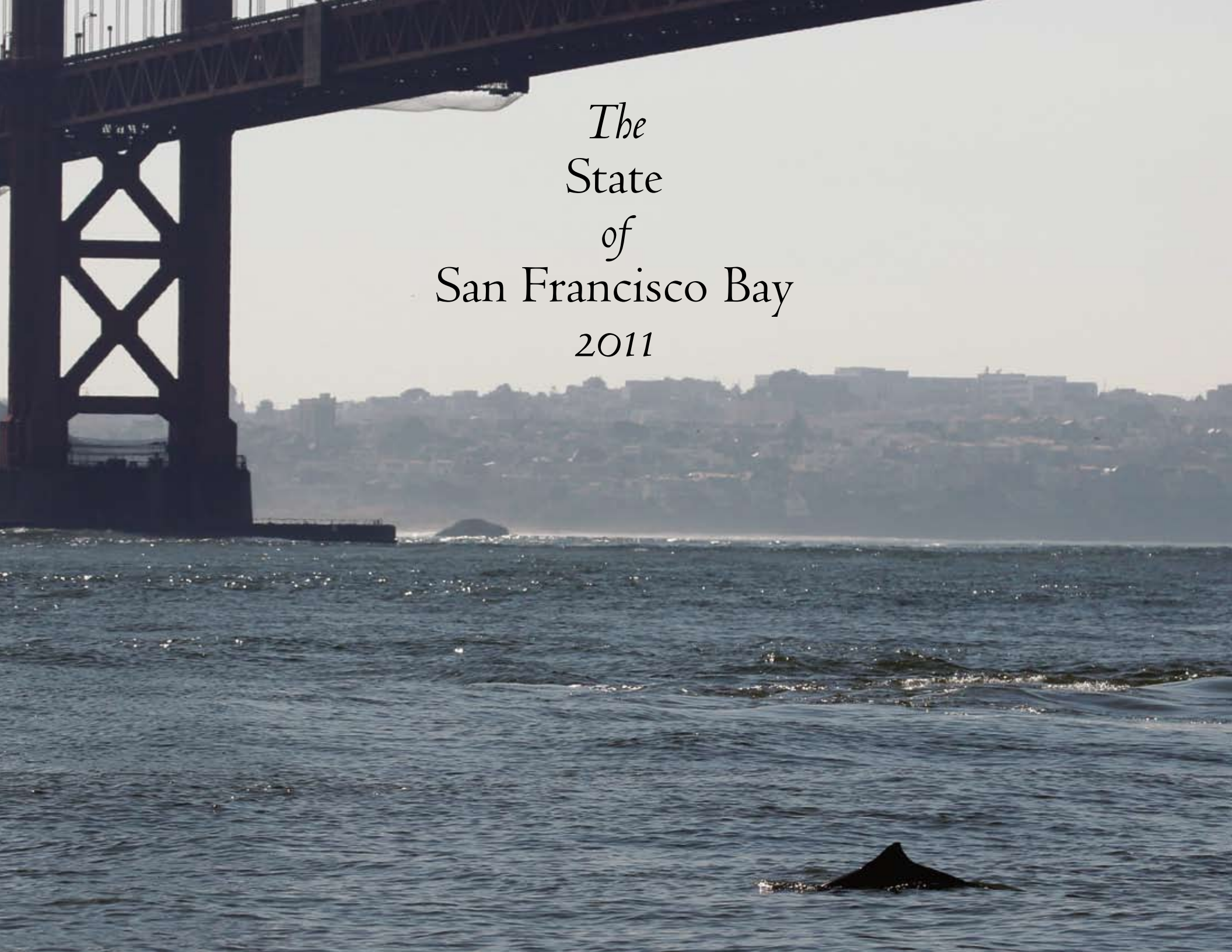
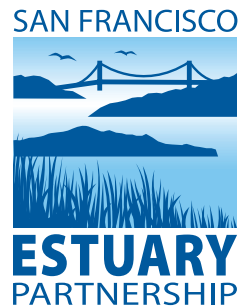


*The
State
of
San Francisco Bay
2011*





*The
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2011*



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Please cite as The State of San Francisco Bay 2011, San Francisco Estuary Partnership.

Cover photos:

Great egret: Verne Nelson

Harbor seals: Mark Rauzon

Ampithoe valida in eelgrass: Jeffrey Lewis

Tanker refueling in San Francisco Bay: Lisa Owens Viani

Title page photo:

Harbor porpoises have begun to enter San Francisco Bay again after being seen only rarely for decades.

Corbis / Paul Chinn / San Francisco Chronicle

Design, illustration and composition: Seventeenth Street Studios, Oakland, CA

Printing: JT Litho, Oakland, CA. Printed on recycled paper.

Additional details about the methods and data sources used in this report are available at www.sfestuary.org

Executive Summary

The State of San Francisco Bay 2011

The broad blue-green water body in the center of it all—San Francisco Bay—provides Bay Area residents with their inimitable sense of place and iconic geography. Underneath the water and at its surface, in its wetlands and watersheds, the Bay is also habitat for hundreds of species of fish and wildlife, including several endangered species and the multitudes of birds that reside here or migrate along the Pacific Flyway of North America. It is San Francisco Bay that defines a world-renowned tourist destination and supports a thriving state and local economy, enabling our region to be a global center of water-borne commerce and providing an enviable quality of life for over 7.5 million residents.

Bay Area residents and many other Californians—upwards of 30 million people—use freshwater diverted from the Bay's watersheds for drinking and other residential uses, industrial applications, and to irrigate over four million acres of agricultural land. At the same



time, each day we rely on the Bay to absorb over 500,000,000 gallons of treated wastewater and even greater quantities of urban floodwaters during rainstorms. Each year we mine two million tons of sand from its bottom for construction, and 65,000 cubic yards of oyster shell deposits for calcium supplements, while the Bay continues to support a fishing industry and spectacular recreational opportunities.

By protecting the health of the Bay we demonstrate to ourselves and the world that we are doing our part to care for this national treasure and the ecological services it provides. This

report examines the current state of the Bay's health, by reporting on five key attributes: water quality and quantity, habitats, ecological processes, and living resources (See Summary of Bay Health, 2011, page v).

So how are we doing? Is San Francisco Bay healthy?

The Bay is certainly less polluted than in past decades, thanks to our investment in sewage treatment, improved solid waste handling, and regulation of chemicals like DDT and PCBs. Unlike the past, when raw sewage turned the

Bay into "the Big Stench," the Bay today is safe for recreation and deeply valued by Bay Area residents and visitors from around the world.

