgrades, with specific reductions observed in the winter months during low-flow conditions. Results for Suisun Bay showed that chlorophyll a production in early years was directly stimulated by flow, whereas the relationship with flow in later years was indirect and influenced by grazing pressure. Although these trends and potential causes of change have been described in the literature, results from WRTDS provided an approach to test alternative hypotheses of spatiotemporal drivers of nutrient dynamics in the Delta.

CITATION

Beck, M., T.W. Jabusch, P.R. Trowbridge, D.B. Senn. 2018. Four decades of water quality change in the upper San Francisco Estuary. *Estuarine, Coastal and Shelf Science* 212:11-22.

SCCWRP Journal Article #1043
Full text available by request: pubrequest@sccwrp.org

Water quality trends following anomalous phosphorus inputs to Grand Bay, Mississippi, USA

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[2]*Missisippi Department of Marine Resources, Biloxi, MS*
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ABSTRACT

Grand Bay National Estuarine Research Reserve (GBNERR) is a 7500 ha protected area in Jackson County, MS. In 2005, a levee breach at a fertilizer manufacturing facility released highly acidic and phosphate-rich wastewater into the reserve. A second spill occurred in September 2012 following Hurricane Isaac. We used orthophosphate (PO^4_{3-}) concentrations to categorize the 2 events, post-events, and non-impact periods between the 2 spills. We examined spatial and temporal patterns in nutrients, chlorophyll, pH, and other parameters within and between monitoring stations. After the first event, pH at the Bangs Lake water quality station decreased to 3.7 and PO^4_{3-} increased to over 4 mg P/l. Orthophosphate returned to background concentrations near the detection limit after approximately one year. Sampling 3 weeks after Hurricane Isaac showed PO^4_{3-} concentrations over 1 mg P/l in Bangs Lake. Elevated PO^4_{3-} levels were detected at other monitoring locations for 3–5 months, depending on distance from the fertilizer facility. Multiple comparison tests of trends within stations showed that both events had statistically similar PO^4_{3-} concentrations, although the magnitudes and the time to return to baseline concentrations differed between stations. Temporal patterns of other nutrients had apparent long-term trends, particularly chlorophyll a, which showed an increase from 18–56% depending on station. This study provides a rare description of decadal water quality trends in a shallow, temperate estuary in response to discrete spill events. The results provide new information on the effects of phosphorus inputs to nitrogen-limited systems, having management implications for Gulf Coast estuaries.

CITATION

Beck, M.W., K. Cressman, C. Griffin, J. Caffrey. 2018. Water Quality Trends Following Anomalous Phosphorus Inputs to Grand Bay, Mississippi, USA. *Gulf and Caribbean Research* 29:1-14.

SCCWRP Journal Article #1018
Full text available by request: pubrequest@sccwrp.org

Effect of non-native versus native invaders on macrophyte richness: Are carp and bullheads ecological proxies?

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ABSTRACT

While it is accepted that invasive species are non-native organisms that become abundant and cause ecological damage in areas where they are introduced, the problem of 'native invaders,' native species that become excessively abundant due to anthropogenic impacts, is frequently encountered by ecologists. Often, native and non-native invaders occur in sympatry. Understanding relative severity of their impacts and niches they occupy is needed to inform management actions. Here, we quantify relative impact of native (black bullhead) and non-native (common carp) benthic fish on macrophytes species richness in over 200 lakes in North America. The impact of each species was addressed while accounting for the effects of water clarity, depth, lake area, watershed size, shoreline irregularity, land use by humans, abundance of planktivorous fishes, and ecoregion. Using model selection, we show that both species had negative impact on macrophytes richness, but the impact of carp was approximately two times as strong when adjusted for catch rates. We also conducted a principal component analysis followed by permutation procedures, which showed that carp and bullheads often occurred together in shallow, turbid lakes in watershed dominated by human use. Our findings have implications for lake-restoration efforts via carp or bullhead management.

CITATION

Bajer, P.G., M. Beck, P.J. Hundt. 2018. Effect of non-native versus native invaders on macrophyte richness: Are carp and bullheads ecological proxies? *Hydrobiologia* 815:1-13.

SCCWRP Journal Article #1030
Full text available by request: pubrequest@sccwrp.org

Nitrogen and phosphorus budgets in the Northwestern Mediterranean deep convection region

Faycal Kessouri[1,2,3], Caroline Ulses[1], Claude Estournel[1], Patrick Marsaleix[1], Tatiana Severin[4], Mireille Pujo-Pay[5], Jocelyne Caparros[5], Patrick Raimbault[6], Orens Pasqueron de Fommervault[7], Fabrizio D'Ortenzio[7], Vincent Taillandier[7], Pierre Testor[8], Pascal Conan[5]

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[6]*Institut Mediterraneen d'Oceanologie, Mareille, France*
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[8]*CNRS/LOCEAN, Paris, France*

ABSTRACT

The aim of this study is to understand the biogeochemical cycles of the northwestern Mediterranean Sea (NW Med), where a recurrent spring bloom related to dense water formation occurs. We used a coupled physical-biogeochemical model at high resolution to simulate realistic 1-year period and analyze the nitrogen (N) and phosphorus (P) cycles. First, the model was evaluated using cruises carried out in winter, spring, and summer and a Bio-Argo float deployed in spring. Then, the annual cycle of meteorological and hydrodynamical forcing and nutrients stocks in the upper layer were analyzed. Third, the effect of biogeochemical and physical processes on N and P was quantified. Fourth, we quantified the effects of the physical and biological processes on the seasonal changes of the molar NO_3:PO_4 ratio, particularly high compared to the global ocean. The deep convection reduced the NO_3:PO_4 ratio of upper waters, but consumption by phytoplankton increased it. Finally, N and P budgets were estimated. At the annual scale, this area constituted a sink of inorganic and a source of organic N and P for the peripheral area. NO_3 and PO_4 were horizontally advected from the peripheral regions into the intermediate waters (130–800 m) of the deep convection area, while organic matter was exported throughout the whole water column toward the surrounding areas. The annual budget suggests that the NW Med deep convection constitutes a major source of nutrients for the photic zone of the Mediterranean Sea.

CITATION

Kessouri, F., C. Ulses, C. Estournel, P. Marsaleix, T. Severin, M. Pujo-Pay, J. Caparros, P. Raimbault, O. Pasqueron de Fommervault, F. D'Ortenzio, V. Taillandier, P. Testor, P. Conan. 2018. Nitrogen and phosphorus budgets in the Northwestern Mediterranean deep convection region. *Journal of Geophysical Research: Oceans* 12:9429-9454.

SCCWRP Journal Article #1016
Full text available by request: pubrequest@sccwrp.org

Vertical mixing effects on phytoplankton dynamics and organic carbon export in the Western Mediterranean Sea

Faycal Kessouri[1,2,3], Caroline Ulses[1], Claude Estournel[1], Patrick Marsaleix[1], Fabrizio D'Ortenzio[4], Tatiana Severin[5,6], Vincent Taillandier[4], Pascal Conan[8]

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[3]Southern California Coastal Water Research Project, Costa Mesa, CA
[4]Observatoire Oceanologique, Sorbonne Universites, UPMC Universite Paris 06, CNRS, Laboratoire d'oceanographie de Villefranche (LOV), Villefranche-sur-Mer, France,
[5]Marine Science Institute, University of Texas at Austin, Port Aransas, TX
[6]Laboratoire d'Oceanographie Microbienne (LOMIC), Observatoire Oceanologique, Sorbonne Universites, CNRS, UPMC Universite Paris 06, CNRS, Banyuls/Mer, France

ABSTRACT

A 3-D high-resolution coupled hydrodynamic-biogeochemical model of the western Mediterranean was used to study phytoplankton dynamics and organic carbon export in three regions with contrasting vertical regimes, ranging from deep convection to a shallow mixed layer. One month after the initial increase in surface chlorophyll (caused by the erosion of the deep chlorophyll maximum), the autumnal bloom was triggered in all three regions by the upward flux of nutrients resulting from mixed layer deepening. In contrast, at the end of winter, the end of turbulent mixing favored the onset of the spring bloom in the deep convection region. Low grazing pressure allowed rapid phytoplankton growth during the bloom. Primary production in the shallow mixed layer region, the Algerian subbasin, was characterized by a long period (4 months) of sustained phytoplankton development, unlike the deep convection region where primary production was inhibited during 2 months in winter. Despite seasonal variations, annual primary production in all three regions is similar. In the deep convection region, total organic carbon export below the photic layer (150 m) and transfer to deep waters (800 m) was 5 and 8 times, respectively, higher than in the Algerian subbasin. Although some of the exported material will be injected back into the surface layer during the next convection event, lateral transport, and strong interannual variability of MLD in this region suggest that a significant amount of exported material is effectively sequestrated.

REFERENCE

Kessouri, F., C. Ulses, C. Estournel, P. Marsaleix, F. D'Ortenzio, T. Severin, V. Taillandier, P. Conan. 2018. Vertical mixing effects on phytoplankton dynamics and organic carbon export in the Western Mediterranean Sea. *Geophysical Research: Oceans* DOI:10.1002/2016JC012669.

SCCWRP Journal Article #1039
Full text available by request: pubrequest@sccwrp.org

Cyanotoxin and cyanobacteria monitoring in Lake Elsinore and Canyon Lake 2015-2017

Meredith Howard

Southern California Coastal Water Research Project, Costa Mesa, CA

CITATION

Howard, M. 2018. Cyanotoxin and cyanobacteria monitoring in Lake Elsinore and Canyon Lake 2015-2017. Technical Report 1010. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1010
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1010_CyanotoxinCyanobacteriaMonitoringLakeElsinoreCanyonLake2015To2017.pdf

Report outlines strategy for protecting coastal wetlands

Environmental managers have an opportunity to increase the total size of Southern California's coastal wetlands in the coming decades even as rising sea levels permanently submerge existing wetland areas, according to a new report co-authored by SCCWRP.