Yet many of our remaining pollution problems will be challenging to clean up. Some of these problems, such as those caused by mercury, a legacy from the Gold Rush era, will take decades to resolve. Mercury and other pollutants accumulate in fish and other wildlife, so we must limit the amount of Bay fish we eat to protect our health. These pollutants also threaten birds and other animals at the top of the food web, and the smaller animals that live in the



SFEI / FRANK ARNDT

SUMMARY OF BAY HEALTH, 2011

	STATUS	TREND	DETAILS
WATER			
Safe for aquatic life	Fair	Improving	Bay water quality is better than 40 years ago, but the rate of improvement has slowed. Mercury, exotic species, toxic sediments, and trash are still problems, with improvement expected for exotics and trash. Many potentially harmful chemicals have yet to be assessed.
Fish safe to eat	Fair	No change	Limited consumption of most popular Bay fish species is advised due to contamination from legacy pollutants. No signs of improvement since 1994.
Safe for swimming	Good	No change	Most Bay beaches are safe for swimming in summer, but bacterial contamination is still a problem at most beaches in wet weather.
Freshwater inflow	Poor	No change	Amounts and variability of freshwater inflows have been reduced, resulting in chronic drought conditions for the Estuary. Flow conditions have been predominantly poor for the last 10 years, with the Freshwater Inflow Index at a record low level in 2010.
HABITAT			
Estuarine open water	Fair to poor	Deteriorating	Quantity and quality of springtime habitat is declining. Since the 1980s, habitat conditions have generally been poor in all but wet years.
Baylands	Fair	Improving	Historic decline has ended; gradual restoration underway; there is a long way to go.
Watersheds	Fair	No change	Watersheds are largely stabilizing after damage from historical land use changes; monitoring in more watersheds is needed to improve assessment of status.
LIVING RESOURCES			
Fish	Mixed, mostly fair	Deteriorating	Fish abundance and diversity are declining in all regions of the Bay except near the Golden Gate. The fish community is in poor condition in Suisun Bay.
Shrimp/Crab	Good	Improving	Most shrimp and crab populations are increasing, but ocean species dominate in the Bay. The abundance of Dungeness crab juveniles fluctuates widely, but Bay shrimp are generally stable.
Birds	Mixed, mostly fair	Trends mixed	Some populations are increasing, some are static, and some are declining, with some earlier increases recently reversed. Tidal marsh birds are below desired levels. Reproductive success is generally low or has decreased since 1993.
ECOLOGICAL PROCESSES			
Flood events	Poor	Deteriorating	Dams and water diversions have cut frequency and duration of floods by more than half, reducing freshwater inflow variability and transport of sediment and nutrients to the Bay.
Food web	Fair	Deteriorating	Declines in reproduction of fish-eating birds suggest that less food is available.
STEWARDSHIP			
Individual/Community action	Fair	Improving	Active stewardship could be greater, but regional efforts appear to be increasing. Bay Area citizens are using water more efficiently, and we are gradually expanding our use of recycled water.
Management action (example)	Good	Improving	In-Bay disposal of dredged material has been greatly reduced since the Comprehensive Conservation and Management for the Estuary was adopted in 1993.

Bay's sediments. So while the Bay is cleaner than it was, pollution still poses a threat to aquatic life and human health.

Many of the remaining sources of pollution are widespread and diffuse, such as the runoff from streets, driveways, and other urban surfaces, making them harder to control than discharges from a few major facilities. And we continue to release new chemicals into the Bay that do not break down easily, without first analyzing their ecological risks. Concentrations of these chemicals—such as certain flame retardants—are rising in the Bay, suggesting that our grandchildren may confront a new pollution legacy.

Filling the Bay with sediment has essentially ended, and thousands of acres of wetlands are being restored in one of the largest habitat restoration projects in the nation. Restoration takes time, and animal populations will respond slowly as these restored landscapes mature. Yet already native fishes and birds are using newly restored marshes, and these productive nursery areas should bolster their populations in the future. Wildlife face additional threats, however, from pollutants that can have subtle toxic effects on their health, and from invasive species and ubiquitous urban-dwelling or introduced predators like crows, feral house cats, and rats. This results in bird populations that are increasing in some areas but declining in others.

Many fish populations are declining in the Bay, indicating that the goals of the Comprehensive Conservation and Management Plan for San Francisco Bay (signed by over 100 regional leaders in 1993) of reversing these trends has still not

been met. These declines are due, at least in part, to continued low annual freshwater flows into the Bay as water is diverted from its rivers and the Delta. Our water diversion capacities and practices now result in low freshwater inflows to the Bay even when California is not experiencing a drought.

Shrimp and crab populations, representing the important invertebrate part of the food web, have been growing, although the composition of these populations is changing. With less fresh water coming into the Bay, the brackish water habitat of the native San Francisco Bay shrimp is shrinking, and populations of shrimp that live in more ocean-like conditions are growing. Favorable conditions in the nearby ocean are contributing to the recent growth in shrimp and crab populations.

The good news is that our efforts to improve the health of the Bay are having an impact. Rather than disposing of much of the sediment we dredge from shipping channels and ports into the Bay, we now use much of this material to create new wetlands, and we've reduced the discharge of chemicals such as copper, nickel, and mercury from our municipal and industrial wastewater plants. We have greatly improved access to the Bay through ongoing efforts to complete the Bay Trail, and more citizens than ever before are volunteering their time to clean and restore the Bay's wetlands and watersheds.

The future state of the Bay will be influenced not only by humans—either as stressors or stewards—but also by dynamic ecological forces beyond our control. We are so accustomed to

the biological richness of the central California coast that it is easy to forget we live within one of four great ocean upwelling zones on earth, where global-scale winds and currents bring nutrient-rich waters to the surface. These dynamic oceanic processes influence the Bay ecosystem and will continue to do so in the future.

Climate change driven by emissions of greenhouse gases will also impact the future health of the Bay. Whether by droughts altering freshwater flows and water use, or by floods and sea level rise altering landscapes and human behavior, changes are coming in the decades ahead. The physics of our situation is unyielding; we can take action now to control the ultimate magnitude of the changes, but no longer can we prevent their arrival.

San Francisco Bay has played an important role in local and national history, and its natural beauty and ecological attributes support our quality of life and are integral to our regional identity. As we strive to protect and restore the Bay in a time of political and ecological complexity, periodic health assessments are essential. Through them, we improve our understanding of current conditions, and learn how we should adjust our actions and enhance subsequent assessments. The information in this report exists due to decades of work by many Bay Area professionals. To honor and sustain this commitment to our regional environment, we provide this well-documented description of the Bay as we know it today to inform those who will follow.

—Andrew Gunther, Project Leader

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SAN FRANCISCO ESTUARY INSTITUTE

■ ABOUT THE SAN FRANCISCO ESTUARY PARTNERSHIP

The San Francisco Estuary Partnership was established by the State of California and the US EPA to better protect and restore the San Francisco Bay Delta Estuary. The Partnership created and oversees implementation of the Comprehensive Conservation and Management Plan, completed in 1993, that describes over 200 actions aimed at improving the Estuary's chemical, physical, and biological health.

The project area for the Partnership includes San Francisco Bay, the tributary watersheds of the Bay from the Golden Gate up to the Delta, and the Delta (see Map 1, page xiv).

The focus of *The State of the Bay 2011* Report is on the lower portion of the Partnership's project area—the Suisun, San Pablo, Central, and

South Bay regions. The Partnership would like to produce future reports that include the full project area; however, several factors made this infeasible for the current report. The Delta region is the intense focus of several major evaluation and management efforts that are not yet completed. In addition, the *2008 State of the Bay–Delta Science* report (CALFED Science Program) and the *2010 Pulse of the Delta* report (San Francisco Estuary Institute), already provide very recent information on many aspects of Delta health.

The Estuary Partnership is a program of the Association of Bay Area Governments. More information about the Estuary Partnership, our staff, partners, programs, and projects can be found at www.sfestuary.org. The [Technical Appendix](#) to this report can also be viewed there.

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PETER VORSTER has played a key role in the restoration of aquatic ecosystems in the Eastern Sierra and the San Francisco Bay Delta watershed for 35 years. He currently is the staff hydrologist for The Bay Institute (TBI) and a consultant to the Mono Lake Committee and Owens Valley Committee. At TBI, Peter leads the San Joaquin River restoration program and is one of the principals for the Ecological Scorecard project, which develops indicators for the San Francisco Bay Delta system and local watersheds. He is also a contributor to the Oakland Museum’s urban creek and watershed map series for the Bay Area. Peter was a principal researcher on the *California Water Atlas* in 1977 and 1978. In 1979 he became the primary consultant to the Mono Lake Committee and their effort to restore Mono Lake and its inflowing streams. Peter was a Switzer Fellow in 1990–91 and received Switzer Environmental Leadership Grants in 1995, 1996, and 1998. He received a B.A. in Geography and Geology from the University of California at Berkeley, an M.A. in Geography from CSU East Bay, and completed Ph.D. coursework in environmental planning at UC Berkeley.

■ ACKNOWLEDGMENTS

The production of a State of the Bay assessment has been a long-term goal of many professionals in our region, and this report is only possible due to the work of many individuals over the past 15 years. In addition to the great work of his co-authors, and the leadership and vision provided by Judy Kelly, Andy Gunther would like to recognize the contributions of Terry Young, Frederic Nichols, Samuel Luoma, James Cloern, Robert Spies, David Tucker, Stephen Osborne, Dan Watson, Lisa Jacobson, Grant Davis, Anitra Pawley, Gary Bobker, Marc Holmes, Bruce Thompson, Rainer Hoenicke, Mike Connor, Marcia Brockbank, Luisa Valiela, Bruce Herbold, Sam Zeigler, Alexis Strauss, Mike Monroe, Tom Mumley, and Stephan Lorenzato.

Tina Swanson completed much of the work for this report as an employee of The Bay Institute (TBI). The authors and the Estuary Partnership acknowledge the importance of TBI's Ecological Scorecard as a basis for several of the indicators presented here, and as a valuable model for a science-based assessment of the ecological health of the Bay. Dr. Swanson thanks Kathy Hieb, California Department of Fish and Game, for providing data on fish, shrimp, and crabs and for her advice and assistance in

developing the indicators in these categories; and the California Department of Water Resources for data from its Dayflow and California Central Valley Unimpaired Flow Data reports.

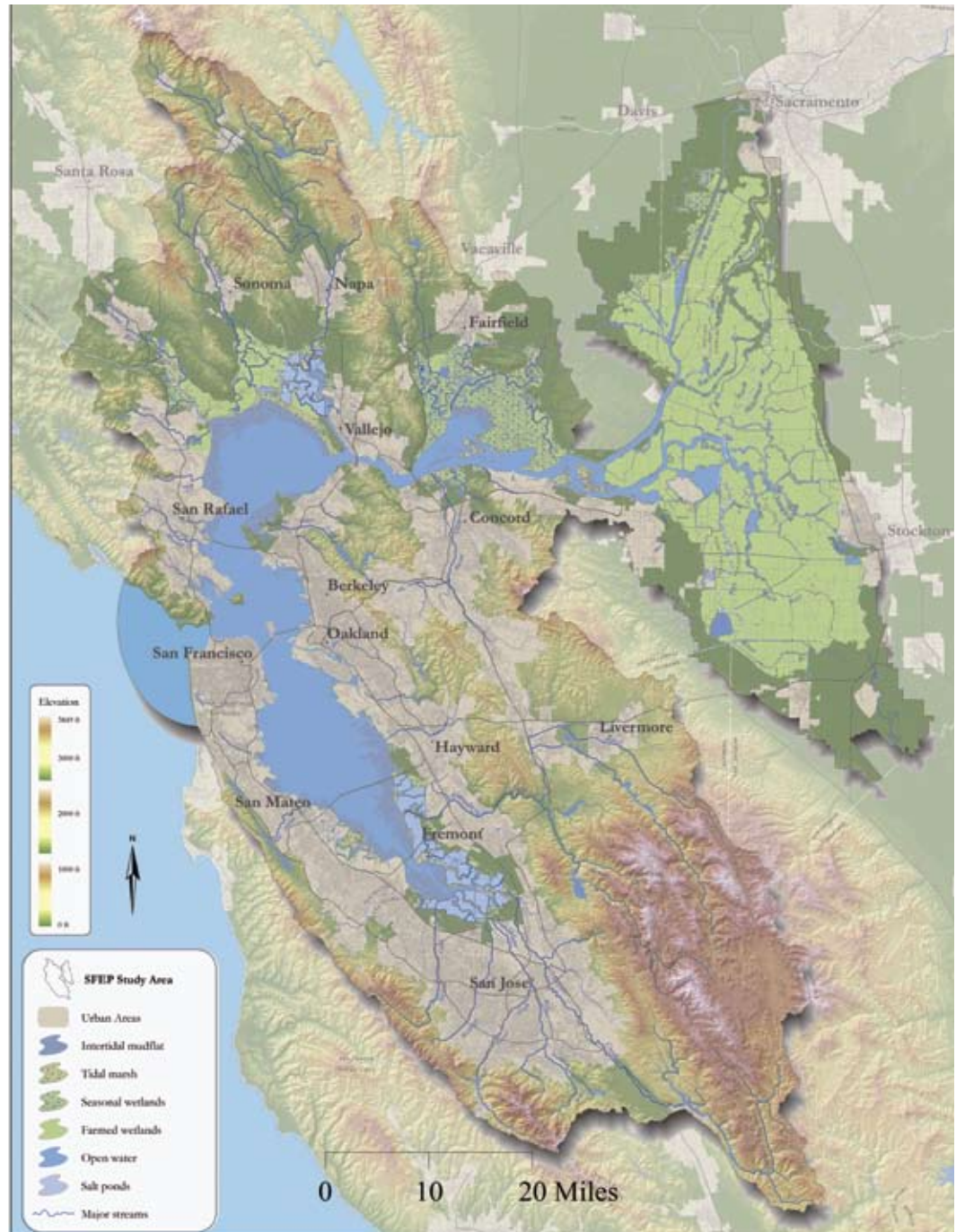
Jay Davis thanks John Ross, SFEI, Michael Kellogg, City and County of San Francisco, and Andrew Cohen, Center for Research on Aquatic Bioinvasions for their assistance with the Water Quality section, specifically Mike Kellogg (Is the Bay Safe to Swim In?), Andy Cohen (exotic species), and John Ross (stats and figures).

Nadav Nur thanks Dr. John Kelly, Audubon Canyon Ranch, for providing data and analysis of heron and egret indicators for nest density, nest survival, and brood size. Thanks also to Joelle Buffa and the USFWS San Francisco Bay National Wildlife Refuge Complex for providing mid-winter waterfowl survey data used in the waterfowl indicator.

Josh Collins wishes to acknowledge the help of the technical staff at SFEI, especially Kristen Cayce for GIS support, Ruth Askevold and Robin Grossinger for ecological science support, and Letitia Grenier, Jay Davis, and Rainer Hoenicke for their insights and assistance.

This report was largely funded by the U.S. Environmental Protection Agency.

Map 1. San Francisco Estuary Partnership Study Area



Projection: California Teale Albers Datum NAD 83

Cartographer: David Asbury CEMAR 2009

Data sources: CADWR, NWI, USGS National Atlas, USGSNHD, NHD Plus, CA DOC, CDF-FRAP, Nat. Geo. TOPO!, CADOT, SFEI, TeleAtlas, ESRI

Introduction

Report purpose

This report presents a science-based assessment of the health of San Francisco Bay. The authors reviewed available data and developed methods for evaluating the status and trends of the Bay's vital signs. By providing all interested parties with these results, the broader community can consider whether resource managers, regulators, and citizens are taking enough of the right actions to protect the Bay. With this assessment, the Estuary Partnership will begin to report on the state of the Bay on a regular basis, with the goal of educating the public and helping scientists and managers make decisions about how to best allocate resources to protect and restore the Bay.