The "Wetlands on the Edge: The Future of Southern California's Wetlands" report, published in 2018 by the Southern California Wetlands Recovery Project, lays out a long-term management strategy for converting thousands of acres of land along Southern California's coastline to vegetated marshes and flats, assuming 5-1/2 feet of sea level rise by the end of the century.

Nearly half of Southern California's remaining coastal wetland areas are projected to become permanently submerged by 2100, the report notes.

The multi-pronged management strategy outlined in the report calls for raising the elevation of existing wetlands, acquiring adjacent upland areas where wetlands could migrate over time, and reconfiguring bridges and removing levees, among other strategies. Removal of homes and commercial buildings would not be necessary, according to the report.

Under a best-case scenario, Southern California could experience a net gain of as much as 7,700 acres of wetlands by 2100.

The 128-page report is the culmination of an effort to develop a regional strategy and quantitative objectives to guide restoration and management efforts in the coming decades.

High tides surround an endangered Ridgeway's rail as it tends to its nest at the Seal Beach National Wildlife Refuge in Orange County. Such low-lying wetland areas are especially vulnerable to rising sea levels.

Modeling run initiated to predict acidification's impacts in Bight

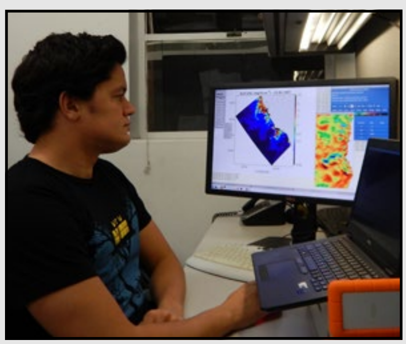
West Coast researchers working to develop a computer model that predicts the impacts of ocean acidification and hypoxia (OAH) on the Southern California Bight decided in 2018 to run the model at a higher resolution than initially planned.

Instead of modeling OAH's impacts using a 1-kilometer grid, a grid size of 300 meters is being used.

Based on feedback from SCCWRP member agencies and other stakeholders, modelers determined that the higher resolution is necessary to adequately capture how nutrients are transported to and through coastal ocean water.

It is expected to take up to a month for computers to run the computationally intensive model at this resolution.

The ongoing modeling work involves coupling West Coast physical and biogeochemical ocean models together to understand the roles of global carbon dioxide emissions, natural upwelling processes and nutrients introduced via wastewater effluent, stormwater runoff and atmospheric deposition in driving coastal ocean acidification.



SCCWRP's Dr. Faycal Kessouri works on developing a computer model that predicts the impacts of ocean acidification and hypoxia on the West Coast, including in the Southern California Bight.

Puget Sound study shows coastal estuaries could be impacted by acidification

SCCWRP and its partners have shown in a set of preliminary analyses of Washington's Puget Sound that coastal estuary environments have the potential to be impacted by ocean acidification (OA) faster and with greater intensity than comparable areas of the open ocean.

The findings, obtained in 2018, are among the first to chronicle how pteropods, or sea snails, are being impacted by OA in estuaries – and how these impacts are predicted to intensify in response to increasing ocean acidity and other stressors.

For more than a decade, scientists have focused on chronicling how the open ocean will be impacted by a gradual increase in seawater acidity. Comparatively less attention has been focused on semi-enclosed estuary environments like Puget Sound.

Return to Table of Contents

Seasonal patterns in aragonite saturation state on the southern California continental shelf

Karen McLaughlin[1], Nikolay P. Nezlin[1], Stephen B. Weisberg[1], Andrew G. Dickson[2], J. Ashley T. Booth[3], Curtis L. Cash[3], Adriano Feit[4], Joseph R. Gully[5], Meredith D.A. Howard[1], Scott Johnson[6], Ami Latker[4], Michael J. Mengel[7], George L. Robertson[7], Alex Steele[4], and Laura Terriquez[7]

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ABSTRACT

Shoaling of the saturation horizon for aragonite in the California Current System has been well-documented; however, these reports are based primarily on surveys conducted in waters off the continental shelf. Here we characterize, for the first time, regional spatial and seasonal patterns in aragonite saturation state (Ω_{arag}) in the shallow, nearshore waters of the southern California continental shelf through a series of synoptic surveys. Spectrophotometric pH and total alkalinity samples were collected quarterly from 72 sites along the shelf for two years. Samples were collected using Niskin bottles deployed at 2–3 depths per station (surface, mixed layer, and near-bottom) to characterize site extremes in Ω_{arag} (highest values near the surface, lowest at depth). Ω_{arag} in bottle samples ranged between 3.0 and 0.54 and was strongly associated with density; average Ω_{arag} from samples collected in the top 10 m was 2.5 compared to an average of 1.1 in samples below 100 m. The average depth of corrosive waters ($\Omega_{arag} < 1$) was interpolated for the shelf from the bottle data and was estimated to be an average of 100 m regionally, though there were instances when the saturation horizon rose to less than 20 m depth, primarily in the northern part of the coast during the spring. Ω_{arag} was strongly correlated with dissolved inorganic carbon and dissolved oxygen indicating that patterns in Ω_{arag} were linked to biological processes. The seasonality and spatial patterns we observed on the continental shelf were comparable to those observed by the California Cooperative Fisheries Investigations (CalCOFI) and West Coast Ocean Acidification (WCOA) programs in offshore southern California waters, suggesting that oceanic forcing is a strong driver defining broad patterns in aragonite saturation state on the shelf.

REFERENCE

McLaughlin, K., N.P. Nezlin, S.B. Weisberg, A.G. Dickson, J.A.T. Booth, C.L. Cash, A. Feit, J.R. Gully, M.D.A. Howard, S. Johnson, A. Latker, M.J. Mengel, G.L. Robertson, A. Steele, L. Terriquez. 2018. Seasonal patterns in aragonite saturation state on the southern California continental shelf. *Continental Shelf Research* 167:77–86.

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Full text available by request: pubrequest@sccwrp.org

Spatial and temporal patterns of chlorophyll concentration in the Southern California Bight

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ABSTRACT

Distinguishing between local, anthropogenic nutrient inputs and large-scale climatic forcing as drivers of coastal phytoplankton biomass is critical to developing effective nutrient management strategies. Here we assess the relative importance of these two drivers by comparing trends in chlorophyll-a between shallow coastal (0.1–16.5 km) and deep offshore (17–700 km) areas, hypothesizing that coastal regions influenced by anthropogenic nutrient inputs may have different spatial and temporal patterns in chlorophyll-a concentration from offshore regions where coastal inputs are less influential. Quarterly conductivity-temperature-depth (CTD) fluorescence measurements collected from three southern California continental shelf regions since 1998 were compared to chlorophyll-a data from the more offshore California Cooperative Fisheries Investigations (CalCOFI) program. The trends in the coastal zone were similar to those offshore, with a gradual increase of chlorophyll-a biomass and shallowing of its maximum layer since the beginning of observations, followed by chlorophyll-a declining and deepening from 2010 to present. An exception was the northern coastal part of SCB, where chlorophyll-a continued increasing after 2010. The long-term increase in chlorophyll-a prior to 2010 was correlated with increased nitrate concentrations in deep waters, while the recent decline was associated with deepening of the upper mixed layer, both linked to the low-frequency climatic cycles of the Pacific Decadal Oscillation and North Pacific Gyre Oscillation. These large-scale factors affecting the physical structure of the water column may also influence the delivery of nutrients from deep ocean outfalls to the euphotic zone, making it difficult to distinguish the effects of anthropogenic inputs on chlorophyll along the coast.

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Nezlin, N.P., K. McLaughlin, J.A.T. Booth, C.L. Cash, D.W. Diehl, K.A. Davis, A. Feit, R. Goericke, J.R. Gully, M.D.A. Howard, S Johnson, A. Latker, M.J. Mengel, G.L. Robertson, A. Steele, L. Terriquez, L. Washburn, S.B. Weisberg. 2018. Spatial and Temporal Patterns of Chlorophyll Concentration in the Southern California Bight. *Journal of Geophysical Research: Oceans* 123:231-245.

SCCWRP Journal Article #1017
Full text available by request: pubrequest@sccwrp.org

 Return to Table of Contents

Influence of bacteria on shell dissolution in dead gastropod larvae and adult *Limacina helicina* pteropods under ocean acidification conditions

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Abstract

Ocean acidification (OA) increases aragonite shell dissolution in calcifying marine organisms. It has been proposed that bacteria associated with molluscan shell surfaces in situ could damage the periostracum and reduce its protective function against shell dissolution. However, the influence of bacteria on shell dissolution under OA conditions is unknown. In this study, dissolution in dead shells from gastropod larvae and adult pteropods (*Limacina helicina*) was examined following a 5-day incubation under a range of aragonite saturation states (Ω_{arag}; values ranging from 0.5 to 1.8) both with and without antibiotics. Gastropod and pteropod specimens were collected from Puget Sound, Washington (48°33′19″N, 122°59′49″W and 47°41′11″N, 122°25′23″W, respectively), preserved, stored, and then treated in August 2015. Environmental scanning electron microscopy (ESEM) was used to determine the severity and extent of dissolution, which was scored as mild, severe, or summed (mild + severe) dissolution. Shell dissolution increased with decreasing Ω_{arag}. In gastropod larvae, there was a significant interaction between the effects of antibiotics and Ω_{arag} on severe dissolution, indicating that microbes could mediate certain types of dissolution among shells under low Ω_{arag}. In *L. helicina*, there were no significant interactions between the effects of antibiotics and Ωarag on dissolution. These findings suggest that bacteria may differentially influence the response of some groups of shelled planktonic gastropods to OA conditions. This is the first assessment of the microbial–chemical coupling of dissolution in shells of either gastropod larvae or adult *L. helicina* under OA.