Background

San Francisco Bay is an extraordinary natural resource that contributes to our region's economy and quality of life. Its iconic presence attracts tourists from around the globe who contribute to a thriving Bay Area economy. One of the world's great natural harbors, it has played a defining role in the history of the United States and is the aesthetic, economic, and ecological centerpiece of America's fourth largest metropolitan area. It is also an estuary—a body of water where fresh water from rivers meets salt water from the ocean.



JUDY IRVING



MICHAEL BUKAY



LISA OWENS VIANI

State, local, and federal water projects divert fresh water from the rivers flowing into this Estuary to serve 30 million people with some portion of their drinking water, and to irrigate four million acres of agricultural land. At the same time Bay Area residents rely on the Bay to absorb over 500 million gallons of treated wastewater each day and vast quantities of urban floodwaters during rainstorms. Each year we mine two million tons of sand from the Bay for construction, and 65,000 cubic yards of oyster shell deposits for calcium supplements.

The Bay delivers these benefits while providing habitat for fish, birds, and other wildlife, recreational opportunities for residents, and support for an over \$34 billion maritime industry.¹ Two-thirds of the state's salmon pass through the Bay, a commercial fishery continues for Pacific herring, and nearly half of the Pacific coast waterfowl and shorebirds depend upon the Bay and its mudflats for sustenance during their migrations.

Considering all of these benefits the Bay provides, it is not surprising that in a recent poll, 92 percent of Bay Area voters agreed with the statement that “it is important for the region's economy to have a clean, healthy and vibrant San Francisco Bay.”² This desire is reflected in the largest, most ambitious restoration project now taking place on the West Coast, the restoration of 15,100 acres of former solar evaporation salt ponds in the South Bay to tidal marsh habitat and managed ponds (see “Salt Ponds to Shorebird Heaven,” pages 10–11).

■ A BRIEF HISTORY OF EFFORTS TO EVALUATE THE STATE OF THE BAY

The Bay was not always appreciated as a valuable resource. For the century after the Gold Rush it was often treated as an enemy of progress, to be conquered by draining and filling, or as a convenient dump for wastes.

In retrospect, we realize that people did not understand how their actions were affecting the Bay or how their quality of life and the economy were connected to it. Our actions resulted in a decline in ecological health, as indicated by fish kills, waste buildup, and the stench at the shoreline. As late as the 1950s, South Bay marshes were so polluted that the local atmosphere would turn silver coins in one's pocket brownish-grey in a matter of minutes.³

In response, new legal frameworks emerged to control pollution (Water Pollution Control Act of 1948; amendments in 1956, 1965, and the Porter Cologne Act of 1969). And prompted by the work of citizen activists Sylvia McLaughlin, Esther Gulick, and Kay Kerr, the McAteer-Petris Act was adopted in 1965 establishing the Bay Conservation and Development Commission and ending the unregulated filling of the Bay. Efforts like these, by citizen activists and by concerned regulators and resource managers, led to attempts to evaluate the state of the Bay so that actions could be taken to protect and improve it.

In 1987, Congress established the National Estuary Program by amending the Clean Water Act (33 USC 1330) to further improve the chemical, physical, and biological integrity of the nation's estuaries. San Francisco Bay was identified as an Estuary of National Significance

under this program, and from 1987 to 1993, hundreds of stakeholders worked together to craft a Comprehensive Conservation and Management Plan (CCMP) for the Estuary using the existing base of high quality science. In that process, community leaders, scientists, resource managers, regulatory agencies, and citizen activists came together to promote the goal of achieving and maintaining an ecologically diverse and productive natural estuarine system.⁴ The CCMP, approved in 1993 by the Governor and the US EPA (updated in 2007), set forth a list of 145 actions to preserve, enhance, and restore the Estuary's ecosystem.

As part of the development of the CCMP, the first *State of the Estuary* report (1992) concluded that the Estuary "has some very real and significant environmental problems" that are "documented by research and monitoring data."

The report noted that "many of the Estuary's problems are getting worse, while only a few have improved" and that "additional actions are needed to solve them."⁵

The report identified the major stressors affecting the health of the Bay as

- intensified land use (and the resulting conversion of natural land cover to human uses)
- diversions of fresh water and altered flow regimes
- increased pollutants
- increased dredging and waterway modification

The CCMP was structured to address these stressors, with a diverse array of actions for management agencies to take.

Since the 1992 *State of the Estuary* report was published, management efforts to address the problems have continued and expanded. Progress toward implementing these efforts has been reported every other year at State of the Estuary conferences, and in reports summarizing those conference presentations as well as the status of species of concern, fish populations, and flows. In addition, several monitoring and assessment programs have provided information about the Bay's resources and whether our investments in environmental protection and restoration are achieving desired outcomes. These programs have heightened our appreciation of the complexity of the ecosystem and how its health is a product of both human and natural influences.⁶



PETER BAYE

In 1996, The Bay Institute (TBI), Environmental Defense Fund, and the UC Berkeley Center for Sustainable Resources issued a report describing a framework for developing San Francisco Bay-specific health indicators. In 2003 and 2005, TBI developed and issued an *Ecological Scorecard* for San Francisco Bay, extremely valuable pilot efforts to develop and evaluate science-based ecological indicators in a manner accessible to the public. Many indicators in this report build on TBI's efforts.

The Estuary Partnership then continued to develop ecological indicators in collaboration with TBI and other partners. With support from the Department of Water Resources from 2008 to 2010, a number of potential indicators, identified in previous assessments, were screened using a set of established criteria. The indicators were then used by this report's authors—scientists from the San Francisco Estuary Institute, The Bay Institute, PRBO Conservation Science, and the Center

for Ecosystem Management and Restoration—to prepare this report. This report thus builds upon previous plans and assessments to evaluate the health of San Francisco Bay. It is also based on guidance documents from the National Academy of Sciences and the US EPA Science Advisory Board (see timeline, below).

The goal of this report is to transform scientific measurements into assessments of “health” or “integrity.” The methods and judgments applied herein are fully transparent and documented, and the data used are all publicly available. Interested readers can review the appendix to this report to understand the data and methods used to develop all aspects of the analyses. Continued review and refinement of the data and the conclusions presented here will give the citizens and resource managers of our region an increasingly accurate assessment of the overall health of San Francisco Bay.

How do we assess the state of the Bay?

How do we determine if the Bay is healthy? How do we decide if the goals of the Clean Water Act to “protect and restore the chemical, physical, and biological integrity” of the Bay are being met? The authors drew upon science and public policy to make informed judgments, first by identifying the attributes of the Bay that comprise its integrity and reflect its health. With those attributes identified, we then selected indicators of these attributes using meaningful and systematic criteria. In the third step we determined benchmarks against which to compare the measurements of the indicators in order to evaluate the status of the attributes and judge the Bay's health.

Milestones in the development of health indicators for San Francisco Bay

February 1986

“The Modification of an Estuary.” Nichols et al, *Science*

1986

Management Conference created per §320 of Clean Water Act

1990–92

Six *Status and Trends Reports* completed

June 1992

State of the Estuary report

November 1993

CCMP adopted

1995

Baylands Habitat Goals process begins

1996

UC Berkeley: *Restoration of the San Francisco Bay-Delta-River Ecosystem: Choosing Indicators of Ecological Integrity*

1998

First Pulse of the Estuary (1993–1998) (SFEI)

STEP 1: Identify key attributes, and their conceptual relationship

Following the guidance of US EPA's Science Advisory Board, the key attributes of an estuary are

- water (both the amount of water and its chemical quality)
- physical habitats
- ecological processes such as the cycling of nutrients and predator-prey interactions that are part of the food web
- living resources

These attributes are interacting parts of an ecosystem that influence each other (directly and indirectly), and so affect the environmental goods and services upon which humans depend. Humans are also an integral part of this ecosystem, and exert a variety of influences on the Bay's different attributes (Figure 1, page 8). Humans can also reduce some of their impacts on the ecosystem. To evaluate the effectiveness of

some of the actions taken to reduce impacts, the report also assesses indicators of stewardship.

In a healthy Bay:

- Water should not be toxic to living creatures, nor cause these animals to be toxic to humans.
- Water should be of good enough quality to allow for recreation in and on the Bay.
- Seasonal freshwater flows are adequate to support native plants and animals and the ecological processes driven by flows.
- Habitats should include a diverse and well-distributed array of key components such as wetlands, waters of varying salinity, sediments, and sea grass beds that support valued ecosystem components.
- Ecological processes should support vibrant food webs, replenish sediment in the landscape, cycle nutrients, mix fresh and salt water, and flush wastes.

- Living resources should include robust and resilient populations of diverse native species groups, including birds, fish, mammals, invertebrates, and plankton.
- Stewardship efforts should include individual and community actions that reduce adverse impacts on the ecosystem. Stewardship includes actions by volunteers as well as regulators, managers, and the regulated community, such as cities, counties, and industry.

STEP 2: Select indicators

With these attributes of health defined, our next step was to identify measurable indicators. Based upon the work of the National Academy of Sciences and others, a set of criteria was used to select valuable indicators (Table 1).⁷ Indicators are valuable if they are meaningful and relevant to the public, consistent with scientific understanding of the ecosystem, and can be measured with existing, reliable data. Our indicators also

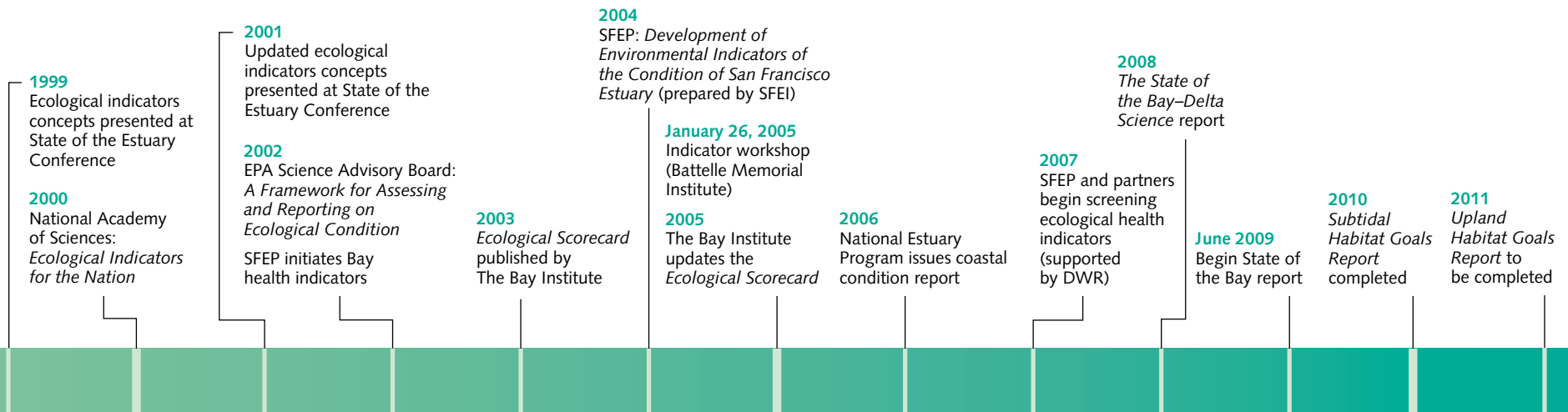


Table 1. State of the Bay 2011 Health Indicators*

ATTRIBUTE	INDICATOR	BENCHMARKS
WATER		
Quality	<ul style="list-style-type: none"> • Safe for aquatic life? Toxicity to the animal and plant species that live in or depend upon the Bay (excluding humans), including phytoplankton, algae, zooplankton, macroinvertebrates, fish, aquatic birds, and marine mammals 	Goals are standards set by the State of California for concentrations of chemical pollutants in water, methylmercury concentrations in the food web, and the toxicity of Bay waters and sediments in laboratory tests.
	<ul style="list-style-type: none"> • Safe to eat Bay fish: Contamination of fish 	Goals are established by the State of California to protect public health (OEHHA).
	<ul style="list-style-type: none"> • Safe for humans to swim: Concentrations of bacteria indicating fecal contamination 	Goals are standards for bacteria and fecal contamination established by the California Department of Public Health.
Quantity	<ul style="list-style-type: none"> • Amounts, timing, and patterns of freshwater inflow, variability 	Benchmarks are based on the State Water Resources Control Board's conclusion that protection of public trust resources requires 75 percent of unimpaired runoff from the Sacramento–San Joaquin watershed flow into the San Francisco Bay during the winter and spring.
HABITAT		
Estuarine open water	<ul style="list-style-type: none"> • Quantity and quantity of seasonal low-salinity habitat 	The benchmark for high quality open water habitat is that X2 (salinity is 2 parts per thousand) be located less than 65 kilometers from the Golden Gate for more than 100 days from February through June.
Baylands (tidal marsh and tidal flat)	<ul style="list-style-type: none"> • Regional extent 	The 1999 <i>Baylands Ecosystem Habitat Goals Report</i> established the goal of restoring 100,000 wetland acres. The benchmark for tidal flats is half of the historical extent, or 30,000 acres.
	<ul style="list-style-type: none"> • Size of existing parcels (patch size) 	The benchmark is ± 25 percent of the historical patch size for each size category.
	<ul style="list-style-type: none"> • Physical/biological condition 	The benchmark is the physical structure score for North Coast marshes using the California Rapid Assessment Method (CRAM).
Watersheds	<ul style="list-style-type: none"> • Width of riparian areas 	The benchmark is a percent of the historical riparian width distribution.
	<ul style="list-style-type: none"> • Stream habitat condition 	The benchmark is a CRAM score of 75 percent of the reference stream value.
	<ul style="list-style-type: none"> • Stream biological integrity 	The benchmark is that 75 percent of watershed stream assessments should have excellent or good health as evaluated using the Benthic Macroinvertebrate Index (BMI).

*Detailed information on data sources and indicator calculations are provided in the [Technical Appendix at www.sfestuary.org](http://www.sfestuary.org).