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Bausch, A.R., M.A. Gallego, J. Harianto, P. Thibodeau, N. Bednarsek, J.N. Havenhand, T. Klinger. 2018. Influence of bacteria on shell dissolution in dead gastropod larvae and adult Limacina helicina pteropods under ocean acidification conditions. *Marine Biology* 165:40.

SCCWRP Journal Article #1037
Full text available by request: pubrequest@sccwrp.org

El Niño-related thermal stress coupled with upwelling-related ocean acidification negatively impacts cellular to population-level responses in Pteropods along the California Current System with implications for increased bioenergetic costs

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Abstract

Understanding the interactive effects of multiple stressors on pelagic mollusks associated with global climate change is especially important in highly productive coastal ecosystems of the upwelling regime, such as the California Current System (CCS). Due to temporal overlap between a marine heatwave, an El Niño event, and springtime intensification of the upwelling, pteropods of the CCS were exposed to co-occurring increased temperature, low Ω_{ar} and pH, and deoxygenation. The variability in the natural gradients during NOAA's WCOA 2016 cruise provided a unique opportunity for synoptic study of chemical and biological interactions. We investigated the effects of *in situ* multiple drivers and their interactions across cellular, physiological, and population levels. Oxidative stress biomarkers were used to assess pteropods' cellular status and antioxidant defenses. Low aragonite saturation state (Ω_{ar}) is associated with significant activation of oxidative stress biomarkers, as indicated by increased levels of lipid peroxidation (LPX), but the antioxidative activity defense might be insufficient against cellular stress. Thermal stress in combination with low Ω_{ar} additively increases the level of LPX toxicity, while food availability can mediate the negative effect. On the physiological level, we found synergistic interaction between low Ω_{ar} and deoxygenation and thermal stress (Ω_{ar}:T, O_2:T). On the population level, temperature was the main driver of abundance distribution, with low Ω_{ar} being a strong driver of secondary importance. The additive effects of thermal stress and low Ω_{ar} on abundance suggest a negative effect of El Niño at the population level. Our study clearly demonstrates Ω_{ar} and temperature are master variables in explaining biological responses, cautioning the use of a single parameter in the statistical analyses. High quantities of polyunsaturated fatty acids are susceptible to oxidative stress because of LPX, resulting in the loss of lipid reserves and structural damage to cell membranes, a potential mechanism explaining extreme pteropod sensitivity to low Ω_{ar}. Accumulation of oxidative damage requires metabolic compensation, implying energetic trade-offs under combined thermal and low Ω_{ar} and pH stress.

Oxidative stress biomarkers can be used as early-warning signal of multiple stressors on the cellular level, thereby providing important new insights into factors that set limits to species' tolerance to in situ multiple drivers.

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SCCWRP Journal Article #1065
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1065_ElNinoRelatedThermalStress.pdf

The combined effects of acidification and hypoxia on pH and aragonite saturation in the coastal waters of the California current ecosystem and the northern Gulf of Mexico

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Abstract

Inorganic carbon chemistry data from the surface and subsurface waters of the West Coast of North America have been compared with similar data from the northern Gulf of Mexico to demonstrate how future changes in CO_2 emissions will affect chemical changes in coastal waters affected by respiration-induced hypoxia ($[O_2] \leq \sim 60$ μmol kg^{-1}). In surface waters, the percentage change in the carbon parameters due to increasing CO_2 emissions are very similar for both regions even though the absolute decrease in aragonite saturation is much higher in the warmer waters of the Gulf of Mexico. However, in subsurface waters the changes are enhanced due to differences in the initial oxygen concentration and the changes in the buffer capacity (i.e., increasing Revelle Factor) with increasing respiration from the oxidation of organic matter, with the largest impacts on pH and CO_2 partial pressure (pCO_2) occurring in the colder West Coast waters. As anthropogenic CO_2 concentrations begin to build up in subsurface waters, increased atmospheric CO_2 will expose organisms to hypercapnic conditions (pCO_2 > 1000 μatm) within subsurface depths. Since the maintenance of the extracellular pH appears as the first line of defense against external stresses, many biological response studies have been focused on pCO_2-induced hypercapnia. The extent of subsurface exposure will occur sooner and be more widespread in colder waters due to their capacity to hold more dissolved oxygen and the accompanying weaker acid-base buffer capacity. Under present conditions, organisms in the West Coast are exposed to hypercapnic conditions when oxygen concentrations are near 100 μmol kg^{-1} but will experience hypercapnia at oxygen concentrations of 260 μmol kg^{-1} by year 2100 under the highest elevated-CO_2 conditions. Hypercapnia does not occur at present in the Gulf of Mexico but will occur at oxygen concentrations of 170 μmol kg^{-1} by the end of the century under similar conditions. The aragonite saturation horizon is currently above the hypoxic zone in the West Coast. With in-creasing atmospheric CO_2, it is expected to shoal up close to surface waters under the IPCC Representative Concentration Pathway (RCP) 8.5 in West Coast waters, while aragonite saturation state will exhibit steeper gradients in the Gulf of Mexico. This study demonstrates how different biological thresholds (e.g., hypoxia, $CaCO_3$ under-saturation, hypercapnia) will vary asymmetrically because of local initial conditions that are affected differently with increasing atmospheric CO_2. The direction of change in amplitude of hypercapnia will be similar in both ecosystems, exposing both biological communities from the West Coast and Gulf of Mexico to intensification of stressful conditions. However, the region of lower Revelle factors (i.e., the Gulf of Mexico), currently provides an adequate refuge habitat that might no longer be the case under the most severe RCP scenarios.

Reference

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SCCWRP Journal Article #1025
Full text available by request: pubrequest@sccwrp.org

Biogeography and genetic diversity of the atlantid heteropods

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Abstract

The atlantid heteropods are regularly encountered, but rarely studied marine planktonic gastropods. Relying on a small (< 14 mm), delicate aragonite shell and living in the upper ocean means that, in common with pteropods, atlantids are likely to be affected by imminent ocean changes. Variable shell morphology and widespread distributions indicate that the family is more diverse than the 23 currently known species. Uncovering this diversity is fundamental to determining the distribution of atlantids and to understanding their environmental tolerances. Here we present phylogenetic analyses of all described species of the family Atlantidae using 437 new and 52 previously published cytochrome c oxidase subunit 1 mitochondrial DNA (mtCO1) sequences. Specimens and published sequences were gathered from 32 Atlantic Ocean stations, 14 Indian Ocean stations and 21 Pacific Ocean stations between 35°N and 43°S. DNA barcoding and Automatic Barcode Gap Discovery (ABGD) proved to be valuable tools for the identification of described atlantid species, and also revealed ten additional distinct clades, suggesting that the diversity within this family has been underestimated. Only two of these clades displayed obvious morphological characteristics, demonstrating that much of the newly discovered diversity is hidden from morphology-based identification techniques. Investigation of six large atlantid collections demonstrated that 61% of previously described (morpho) species have a circumglobal distribution. Of the remaining 39%, two species were restricted to the Atlantic Ocean, five occurred in the Indian and Pacific oceans, one species was only found in the northeast Pacific Ocean, and one occurred only in the Southern Subtropical Convergence Zone. Molecular analysis showed that seven of the species with wide distributions were comprised of two or more clades that occupied distinct oceanographic regions. These distributions may suggest narrower environmental tolerances than the described morphospecies. Results provide an updated biogeography and mtCO1 reference dataset of the Atlantidae that may be used to identify atlantid species and provide a first step in understanding their evolutionary history and accurate distribution, encouraging the inclusion of this family in future plankton research.

Reference

Wall-Palmer, D., A.K. Burridge, E. Goetze, F.R. Stokvis, A.W. Janssen, L. Mekkes, M. Moreno-Alcántara, N. Bednarsek, T. Schiøtte, M.V. Sørensen, C.W. Smart, K.T.C.A. Peijnenburg. 2018. Biogeography and genetic diversity of the atlantid heteropods. *Progress in Oceanography* 160:1-25.

SCCWRP Journal Article #1038
Full text available by request: pubrequest@sccwrp.org

Tidal asymmetry and residual sediment transport in a short tidal basin under sea level rise

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Abstract

Tidal asymmetry in estuaries and lagoons (tidal basins) controls residual sediment transport, and quantifying tidal asymmetry is important for understanding the factors contributing to long-term morphological changes. Asymmetry in peak flood and ebb currents (Peak Current Asymmetry –PCA) controls residual transport of coarse sediment, and asymmetry in slack water duration preceding flood and ebb currents (Slack Water Asymmetry –SWA) controls residual transport of fine sediment. PCA and SWA are analyzed herein for Newport Bay, a tidal embayment in southern California, based on the skewness of tidal currents predicted for several stations by a hydrodynamic model. Use of skewness for tidal asymmetry is relatively new and offers several advantages over a traditional harmonic method including the ability to resolve variability over a wide range of time scales. Newport Bay is externally forced by mixed oceanic tides that are shown to be ebb dominant because of shorter falling tide than rising tide. Both PCA and SWA indicate ebb dominance that favors export of coarse and fine sediments, respectively, to the coastal ocean. However, we show that the ebb dominance of SWA is derived from the basin geometry and not the external forcing, while ebb dominance of PCA is linked to the external forcing and the basin geometry. We also show that tidal flats in Newport Bay play an important role in maintaining ebb dominated transport of both coarse and fine sediments. Loss of tidal flats could weaken PCA and reverse SWA to become flood dominant. Specifically, we show that sea level rise > 0.8 m that inundates tidal flats will begin to weaken ebb dominant PCA and SWA and that sea levelrise > 1.0 m will reverse SWA to become flood dominant. This feedback mechanism is likely to be important for predicting

long-term evolution of tidal basins under accelerating sea level rise.

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Guo, L., M. Brand, B.F. Sanders, E. Foufoula-Georgiou, E.D. Stein. 2018. Tidal asymmetry and residual sediment transport in a short tidal basin under sea level rise. *Advances in Water Resources* 121:1-8.