ATTRIBUTE	INDICATOR	BENCHMARKS
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LIVING RESOURCES

Invertebrates	<ul style="list-style-type: none"> • Shrimp and crab abundance • Shrimp distribution • Shrimp and crab species composition 	The benchmark is the average for comparable data from 1980–89; for species composition, the benchmark is 85 percent native species.
Fish	<ul style="list-style-type: none"> • Abundance, diversity, species composition, and distribution of the Bay's fish community 	The benchmark is the average for comparable data from 1980–89; for species composition, the benchmark is 85 percent native species.
Birds	<ul style="list-style-type: none"> • Abundance of breeding tidal marsh birds • Tidal marsh bird reproductive success • Heron/egret nest density • Heron/egret nest success • Winter waterfowl abundance 	<p>The benchmark is the upper quartile value of birds observed in mature tidal marsh, or an average of 0.93 birds per acre across Bay regions.</p> <p>The benchmark is a nest success rate of 20 percent, the minimum needed to sustain populations.</p> <p>The benchmark value for nest density is the average density observed from 1991 to 1995, calculated for each Bay region. For nesting success, the benchmark is the average value observed between 1994 and 1998.</p> <p>The benchmark calculated for the four Bay regions is the mean per species count of dabbling ducks and diving ducks from 1989 to 1993.</p>

ECOLOGICAL PROCESSES

Flood events	<ul style="list-style-type: none"> • Frequency and magnitude of high freshwater inflow events 	The benchmark consists of the number of years in the past decade in which inflows exceeded 50,000 cfs for a total of 90 days during the year; the average flow during the 90 days of highest flow in the year; and the number of days flows exceeded the 50,000 cfs flood threshold in given year.
Food web	<ul style="list-style-type: none"> • Number of young reared per great blue heron and great egret successful breeding attempt • Number of Brandt's cormorant young per breeding pair on Alcatraz Island 	<p>The benchmark is the number of young reared per brood observed from 1991 to 1995, calculated across all regions of the Bay (2.17 young per brood).</p> <p>The benchmark is the average number of young reared per breeding pair at the Southeast Farallon Islands reference site between 1991 and 2005 (1.69 chicks fledged per pair).</p>

STEWARDSHIP

<p>Individual and community actions</p> <ul style="list-style-type: none"> • Recycled water use • Urban water use • Coastal cleanup (volunteer effort) • Public access (trails completion) <p>Management actions (example)</p> <ul style="list-style-type: none"> • Dredged material disposal and reuse 	<p>Benchmarks are previous projections for recycled water use, potential demand for recycled water, and total wastewater available for recycling.</p> <p>The California Department of Water Resources 2020 goal for Bay Area residential consumption is 124 gallons per day per person.</p> <p>The volunteer stewardship benchmark is the number of volunteers participating in Coastal Cleanup Day in 1998.</p> <p>The goal is the completion of the 500-mile regional hiking and bicycling trail around the perimeter of San Francisco and San Pablo Bays. The Bay Area Ridge Trail goal is 550 miles of trail along the ridgelines surrounding San Francisco Bay.</p> <p>The goal used was in-Bay disposal reduced to approximately 1.25 million cubic yards per year; annually no more than 20 percent dredged material to be disposed of in-Bay; at least 40 percent to be beneficially reused or disposed of at upland sites; remainder to be disposed in deep ocean site.</p>
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must represent the Bay's characteristics broadly by integrating the many detailed scientific measurements that are available about the ecosystem.

In several instances a suite of indicators represents a particular attribute. For example, this report includes measurements for several different indicator species that reflect the health of the Bay's living resources. For simplicity, in some cases multiple indicators were combined into a single index.⁸ Readers should recognize that there are important attributes of the Bay for which we do yet have indicators, such as the ecological processes of nutrient cycling and sediment transport, or an indicator to represent the myriad of creatures that live in the Bay sediments. There are also indicators that we would like to report on but for which no data are available, and so the set of indicators in this report will hopefully be expanded in the future (See Next Steps).

STEP 3: Determine benchmarks for evaluating the indicators

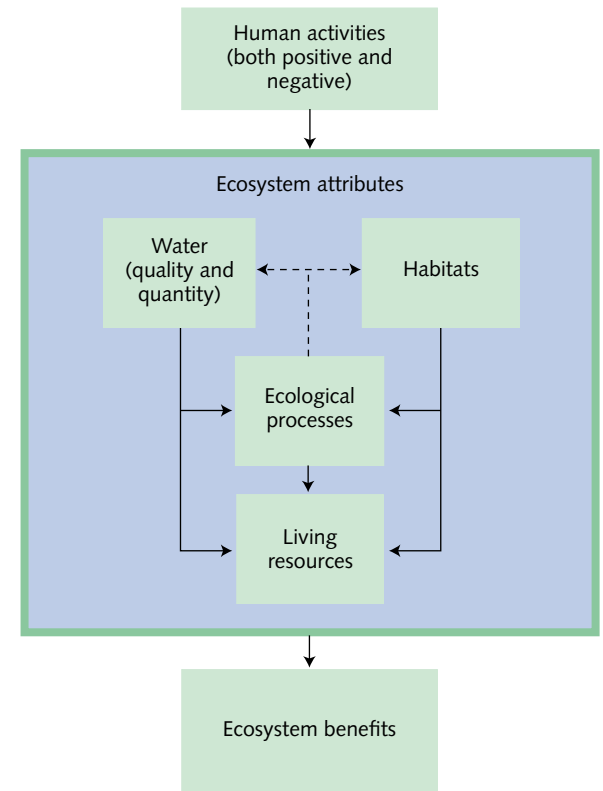
The last step was to determine benchmarks against which to compare the measured values for the indicators. Having benchmarks is essential for evaluating the status of the Bay's attributes. Benchmarks allow us to make definitive statements that can be used to assess how far we've come toward a goal or how far we still have to go.

In some instances, whether through law, regulation, or other public process, quantitative standards or goals have been established that were used as benchmarks; for example, water quality objectives set for specific chemicals, and the goal of restoring 100,000 acres of tidal marsh around the Bay established in the stakeholder-based *Baylands Ecosystem Habitat Goals* report published in 1999.

When such adopted goals were not available, we derived benchmarks using best professional

Figure 1. The attributes of a healthy Bay ecosystem and their relationship with each other and human activities.

The status of these attributes is a product of a dynamic ecosystem. The attributes are constantly being shaped by natural and human influences.



judgment to identify a reference condition against which to compare the measured value of the indicators or indices. For instance, to evaluate the status of some of the fish indicators, we used the average values for 1980–89 as the reference condition.

Selecting reference conditions is further complicated as long term studies document that climatic and ocean conditions influence the Bay on the scale of years to decades. This means changes determined by reference to a previous decade can be caused by ecological changes beyond the influence of Bay Area residents. We present the reference conditions in this report in the spirit of starting an important regional dialogue in which we continue to develop and refine goals and benchmarks for use in future assessments of the Bay's health.

WHERE TO LEARN MORE

This report is a condensed presentation of a large amount of technical information. It is meant to give a snapshot of the Bay's health to those who are interested but who do not have the time to read more detailed technical materials about the various ecological attributes and indicators described in the following sections.

For those who want to read that material, a [Technical Appendix](#) to the State of the Bay report is available on-line on the Estuary Partnership website (www.sfestuary.org). There you will find background information about the various indicators, including the rationale for their selection, calculation methods, sources of data, and more details about the results of the analysis.

Readers can find other materials related to the state of the Bay on our website (www.sfestuary.org) and at the San Francisco Estuary Institute's web site (www.sfei.org).



MICHAEL BUKAY



The South Bay Salt Pond Restoration Project, the largest tidal wetland restoration project on the West Coast, will restore 15,100 acres of industrial salt ponds to a rich mosaic of tidal wetlands and other habitats. Under the leadership of Senator Dianne Feinstein, the South Bay Salt Ponds were purchased in 2003 from Cargill Inc. Funds for the purchase were provided by federal and state resource agencies and several private foundations. The 15,100 acre purchase represents the largest single acquisition in a larger campaign to restore 40,000 acres of lost tidal wetlands to San Francisco Bay.

The salt pond effort is about to move into a new phase. Phase 1 included seven projects.

"We're getting ready to wrap up Phase 1," says project manager John Bourgeois. "After a series of stakeholder meetings to solicit input, we recently decided what the Phase 2 projects are going to be." The project, he explains, is moving carefully to ensure that habitat restoration doesn't conflict with flood

control priorities in a part of the Bay that is particularly vulnerable to the effects of rising sea levels.

The restoration area includes the Department of Fish and Game reserve at Eden Landing and the Alviso and Ravenswood sections of the Don Edwards National Wildlife Refuge. Bourgeois also collaborates with the US Army Corps of Engineers, the San Francisco Bay Regional Water Quality Control Board, and local agencies like the Santa Clara Valley Water District and the Alameda County Flood Control District.

"We established bookends of what the project could look like," he explains. One scenario calls for 90 percent of the area to be restored to tidal marsh, with 10 percent remaining as managed ponds. The alternative is a fifty-fifty split. "In Phase 2 we're still trying to get up to 50 percent," Bourgeois adds. "We need results from the adaptive management program to refine that decision. We're not moving past fifty-fifty until we have the science to allow us to. Some want us to move really fast and some think we're moving too fast."

Adaptive management involves, among other things, coping with the 45,000 California gulls that nest on islands and levees among the ponds. Last December pond A6, one of the Alviso ponds, was breached, flooding a former gull nesting colony. The concern is that displaced gulls will add to the predation pressure on shorebirds like American avocets, black-necked stilts, and endangered western snowy plovers. "We banded about a thousand gulls there," says Bourgeois. "Some are going to other existing colonies at Mowry and Newark." "It's the best-case scenario," says Cheryl Strong of the US Fish and Wildlife Service. "They didn't colonize new areas." "We're targeting areas like SF2, A22, and Eden Landing where we don't want them to show up," Bourgeois adds.

Other issues being addressed through adaptive management include methylmercury generation and

dissolved oxygen levels in the ponds. "We're working closely with the Water Board on mercury," Bourgeois notes. Pond A8, which was opened to the tides in June, will be a key test site. "As for dissolved oxygen, we've tried to maximize the amount of turnover we get in these ponds, also working with baffles and aeration. The problem is a lot better. The US Geological Survey is studying larger and deeper ponds like A3W, where getting enough water turnover in all the little nooks and crannies is difficult."

Ravenswood pond SF2 near the west end of the Dumbarton Bridge is an ongoing experiment in habitat enhancement: "The ponds were engineered to make salt, not as wildlife habitat. We wanted to take a smaller footprint and modify it specifically for wildlife species, trying to create as much nesting and foraging habitat for shorebirds as we can. Based on similar work in the Central Valley, we built 30 islands in two different shapes, half round and half linear. The whole back third of the pond is dry seasonal salt panne for the plovers. Volunteers have spread oyster shells to create camouflage for plover nest sites, and we built moats to exclude mammalian predators."

Project staff thought it would take a couple of years for the birds to discover SF2. Bourgeois says, "We had hundreds of waterbirds within two or three weeks of opening it up. This spring we had a pair of snowy plovers nesting on each of four islands." A hundred pairs of American avocets and a few pairs of black-necked stilts also nested. Strong says the pond, with areas of varying depth, attracted large numbers of both dabbling ducks (shoveler and pintail) and diving ducks (scaup, common goldeneye, and ruddy duck) during its first winter; the ducks forage by day and use the islands as night roosts. Migratory shorebirds, including least sandpipers, marbled godwits, willets, and semipalmated plovers, foraged along its edges. Biologists will continue

to monitor shorebird and waterbird use to inform pond management and future managed pond projects.

Proposed Phase 2 steps at the Ravenswood unit will include tidal restoration of Pond R4 and enhanced management of R5 and S5 as bird habitat. The project is also looking at restoring Alviso ponds A1 and A2W, next to Mountain View's Shoreline Park,

to tidal marsh. The "Island Ponds," A19, A20, and A21, breached for tidal circulation in 2006, will be enhanced. "We're considering additional breaches of the Island Ponds along Mud Slough on the north side. The Corps of Engineers is also analyzing the Alviso complex, one of their top priorities, for their Shoreline Study. Flood protection is one of our three

major goals, along with restoration and public access. We aren't taking any actions in Phase 1 or Phase 2 at Alviso that would increase flood risk."

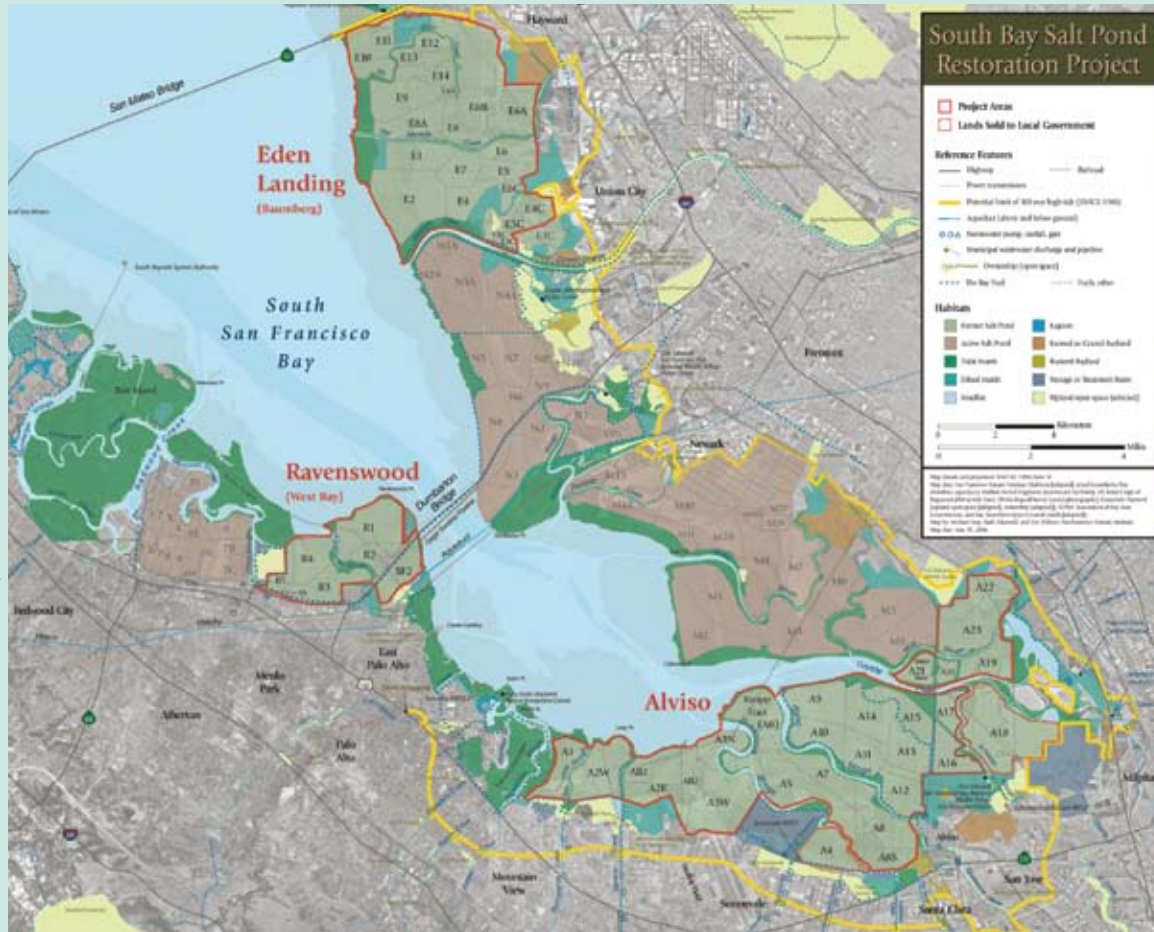
Flood control imperatives will also drive Phase 2 at Eden Landing. "The whole southern half between Alameda Creek and the Flood Control Channel will go to tidal restoration," says Bourgeois. "But we can't restore that area without flood protection for Union City. We're working closely with the Alameda County Flood Control District on that." He also points out that the spine of the Bay Trail will go through Eden Landing. Balancing the three goals here will require a "multi-year and multi-stage" process.