SCCWRP Journal Article #1045
Full text available by request: pubrequest@sccwrp.org

Evaluating regional resiliency of coastal wetlands to sea level rise through hypsometry-based modeling

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Abstract

Sea level rise (SLR) threatens coastal wetlands worldwide, yet the fate of individual wetlands will vary based on local topography, wetland morphology, sediment dynamics, hydrologic processes, and plant-mediated feedbacks. Local variability in these factors makes it difficult to predict SLR effects across wetlands or to develop a holistic regional perspective on SLR response for a diversity of wetland types. To improve regional predictions of SLR impacts to coastal wetlands, we developed a model that addresses the scale-dependent factors controlling SLR response and accommodates different levels of data availability. The model quantifies SLR-driven habitat conversion within wetlands across a region by predicting changes in individual wetland hypsometry. This standardized approach can be applied to all wetlands in a region regardless of data availability, making it ideal for modeling SLR response across a range of scales. Our model was applied to 105 wetlands in southern California that spanned a broad range of typology and data availability. Our findings suggest that if wetlands are confined to their current extents, the region will lose 12% of marsh habitats (vegetated marsh and un-vegetated flats) with 0.6 m of SLR (projected for 2050) and 48% with 1.7 m of SLR (projected for 2100). Habitat conversion was more drastic in wetlands with larger proportions of marsh habitats relative to subtidal habitats and occurred more rapidly in small lagoons relative to larger sites. Our assessment can inform management of coastal wetland vulnerability, improve understanding of the SLR drivers relevant to individual wetlands, and highlight significant data gaps that impede SLR response modeling across spatial scales. This approach augments regional SLR assessments by considering spatial variability in SLR response drivers, addressing data gaps, and accommodating wetland diversity, which will provide greater insights into regional SLR response that are relevant to coastal management and restoration efforts.

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SCCWRP Journal Article #1056
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1056_CoastalWetlandResiliencySLR_Hypsometry.pdf

Evaluating the effect of changes in flow and water temperature on stream habitats and communities in the Los Angeles/Ventura region

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Reference

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SCCWRP Technical Report #1034
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1034_LosAngelesAndVenturaStreamHabitats.pdf

Wetlands on the edge: The future of Southern California's wetlands – Regional strategy 2018

Jeremy Lowe[1], Eric Stein[2], Erin Beller[1], Josh Collins[1], Megan Cooper[3], Jeff Crooks[4], Heather Dennis[5], Cheryl Doughty[6], Greg Gauthier[3], Julie Gonzalez[7], Kerstin Kalchmayr[7], Shawn Kelly[8], Jeremy Lowe[1], Katie McKnight[1], Amy Richey[1], April Robinson[1], Evyan Sloane[3], Martha Sutula[2], and Christine Whitcraft[9]

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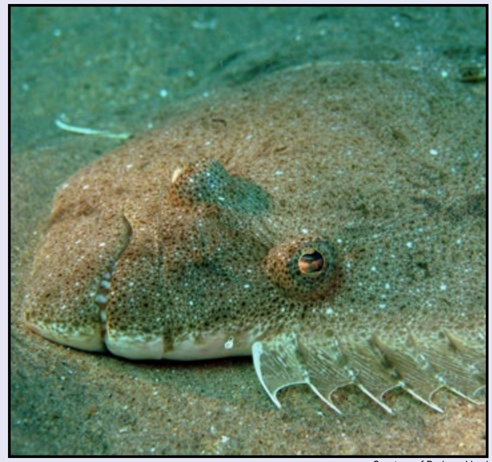
SCCWRP Technical Report #1055
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1055_SouthernCaliforniaWetlandRegionalStrategy.pdf

Framework approved to assess sediment's impacts on humans



Courtesy of Barbara Lloyd

SCCWRP has co-developed a sediment assessment framework intended to protect the health of humans who consume sportfish such as the California halibut, above, a bottom-feeding fish that camouflages with seafloor sediment.

The State Water Board has approved a standardized sediment assessment framework intended to better protect the health of humans who consume seafood caught in California's enclosed bays and estuaries, the latest development in SCCWRP's efforts to improve management of legacy sediment contamination.

The framework, approved in 2018, defines for environmental managers how to assess compliance with a statewide regulatory program intended to reduce the ecological impacts of sediment contamination on humans, who can be exposed via food web transfer. Already, the framework has been applied to the Los Angeles/Long Beach Harbors area and the Dominguez Channel that drains to it.

To become State policy, the framework next must undergo review by California's Office of Administrative Law and U.S. Environmental Protection Agency, Region 9.

If the framework receives final approvals, it will become the official method for implementing California's Sediment Quality Objective (SQO) for protection of human health. The human health SQO – one of three adopted by the State Water Board in 2008 for enclosed bays and estuaries – calls on sediment contamination to not be present "at levels that will bioaccumulate in aquatic life to levels that are harmful to human health."

Field sampling completed for study probing origins of sediment contaminants that bioaccumulate in fish

A field crew deploys a passive sampling device into San Diego Bay for a study probing the origins of contamination found in fish in the bay. The device consists of a pointed metal frame containing polyethylene film that is inserted into seafloor sediment.

SCCWRP and its partners have completed field sampling for a study investigating whether legacy contaminants found in the tissue of San Diego Bay fish are coming from contaminated bay sediment or from somewhere else.

The study is revisiting a common assumption in sediment management – that all legacy chemical contaminants that have bioaccumulated in fish tissue collected at a given site originated with contaminated sediment at the site.

Although now-banned chemical contaminants like PCBs and DDTs – which have sorbed to sediment particles on the seafloor – are known to gradually dissolve back into the water column, it is unclear if these contaminants also are spreading extended distances through the water column.

During field sampling, which was completed in 2018, researchers used passive sampling devices to measure the dissolved concentration of sediment-associated contaminants in three locations – just beneath the surface sediment layer, just above the surface sediment layer, and in the water column.

Seabirds as regional biomonitors of legacy toxicants on an urbanized coastline

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Abstract

Seabirds are often cited as sentinels of the marine environment, but are rarely used in traditional ocean and coastal contaminant monitoring. Four classes of persistent organic pollutants (POPs, n=68) and three trace elements (mercury, selenium, and arsenic) were measured in the eggs of California least terns (*Sterna antillarum browni*), caspian terns (*Hydroprogne caspia*), double-crested cormorants (*Phalacrocorax auritus*), and western gulls (*Larus occidentalis*) that nest in the Southern California Bight. Building on a periodic five year regional monitoring program, we measured contaminant exposure and assessed the utility of seabirds as regional contaminant biomonitors. We found that the eggs of larger, more piscivorous species generally had the highest concentrations of POPs and trace elements while California least terns had the lowest concentrations, except for mercury which was higher in least terns. As expected, DDT concentrations were elevated near the Palos Verdes Superfund site. However, we also detected a previously unknown latitudinal pattern in PBDE concentrations in least terns. POP congener profiles also confirmed differences in contamination in urban least tern colonies closest to urban centers. Though toxicants were at detectable levels across species and sites, concentrations were below those known to cause adverse effects in avian taxa and are steady or declining compared to previous studies in this region. Our results suggest that regional seabird monitoring can inform site-specific remediation and support management and protection of regionally-threatened wildlife and coastal systems. Integration of seabird contaminant data with traditional sediment, water, bivalve and fish monitoring is needed to further our understanding of exposure pathways and food web contaminant transfer.

Citation

Clatterbuck, C.A., R.L. Lewison, N.G. Dodder, C. Zeeman, K.C. Schiff. 2017. Seabirds as regional biomonitors of legacy toxicants on an urbanized coastline. *Science of the Total Environment* DOI:10.1016/j.scitotenv.2017.

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Full text availability by request: pubrequest@sccwrp.org

Assessing the release of copper from nanocopper-treated and conventional copper-treated lumber into marine waters I: Concentration and rates

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Abstract

Little is known about the release of metal engineered nanomaterials (ENMs) from consumer goods, including lumber treated with micronized copper. Micronized copper is a recent form of antifouling wood preservative containing nanosized copper particles for use in pressure-treated lumber. The present study investigated the concentrations released and the release rate of total copper over the course of 133 d under freshwater, estuarine, and marine salinity conditions (0, 1, 10, and 30‰) for several commercially available pressure-treated lumbers: micronized copper azole (MCA) at 0.96 and 2.4 kg/m^3, alkaline copper quaternary (ACQ) at 0.30 and 9.6 kg/m^3, and chromated copper arsenate (CCA) at 40 kg/m^3. Lumber was tested as blocks and as sawdust. Overall, copper was released from all treated lumber samples. Under leaching conditions, total release ranged from 2 to 55% of the measured copper originally in the lumber, with release rate constants from the blocks of 0.03 to 2.71 (units per day). Generally, measured release and modeled equilibrium concentrations were significantly higher in the estuarine conditions compared with freshwater or marine salinities, whereas rate constants showed very limited differences between salinities. Furthermore, organic carbon was released during the leaching and demonstrated a significant relationship with released copper concentrations as a function of salinity. The results indicate that copper is released into estuarine/marine waters from multiple wood treatments including lumber amended with nanoparticle-sized copper.

Citation

Parks, A.N., M.G. Cantwell, D.R. Katz, M.A. Cashman, T.P. Luxton, K.T. Ho, R.M. Burgess. 2018. Assessing the release of copper from nanocopper-treated and conventional copper-treated lumber into marine waters I: Concentration and rates. *Environmental Toxicology and Chemistry* 37:1956-1968.

SCCWRP Journal Article #1040
Full text available by request: pubrequest@sccwrp.org

Assessing the release of copper from nanocopper-treated and conventional copper-treated lumber into marine waters II: forms and bioavailability

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ABSTRACT

One application of nanocopper is as a wood-preserving pesticide in pressure-treated lumber. Recent research has shown that pressure-treated lumber amended with micronized copper azole (MCA), which contains nanosized copper, releases copper under estuarine and marine conditions. The form of copper released (i.e., ionic, nanocopper [1–100 nm in size]) is not fully understood but will affect the bioavailability and toxicity of the metal. In the present study, multiple lines of evidence, including size fractionation, ion-selective electrode electrochemistry, comparative toxicity, and copper speciation were used to determine the form of copper released from lumber blocks and sawdust. The results of all lines of evidence supported the hypothesis that ionic copper was released from MCA lumber and sawdust, with little evidence that nanocopper was released. For example, copper concentrations in size fractionations of lumber block aqueous leachates including unfiltered, 0.1 mm, and 3 kDa were not significantly different, suggesting that the form of copper released was in the size range operationally defined as dissolved. These results correlated with the ion-selective electrode data which detects only ionic copper. In addition, comparative toxicity testing resulted in a narrow range of median lethal concentrations (221–257 mg/L) for MCA lumber blocks and $CuSO_4$. We conclude that ionic copper was released from the nanocopper pressure-treated lumber under estuarine and marine conditions.

CITATION

Parks, A.N., M.G. Cantwell, D.R. Katz, M.A. Cashman, T.P. Luxton, J.G. Clar, M.M. Perron, L. Portis, K.T. Ho, R.M. Burgess. 2018. Assessing the release of copper from nanocopper-treated and conventional copper-treated lumber into marine waters II: Forms and bioavailability. *Environmental Toxicology* and Chemistry 37:1969-1979.

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Magnitude of acute toxicity of marine sediments amended with conventional copper and nanocopper

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ABSTRACT

It is well known that copper (Cu) is toxic to marine organisms. We measured and compared the acute toxicity of several forms of Cu (including nanoCu) amended into a marine sediment with mysids and amphipods. For all the forms of Cu tested, toxicity, measured as the median lethal concentration, ranged from 708 to > 2400 mg Cu/kg (dry sediment) for mysids and 258 to 1070 mg Cu/kg (dry sediment) for amphipods.

CITATION

Parks, A.N., M.A. Cashman, M.M. Perron, L. Portis, M.G. Cantwell, D.R. Katz, K.T. Ho, R.M. Burgess. 2018. Magnitude of Acute Toxicity of Marine Sediments Amended with Conventional Copper and Nanocopper. *Environmental Toxicology* 37:2677-2681.

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Full text available by request: pubrequest@sccwrp.org

Using spatial and temporal variability data to optimize sediment toxicity identification evaluation (TIE) study designs

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ABSTRACT

Toxicity tests are an important aspect of sediment quality assessments, but knowledge of the cause of toxicity is needed to determine effective management actions. Toxicity identification evaluation (TIE) methods were developed to meet this need. While TIE method manuals provide information on the procedures, little information on study design is presented. The level of variability associated with performing TIEs and how to account for it is also not addressed. The goal of this study was to collect data on both the spatial and temporal variability associated with sediment TIEs by use of the amphipod *Eohaustorius estuarius* 10-day survival test and then apply that information to make recommendations for designing future TIE studies. Ten stations were sampled at Consolidated Slip

in Los Angeles Harbor, California, with samples collected 2 months apart. In the first stage, TIEs were conducted on whole sediment and pore water from 3 of the most toxic stations. In the second stage, focused TIEs were conducted on whole sediment from all stations. Chemical analysis for metals and organic contaminants was also performed. With a weight of evidence approach, it was determined that pyrethroid pesticides were the likely cause of toxicity, with a lesser contribution from polycyclic aromatic hydrocarbons (PAHs). Results of the individual TIEs fell into 3 broad categories: TIEs in which treatments for organic chemicals and pyrethroids were effective; TIEs in which the treatment for pyrethroids was not effective but the treatment for organic contaminants was effective; and TIEs in which the treatment for pyrethroids was effective but the treatment for organic contaminants was not. This variability was used to calculate that at least 3 TIEs were necessary to make a confident assessment of the cause of toxicity. There was not substantial temporal variability in the TIE outcomes. Other recommendations are made regarding effective TIE study design.

Citation

Greenstein, D.J., A.N. Parks, S.M. Bay. 2018. Using spatial and temporal variability data to optimize sediment toxicity identification evaluation (TIE) study designs. *Integrated Environmental Assessment and Monitoring* DOI:10.1002/ieam.4104.

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Full text available by request: pubrequest@sccwrp.org

Spatial and temporal variability in sediment toxicity identification evaluations

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Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Bay, S.M., D.J. Greenstein, A.N. Parks. 2018. Spatial and temporal variability in sediment toxicity identification evaluations. Technical Report 1014. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1014
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1014_SpatialTemporalVariabilityInSediment.pdf

Bioanalytical screening adopted into State policy

The State Water Board has adopted a policy amendment requiring chemical contaminants in certain types of recycled water to be tracked using bioanalytical screening, a technology that SCCWRP and its partners have been working to adapt for aquatic monitoring applications.

The State Water Board, which adopted the policy amendment in 2018, is interested in understanding whether bioanalytical screening could provide a rapid, cost-effective approach to comprehensively screen recycled water for major classes of bioactive contaminants, including unknown chemicals that exert similar biological impacts on aquatic organisms.

In response, SCCWRP has been working to build the California water-quality management community's capacity to use bioanalytical cell assays to screen water bodies for bioactive contaminants.

SCCWRP hosted two meetings in 2018 that brought together cell assay vendors, consultants and the end-user community to discuss how to meet the new State requirements.

Separately, SCCWRP has been asked to serve as an *ex officio* member of a newly formed statewide scientific advisory group that will guide California's water recycling community in implementing the bioanalytical screening requirements for recycled water.

Recycled water is sometimes placed into holding ponds, such as this one in Santa Clara County in Northern California, to allow the water to gradually infiltrate into groundwater. A new State Water Board policy requires that this type of recycled water be screened using bioanalytical assays.

Field work completed for study monitoring CEC exposure in fish

SCCWRP and its partners have wrapped up the field portion of a study examining whether CECs in the Los Angeles River could be impacting the health of fish.

The field work, which was completed in 2018, involved setting up mobile exposure units along the river banks, then placing fish inside the units and allowing river water to flow through the units in real time. Afterward, the fish – all adult male fathead minnows – were dissected, and tissue samples were collected for analysis.

The study is evaluating whether chemical contaminants in L.A. River water trigger biological changes in fish, such as changes in gene expression patterns, tissue integrity and sex characteristics.

The fish were placed just downstream of the L.A.-Glendale Water Reclamation Plant, and in the Sepulveda Basin just upstream of the Tillman Water Reclamation Plant at a site that receives urban runoff.

The goal of the study is to test-drive new field-based methods for monitoring CECs in aquatic environments.

Researchers will compare the fish biological analyses to findings from other types of analyses, including targeted chemical analysis and bioanalytical screening.

Fish that have been placed in mobile exposure units, above, are exposed to flowing Los Angeles River water in real time. Researchers are tracking whether fish are impacted by CECs in the water.

First large-scale CEC screening study targeting marine environment added to Bight '18

Bioanalytical cell screening assays and non-targeted chemical analysis are being used for the first time to screen for CECs across the Southern California Bight as part of an expanded Bight '18 sediment quality study that kicked off in 2018.

The Southern California Bight 2018 Regional Monitoring Program will apply the two laboratory-based techniques to screen both seafloor sediment and the tissue of sportfish for contaminants that have triggered biological impacts in fish.

Bioanalytical screening, a commercially available technology that SCCWRP and its partners are working to adapt for use in aquatic monitoring applications, and non-targeted chemical analysis, an analytical method that identifies chemical mixtures by their unique fingerprints, together have the potential to help water-quality managers cost-effectively and comprehensively screen water bodies for bioactive CECs.

Linking *in vitro* estrogenicity to adverse effects in the inland silverside (*Menidia beryllina*)

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ABSTRACT

High-throughput cell assays that detect and integrate the response of multiple chemicals acting via a common mode of action have the potential to enhance current environmental monitoring practices. Establishing the linkage between *in vitro* and *in vivo* responses is key to demonstrating that *in vitro* cell assays can be predictive of ecologically relevant outcomes. The present study investigated the potency of 17b-estradiol (E2), estrone (E1), nonylphenol (NP), and treated wastewater effluent using the readily available GeneBLAzer1 estrogen receptor transactivation assay and 2 life stages of the inland silverside (*Menidia beryllina*). *In vitro* estrogenic potencies were ranked as follows: E2>E1>>NP. All 3 model estrogens induced vitellogenin and choriogenin expression in a dose-dependent manner in larvae and juveniles. However, apical effects were only found for E2 and E1 exposures of juveniles, which resulted in female-skewed sex ratios. Wastewater effluent samples exhibiting low *in vitro* estrogenicity (below the 10% effective concentration [EC10]), did not cause significant changes in *M. beryllina*. Significant induction of estrogen-responsive genes was observed at concentrations 6 to 26 times higher than *in vitro* responses. Gonadal feminization occurred at concentrations at least 19 to 26 times higher than the *in vitro* responses. These findings indicated that *in vitro* cell assays were more sensitive than the fish assays, making it possible to develop *in vitro* effect thresholds protective of aquatic organisms.

CITATION

Mehinto, A.C., K.J. Kroll, B.S. Jayasinghe, C.M. Lavelle, D. VanDervort, O.K. Adeyemo, S.M. Bay, K.A. Maruya, N.D. Denslow. 2018. Linking *in vitro* estrogenicity to adverse effects in the inland silverside (*Menidia beryllina*). *Environmental Toxicology and Chemistry* 37:884-892.

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An exponential model based new approach for correcting aqueous concentrations of hydrophobic organic chemicals measured by polyethylene passive samplers

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ABSTRACT

Although low density polyethylene (PE) passive samplers show promise for the measurement of aqueous phase hydrophobic organic chemicals (HOCs), the lack of a practical and unsophisticated approach to account for non-equilibrium exposure conditions has impeded widespread acceptance and thus application *in situ*. The goal of this study was to develop a streamlined approach based on an exponential model and a convection mass transfer principle for correcting aqueous concentrations for HOCs deduced by PE samplers under non-equilibrium conditions. First, uptake rate constants (k_1), elimination rate constants (k_2), and seawater-PE equilibrium partition coefficients (K_{PEW}s) were determined in laboratory experiments for a diverse suite of HOCs with logK_{ow} range of 3.4–8.3. Linear relationships between log k_2 and logK_{ow}, and between log K_{PEW} and logK_{ow} were established. Second, PE samplers pre-loaded with ^{13}C-labeled performance reference compounds (PRCs) were deployed in the ocean to determine their k_2 *in situ*. By applying boundary layer and convection mass transfer theories, ratio (C) of k_2 values in field and laboratory exposures was estimated. This C value was demonstrated a constant that was only determined by water velocities and widths of PE strips. A generic equation with C and logK_{ow} as parameters was eventually established for extrapolation of non-equilibrium correction factors for the water boundary layer-controlled HOCs. Characterizing the hydrodynamic conditions indicated the sampler configuration and mooring mode should aim at sustaining laminar flow on the PE surface for optimal mass transfer. The PE estimates corrected using this novel approach possessed high accuracy and acceptable precision, and can be suited for a broad spectrum of HOCs. The presented method should facilitate routine utilization of the PE samplers.

CITATION

Lao, W., K.A. Maruya, D. Tsukada. 2019. An exponential model based new approach for correcting aqueous concentrations of hydrophobic organic chemicals measured by polyethylene passive samplers. *Science of the Total Environment* 646:11-18.

SCCWRP Journal Article #1044
Full text available by request: pubrequest@sccwrp.org

Advancing the use of passive sampling in risk assessment and management of sediments contaminated with hydrophobic organic chemicals: Results of an international *ex situ* passive sampling interlaboratory comparison

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[14]*Civil, Environmental, and Construction Engineering, Texas Tech University, Lubbock, TX*
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Abstract

This work presents the results of an international interlaboratory comparison on ex situ passive sampling in sediments. The main objectives were to map the state of the science in passively sampling sediments, identify sources of variability, provide recommendations and practical guidance for standardized passive sampling, and advance the use of passive sampling in regulatory decision making by increasing confidence in the use of the technique. The study was performed by a consortium of 11 laboratories. and included experiments with 14 passive sampling formats on 3 sediments for 25 target chemicals (PAHs and PCBs). The resulting overall interlaboratory variability was large (a factor of ~10), but standardization of methods halved this variability. The remaining variability was primarily due to factors not related to passive sampling itself, i.e., sediment heterogeneity and analytical chemistry. Excluding the latter source of variability, by performing all analyses in one laboratory, showed that passive sampling results can have a high precision and a very low intermethod variability (<factor of 1.7). It is concluded that passive sampling, irrespective of the specific method used, is fit for implementation in risk assessment and management of contaminated sediments, provided that method setup and performance, as well as chemical analyses are quality-controlled.

Citation

Jonker, M.T.O., S.A. van der Heijden, D. Adelman, J.N. Apell, R.M. Burgess, Y. Choi, L.A. Fernandez, G.M. Flavetta, U. Ghosh, P.M. Gschwend, S.E. Hale, M. Jalalizadeh, M. Khairy, M.A. Lampi, W. Lao, R. Lohman, M.J. Lydy, K.A. Maruya, S.A. Nutile, A.M.P. Oen, M.I. Rakowska, D. Reible, T.P. Rusina, F. Smedes, Y. Wu. 2018. Advancing the use of passive sampling in risk assessment and management of sediments contaminated with hydrophobic organic chemicals: Results of an international *ex situ* passive sampling interlaboratory comparison. *Environmental Science and* Technology 52:3574-3582.

SCCWRP Journal Article #1022
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1022_PassiveSamplingRiskAssessment.pdf

Using high-resolution mass spectrometry to identify organic contaminants linked to urban stormwater mortality syndrome in Coho salmon

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Abstract

Urban stormwater is a major threat to ecological health, causing a range of adverse, mostly sublethal effects. In Western North America, urban runoff is acutely lethal to adult Coho salmon (*Oncorhynchus kisutch*) that spawn each fall in freshwater creeks. Although the mortality syndrome is correlated to urbanization and attributed to road runoff contaminant(s), the causal agent(s) remain unknown. We applied high-resolution mass spectrometry to isolate a Coho mortality chemical signature: a list of nontarget and identified features that co-occurred in waters lethal to Coho spawners (road runoff from controlled exposures and urban receiving waters from two field observations of symptomatic Coho). Hierarchical cluster analysis indicated that tire wear particle (TWP) leachates were most chemically similar to the waters with observed toxicity, relative to other vehicle-derived sources. Prominent road runoff contaminants in the signature included two groups of nitrogen-containing compounds derived from TWP, polyethylene glycols, octylphenol ethoxylates, and polypropylene glycols. A (methoxymethyl) melamine compound family, previously unreported in North America, was detected in road runoff and urban creeks at concentrations up to ~9 and ~0.3 μg/L, respectively. The results indicate TWPs are an under-appreciated contaminant source in urban watersheds

and should be prioritized for fate and toxicity assessment.

CITATION

Peter, K.T., Z. Tian, C. Wu, P. Lin, S. White, B. Du, J.K. McIntyre, N.L. Scholz, E.P. Kolodziej. 2018. Using high-resolution mass spectrometry to identify organic contaminants linked to urban stormwater mortality syndrome in Coho salmon. *Environmental Science and Technology* 52:10317-10327.

SCCWRP Journal Article #1057
Full text available by request: pubrequest@sccwrp.org

Pilot monitoring of Constituents of Emerging Concern (CECs) in the Russian River Watershed (Region 1)

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CITATION

Lin, D., J. Davis, R. Fadness, K.A. Maruya, A.C. Mehinto, W. Lao, R. Sutton, T. Jabusch, J. Sun. 2018. Pilot monitoring of Constituents of Emerging Concern (CECs) in the Russian River Watershed (Region 1). Technical Report 1020. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1020
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1020_PilotCECs.pdf

Monitoring strategies for Constituents of Emerging Concern (CECs) in recycled water

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CITATION

Drewes, J.E., P. Anderson, N. Denslow, W. Jakubowski, A. Olivieri, D. Schlenk, S. Snyder. 2018. Monitoring strategies for Constituents of Emerging Concern (CECs) in recycled water. Technical Report 1032. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1032
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1032_CECMonitoringInRecycledWater.pdf

Sampling completed for POTW antibiotic resistance study

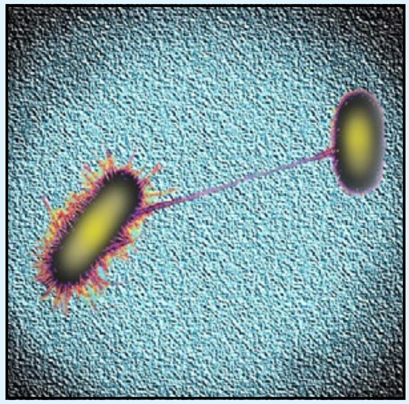
Ten wastewater treatment agencies across Southern California have completed sampling for a SCCWRP-facilitated study examining whether viable antibiotic-resistant bacteria – and the genes that code for antibiotic resistance – are being discharged into the environment following the wastewater treatment process.

The study, launched in 2017, will shed light on whether viable bacteria and genetic material are surviving treatment at POTW facilities, including an international plant at the U.S.-Mexico border. Sampling wrapped up in early 2019, and laboratory analysis is scheduled to be completed in summer 2019.

The study's goal is to develop a baseline understanding of how prevalent antibiotic resistance genes are in wastewater effluent at Southern California treatment facilities.

If these genes are surviving the treatment processes that destroy most bacterial cells, this genetic material could be traveling via treated effluent into aquatic systems, where potentially pathogenic bacteria in the environment could be taking up the antibiotic resistance genes.

In this way, antibiotic resistance could be conferred to bacterial strains that make humans sick – a phenomenon that research has shown can lead to multidrug-resistant "superbugs."



Bacterial conjugation, shown in this image, is one of the ways that bacterial cells can swap genetic material, potentially conferring antibiotic resistance to one another. Researchers are examining whether the genetic material that codes for antibiotic resistance is being discharged into the environment following the wastewater treatment process.

The study also is examining whether differences in wastewater treatment regimens and effluent discharge practices across Southern California affect the viability of antibiotic-resistant bacteria and genes.

Beach fecal contamination being investigated in cross-border study

SCCWRP and its partners have initiated a study to examine whether fecal contamination at Imperial Beach near the U.S.-Mexico border can be linked to primary-treated effluent being released into coastal waters by a Mexican wastewater treatment plant or to another specific source.

The study, launched in 2018, will use DNA sequencing technology to determine whether the microbial sewage community found at the San Antonio de Los Buenos treatment plant near Tijuana has a unique microbial community signature that may be used to identify pollution at Imperial Beach, about 10 miles north.

Researchers are sampling at multiple points along the northward route that the Mexican treatment plant's effluent is hypothesized to be taking to reach Imperial Beach during times when strong ocean swells coming from the south push water north from Mexico.

Researchers also will examine whether unique microbial signatures can be traced to other specific sources, such as stormwater runoff entering the Tijuana River estuary that contains untreated human sewage.

SCCWRP's Dr. Amy Zimmer-Faust collects a water sample at the site where Mexico's San Antonio de Los Buenos treatment plant discharges primary-treated effluent into the coastal ocean. Researchers are examining whether fecal contamination at this site is traveling north to Imperial Beach near the U.S.-Mexico border.

Return to Table of Contents

Quantification of pathogens and markers of fecal contamination during storm events along popular surfing beaches in San Diego, California

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[2]*University of North Carolina Institute of Marine Science, Morehead City, NC*

ABSTRACT

Along southern California beaches, the concentrations of fecal indicator bacteria (FIB) used to quantify the potential presence of fecal contamination in coastal recreational waters have been previously documented to be higher during wet weather conditions (typically winter or spring) than those observed during summer dry weather conditions. FIB are used for management of recreational waters because measurement of the bacterial and viral pathogens that are the potential causes of illness in beachgoers exposed to stormwater can be expensive, time-consuming, and technically difficult. Here, we use droplet digital Polymerase Chain Reaction (digital PCR) and digital reverse transcriptase PCR (digital RT-PCR) assays for direct quantification of pathogenic viruses, pathogenic bacteria, and source-specific markers of fecal contamination in the stormwater discharges. We applied these assays across multiple storm events from two different watersheds that discharge to popular surfing beaches in San Diego, CA. Stormwater discharges had higher FIB concentrations as compared to proximal beaches, often by ten-fold or more during wet weather. Multiple lines of evidence indicated that the stormwater discharges contained human fecal contamination, despite the presence of separate storm sewer and sanitary sewer systems in both watersheds. Human fecal source markers (up to 100% of samples, 20-12440 HF183 copies per 100 ml) and human norovirus (up to 96% of samples, 25-495 NoV copies per 100 ml) were routinely detected in stormwater discharge samples. Potential bacterial pathogens were also detected and quantified: *Campylobacter spp.* (up to 100% of samples, 16-504 gene copies per 100 ml) and *Salmonella* (up to 25% of samples, 6-86 gene copies per 100 ml). Other viral human pathogens were also measured, but occurred at generally lower concentrations: adenovirus (detected in up to 22% of samples, 14-41 AdV copies per 100 ml); no enterovirus was detected in any stormwater discharge sample. Higher concentrations of avian source markers were noted in the stormwater discharge located immediately downstream of a large bird sanctuary along with increased *Campylobacter* concentrations and notably different *Campylobacter* species composition than the watershed that had no bird sanctuary. This study is one of the few to directly measure an array of important bacterial and viral pathogens in stormwater discharges to recreational beaches, and provides context for stormwater-based management of beaches during high risk wet-weather periods. Furthermore, the combination of culture-based and digital PCR-derived data is demonstrated to be valuable for assessing hydrographic relationships, considering delivery mechanisms, and providing foundational exposure information for risk assessment.

CITATION

Steele, J.A., A.D. Blackwood, J.F. Griffith, R.T. Noble, K.C. Schiff. 2018. Quantification of pathogens and markers of fecal contamination during storm events along popular surfing beaches in San Diego, California. *Water Research* 136:137-149.

SCCWRP Journal Article #1026
Full text available by request: pubrequest@sccwrp.org

Statistical models of fecal coliform levels in Pacific Northwest estuaries for improved shellfish harvest area closure decision making

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[2]*Oregon Department of Agriculture, Salem, OR*

ABSTRACT

There is a substantial need for tools that effectively predict spatial and temporal fecal pollution patterns in estuarine waters. In this study, statistical models of exceedances of shellfish fecal coliform (FC) water quality criteria were developed using a 10-year dataset of FC levels and environmental data. Performance (sensitivity, specificity, and predictive capacity) of five different types of models was tested (MLR regression, Tobit (censored) regression, Firth's binary logistic regression (BLR), classification trees, and mixed-effects regression) for each of three conditionally managed shellfish-harvesting areas in Tillamook Bay, Oregon (USA). The most influential variables were related to precipitation and river stage height in the wet season and wind and tidal-stage in the dry season. Classification tree and Firth's BLR approaches better explained exceedances of shellfish water quality standards than the current closure thresholds. Findings demonstrate the utility of statistical modeling approaches for improved management of shellfish harvesting waters.

CITATION

Zimmer-Faust, A.G., C.A. Brown, A. Manderson. 2018. Statistical models of fecal coliform levels in Pacific Northwest estuaries for improved shellfish harvest area closure decision making. *Marine Pollution Bulletin* 137:360-369.

SCCWRP Journal Article #1061
Full text available by request: pubrequest@sccwrp.org

Role of microbial cell properties on bacterial pathogen and coliphage removal in biocharmodified stormwater biofilters

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Abstract

Stormwater biofilters are distributed stormwater control measures for managing urban runoff. Recent work has shown that adding biochar to biofilters can reduce stormwater contaminant concentrations, including fecal indicator bacteria (FIB). However, the potential of biochar-augmented biofilters to remove human pathogens from stormwater has not been investigated. In this study, we investigated the removal of bacterial pathogens *Salmonella enterica* serovar *Typhimurium* and *Staphylococcus aureus*, as well as bacterial and viral indicators *Escherichia coli* and MS2 coliphage in laboratory-scale biochar-amended biofilters. Biochar-amended biofilters performed better than sand biofilters in removing the microorganisms from stormwater and removal of pathogenic bacteria was greater than that of FIB. Biochar-augmented biofilters provided up to 3.9, 1.9, and 1.8 $\log_{10}$ removal for pathogenic bacteria, *E. coli*, and MS2, respectively. We utilized colloid filtration theory to elucidate potential microbial removal mechanisms. In biochar-amended biofilters, electrostatic interactions between the virus and collector surfaces likely controlled bacteriophage removal whereas the electrostatic interactions likely played a minor role in bacterial removal. Bacterial removal in biochar-augmented biofilters was likely controlled by straining and hydrophobic interactions. The findings of this study inform the design of geomedia-amended biofilters to reduce stormwater-derived microbial contamination in receiving waters.

Citation

Afrooz, A.R.M.N, A.K. Pitol, D. Kitt, A.B. Boehm. 2018. Role of microbial cell properties on bacterial pathogen and coliphage removal in biocharmodified stormwater biofilters. *Environmental Science: Water Research & Technology* 4:2160-2619.

SCCWRP Journal Article #1067
Full text available by request: pubrequest@sccwrp.org

Bight '18 keeps focus on key issues of management concern

More than 80 environmental agencies are collaboratively examining new and emerging developments in water-quality science and management through the 2018 cycle of the Southern California Bight Regional Monitoring Program, which initiated field sampling in 2018.

More than half of the Bight '18 studies are new or have new components, ensuring that the 24-year-old program remains responsive to pressing issues of management concern in coastal Southern California. Meanwhile, study elements carried over from previous program cycles will enable Bight '18 to track trends in ecosystem health across time and space.

The design of each of the five Bight '18 study elements is influenced by a number of emerging issues in environmental management:

» **Sediment Quality**: This expanded study element includes tracking of chemical contaminants that have bioaccumulated in sport fish, and measuring an expanded list of emerging contaminants, including PBDEs, pyrethroids, fipronils and neonicitanoids.

» **Ocean Acidification**: In addition to tracking changes to Bight seawater chemistry resulting from ocean acidification and hypoxia, Bight '18 is for the first time documenting the relationship between the seawater chemistry changes and effects on vulnerable, shell-forming organisms.

» **Harmful Algal Blooms**: This new Bight '18 study element is focused on understanding the long-term impacts of ecologically disruptive blooms that can be transported through waterways and linger in seafloor sediment, potentially impacting the health of marine organisms for months, including shellfish consumed by humans.

Courtesy of Amec Foster Wheeler

A field crew lowers a sediment grab sampler into San Diego Bay during field sampling for the Southern California Bight 2018 Regional Monitoring Program. Bight '18 studies encompass more than 1,500 square miles of coastal waters.

» **Trash**: New to the Bight '18 trash monitoring element is test-driving a series of standardized methods for quantifying the levels and types of trash found in urbanized streams; this work is being done in partnership with the Southern California Stormwater Monitoring Coalition.

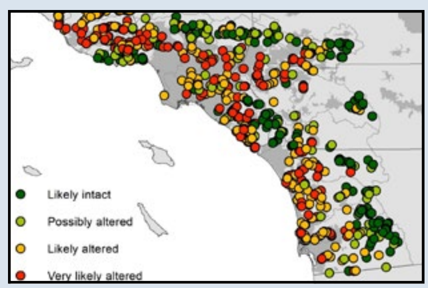
» **Microbiology**: This Bight '18 study element is examining the relevance and reliability of using coliphage viruses to detect fecal contamination at Southern California beaches. Coliphage-based methods will be compared to traditional *Enterococcus* bacteria-based methods for monitoring microbial water quality.

Management impacts of stream biointegrity policies explored in new SMC report

The Southern California Stormwater Monitoring Coalition (SMC) has released a comprehensive new report chronicling how the region's stream management community will potentially be impacted by new and proposed changes to statewide policies governing the health of streams.

The 2017 Report on the SMC Regional Stream Survey, published in 2018 as an SMC technical report, is a forward-looking analysis intended to help SMC members and other stream managers prepare for anticipated changes in the regulatory landscape.

The 22-page report provides in-depth analysis of how streams in coastal Southern California are evaluated and scored using a suite of new stream monitoring tools co-developed by SCCWRP. A number of these tools form the technical backbone of stream biointegrity policies under development in California.



An analysis of the Algal Stream Condition Index (ASCI) scoring tool by the Southern California Stormwater Monitoring Coalition (SMC) has found that streams that scored low with the ASCI are found predominantly in the urban or agricultural areas of coastal Southern California, while streams with high scores tend to be clustered in the mountain regions.

Southern California Bight

Kenneth Schiff, Karen McLaughlin, Shelly Moore, Yiping Cao

Southern California Coastal Water Research Project, Costa Mesa, CA

Abstract

The Southern California Bight (SCB) coastal environment is a unique ecological resource. Extending >600 km from Point Conception (United States) to Punta Colonet (Mexico), the SCB is a dynamic subtemperate region where the cold, southward-flowing California Current mixes with the warm, northward-flowing California Countercurrent. Large variations of interannual average ocean temperature occur during El Niño and La Niña, ranging >10 °C in surface waters of the SCB.

The SCB borderland has relatively complicated geography. Located at the margin of the North American and Pacific plates, this active tectonic region has a narrow continental shelf averaging 5 km width. At the continental shelf break in roughly 200 m depth, continental slopes plunge to 1000 m depth forming deepwater basins, only to rise again in a chain of nine offshore islands.

The SCB's heterogenous physical settings and dynamic ocean currents provide habitat for a large diversity of flora and fauna. Cumulative across all habitats, >350 fish and 5000 invertebrate species are endemic to the SCB, including over one dozen threatened or endangered marine mammals and seabirds. Biomes are generally spread across latitude which varies with ocean temperature—warmer species to the south and colder species to the north—and depth.

Population recruitment and senescence are often coincident with El Niño when warm water species dominate and La Niña when cold water species dominate. Approximately 85% of the species in the SCB are at the extreme northern or southern end of their range.

The SCB has several ecologically critical habitats. One characteristic ecosystem in the SCB is subtidal rocky reefs dominated by the giant kelp Macrocystis. These "kelp forests" are estimated to be among the most productive on earth, rivaling coral reefs. The SCB has 331 coastal wetlands, but only 23 are >100 HA and most are very small and fractured (<1 HA). The majority (57%) of the SCB coastal wetland area has been lost to coastal development since the turn of the 19th century. The remaining coastal wetlands are critical habitat providing fish nurseries and overwintering stops for birds along the Pacific Flyway.

Citation

Schiff, K.C., K. McLaughlin, S.L. Moore, Y. Cao. 2019. Southern California Bight. in: C. Sheppard (ed.), *World Seas: An Environmental Evaluation* pp. 465-482. Academic Press. London, UK.

SCCWRP Book Chapter #1051
Full text available by request: pubrequest@sccwrp.org

Extending Esri Geoportal Server to meet the needs of the West Coast Ocean Data Network and inform regional ocean management

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Abstract

Lack of accessibility to geospatial data by coastal resource managers has been identified at the regional and national levels as a hurdle to improved ecosystem-based management in the United States. The West Coast Ocean Data Portal (http://portal.westcoastoceans.org) is a project of the West Coast Governors Alliance on Ocean Health to address this problem by working to increase discovery and connectivity of coastal and ocean data users and systems to better inform West Coast ocean health decisions. The West Coast Ocean Data Network is a community of practice connecting West Coast data managers and users to develop best practices for regional data sharing. Building on the West Coast Ocean Data Portal, we demonstrate how subsequent development of the data and tools can be used by resource managers to better assess the effectiveness of marine debris prevention policies on the composition and distribution of debris along West Coast beaches.

Citation

Hallenbeck, T., S.J. Steinberg, A. Lanier, T. Welch. 2018. Extending Esri Geoportal Server to meet the needs of the West Coast Ocean Data Network and inform regional ocean management. in: D.J. Wright (ed.), *Ocean Solutions Earth Solutions: Second Edition* pp. 167-183. Esri Press. Redlands, CA.

SCCWRP Book Chapter #1027
Full text available by request: pubrequest@sccwrp.org

An ecological framework for informing permitting decisions on scientific activities in protected areas

Emily T. Saarman[1], Brian Owens[2], Steven N. Murray[3], Stephen B. Weisberg[4], Richard F. Ambrose[5], John C. Field[6], Karina J. Nielsen[7], Mark H. Carr[1]

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[2]*California Department of Fish and Wildlife, Belmont, CA*
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[7]*San Francisco State University, Romberg Tiburon Center for Environmental Studies, Tiburon, CA*

Abstract

There are numerous reasons to conduct scientific research within protected areas, but research activities may also negatively impact organisms and habitats, and thus conflict with a protected area's conservation goals. We developed a quantitative ecological decision-support framework that estimates these potential impacts so managers can weigh costs and benefits of proposed research projects and make informed permitting decisions. The framework generates quantitative estimates of the ecological impacts of the project and the cumulative impacts of the proposed project and all other projects in the protected area, and then compares the estimated cumulative impacts of all projects with policy-based acceptable impact thresholds. We use a series of simplified equations (models) to assess the impacts of proposed research to: a) the population of any targeted species, b) the major ecological assemblages that make up the community, and c) the physical habitat that supports protected area biota. These models consider both targeted and incidental impacts to the ecosystem and include consideration of the vulnerability of targeted species, assemblages, and habitats, based on their recovery time and ecological role. We parameterized the models for a wide variety of potential research activities that regularly occur in the study area using a combination of literature review and expert judgment with a precautionary approach to uncertainty. We also conducted sensitivity analyses to examine the relationships between model input parameters and estimated impacts to understand the dominant drivers of the ecological impact estimates. Although the decision-support framework was designed for and adopted by the California Department of Fish and Wildlife for permitting scientific studies in the statewide network of marine protected areas (MPAs), the framework can readily be adapted for terrestrial and freshwater protected areas.

Citation

Saarman, E.T., B. Owens, S.N. Murray, S.B. Weisberg, R.F. Ambrose, J.C. Field, K.J. Nielsen, M.H. Carr. 2018. An ecological framework for informing permitting decisions on scientific activities in protected areas. *PLoS ONE* 13:e0199126.

SCCWRP Journal Article #1042
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/JournalArticles/1042_EcologicalFrameworkInformingPermittingDecisionsProtectedAreas.pdf

2017 report on the Southern California Stormwater Monitoring Coalition regional stream survey

Raphael Mazor, Marcus Beck, Jeff Brown

Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Mazor, R.D., M. Beck, J.S. Brown. 2018. 2017 Report on the Southern California Stormwater Monitoring Coalition regional stream survey. Technical Report 1029. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1029
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1029_2017SMCReport.pdf

Southern California Stormwater Monitoring Coalition unified approach to stormwater monitoring

A.R.M. Nabiul Afrooz, Kenneth Schiff

Southern California Coastal Water Research Project, Costa Mesa, CA

Citation

Afrooz, A.R.M.N., K.C. Schiff. 2018. Southern California Stormwater Monitoring Coalition unified approach to stormwater monitoring. Technical Report 1059. Southern California Coastal Water Research Project. Costa Mesa, CA.

SCCWRP Technical Report #1059
Full text available online: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1059_USAMInventoryandWorkplan.pdf

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Return to Table of Contents

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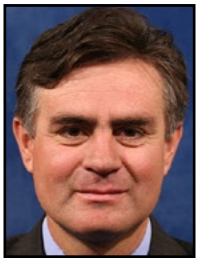
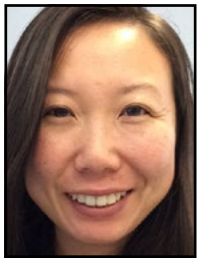
City of Los Angeles Bureau of Sanitation


Enrique Zaldivar
Commissioner


Dr. Mas Dojiri
Alternate Commissioner


Denise Li
CTAG Representative

Sanitation Districts of Los Angeles County


Grace Hyde
Commissioner

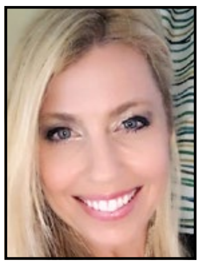

Robert Ferrante
Alternate Commissioner


Philip Markle
CTAG Representative

Orange County Sanitation District


James Herberg
Commissioner


Jim Colston
Alternate Commissioner


Lisa Haney
CTAG Representative

City of San Diego Public Utilities Department


Dr. Peter Vroom
Alternate Commissioner


Dr. Tim Stebbins
CTAG Representative

Stormwater Management Agencies

Los Angeles County Flood Control District


Daniel Lafferty
Commissioner


Paul Alva
Alternate Commissioner
and CTAG Representative

Orange County Public Works


Amanda Carr
Commissioner


Chris Crompton
Alternate Commissioner
and CTAG Representative

San Diego County Watershed Protection Program


Todd Snyder
Commissioner


Richard Crompton
Alternate Commissioner


Jo Ann Weber
CTAG Representative

Ventura County Watershed Protection District


Arne Anselm
Commissioner


Glenn Shephard
Alternate Commissioner


Dave Laak
CTAG Representative

Return to Table of Contents

Water-Quality Regulatory Agencies

California State Water Resources Control Board

Karen Mogus
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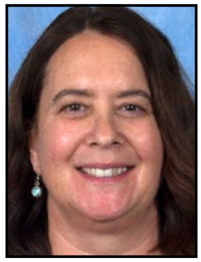
Greg Gearheart
Alternate Commissioner



Lori Webber
CTAG Representative

U.S. Environmental Protection Agency, Region 9

Ellen Blake
Commissioner

David Smith
Alternate Commissioner

Terry Fleming
CTAG Representative

California Ocean Protection Council

Deborah Halberstadt
Commissioner

Holly Wyer
CTAG Representative

Los Angeles Regional Water Quality Control Board

Deborah Smith
Commissioner

Renee Purdy
Alternate Commissioner

Dr. Jun Zhu
CTAG Representative

Santa Ana Regional Water Quality Control Board

Hope Smythe
Commissioner

Jayne Joy
Alternate Commissioner

Doug Shibberu
CTAG Representative

San Diego Regional Water Quality Control Board

David Gibson
Commissioner

David Barker
Alternate Commissioner

Chad Loflen
CTAG Representative

Return to Table of Contents

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Senior Scientist


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Dr. Marcus Beck
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Return to Table of Contents

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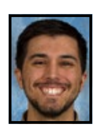
Cross-Departmental Technical Support


Dario Diehl
Marine Programs Coordinator


Scott Martindale
Communications Coordinator


Dr. Nabiul Afrooz
Scientist


Valerie Raco-Rands
Research Technician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Leah Russell
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