Looking back at Phase 1, Bourgeois says the biggest and best surprise is the rapid rate of sedimentation in restored ponds: "The rate has been much faster than projected, with lots of marsh development. The South Bay is very sediment-rich. In light of sea level rise projections, we find we need to capitalize on that as soon as we can."

For the future, he sees "a lot of uncertainties. Flood protection is one of our biggest challenges. Pretty soon we'll hit a point where we can't do any more restoration until we have real flood protection in place." Bourgeois says project managers are working with the Corps and local flood control agencies to make sure these elements come together. He is also looking forward to seeing more results from the project's monitoring program in the coming years to better understand how the system is responding to these large-scale changes. To see more maps of the salt pond restoration projects, go to www.southbay-restoration.org/maps.

A slightly different version of this article first appeared in ESTUARY NEWS, August 2011.

South Bay Salt Pond Restoration Project



SOUTH BAY SALT POND RESTORATION PROJECT

Water

Quality

Important ecosystem services provided by the Bay are affected by contaminants. Our water quality evaluation is based on the premise that people should be able to fish and swim in the Bay, and that the Bay should support abundant, diverse communities of all of the animal and plant species that live in or depend upon the Bay, including algae, zooplankton, macroinvertebrates, fish, aquatic birds, and marine mammals. Our analysis addresses three key questions:

- Is the Bay safe for aquatic life?
- Are fish from the Bay safe to eat?
- Is the Bay safe to swim in?

■ HEALTH INDICATORS

We answered the three water quality questions by assessing the most recent data on Bay water, sediment, and fish. Quantitative water quality indicators for protecting aquatic life included concentrations of dissolved oxygen, copper, and silver in water, concentrations of methylmercury in small fish, and the occurrence of toxicity in



MARK RAUZON

TAKING ACTION TO REDUCE METAL POLLUTION

The Bay Area's progress in reducing metal loads in water discharged from publicly owned treatment works (POTWs) is a pollution-control success story that should be more widely known. Between 1995 and 2010, according to the Regional Monitoring Program, area-wide POTW loads of copper and nickel decreased by 48 percent. This statistic, building on earlier reductions in the 1970s and 1980s, reflects a history of political commitment, technological improvement, and the changing face of local industry.

"It's an incredible story," says Mike Connor of the East Bay Dischargers Authority. "In general the inputs of almost all contaminants are down significantly in the last 20 years. One big thing is the improvement of sewage treatment. Removal efficiency at the plants is such that what comes in isn't going out." Another factor is that in the 1980s, the US Environmental Protection Agency developed pre-treatment standards for different industries, forcing them to discharge to municipal treatment centers. "Most of the benefits happened early on," adds Connor. "What's amazing is that as much as conditions have improved, they're still getting better."

Connor says copper is a metal of concern in the Bay. One relatively recent source was the electroplating process associated with high-tech manufacturing. "The Silicon Valley used to have a lot of platers and printed circuit-board makers," says the San Francisco Bay Regional Water Board's Tom Mumley. "A lot of those facilities have closed up shop or been replaced by more modern chip-making technology. That's one of the reasons metal loads have declined, along with the fact that the San Jose/Santa Clara POTW is one of the best treatment systems in the world."

Copper discharges also decreased after copper-based root-control products were banned in 1985, as a result of lobbying by treatment plant operators. But copper sources also include brake-pad linings in

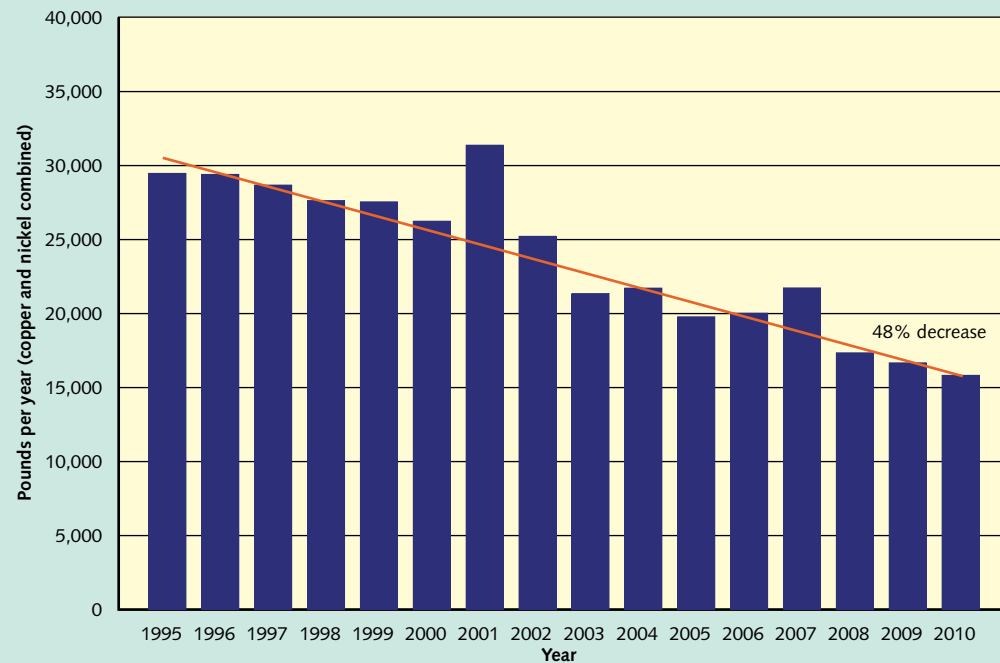
vehicles. To tackle that issue, Sustainable Conservation and the Brake Pad Partnership (initiated years ago by the Estuary Partnership) sponsored AB 346, which was signed into law in September 2010. The bill will allow no more than five percent copper in brake pads in vehicles sold starting in 2021, and will phase out brake pad copper completely starting in 2025.

With copper and other industrial metals under better control, mercury from dental offices is a newer target. Mercury may constitute up to 40 percent of the amalgam used in dental work. Although historic mining is still the source of most of the mercury entering the Bay, dental amalgam is a significant input. One study found that 61 percent of the mercury coming into the San Jose/Santa Clara plant came from dental practices. In 2004, when the Regional Water Board

first adopted a TMDL (Total Maximum Daily Load) for mercury, 20 kilograms reached the Bay annually. That same year San Francisco required dental offices to apply for wastewater discharge permits, implement best management practices, and install city-approved amalgam separators. Other cities followed.

Revising the TMDL in 2006, the Board mandated an initial reduction of 20 percent over the following 10 years, then another 13 percent over the next 10. Connor says the 2020 goal has already been exceeded. Current reductions include 67 percent for the Central Contra Costa County Sanitary District, 64 for the San Francisco Public Utilities District, and 45 for EBMUD. Sixty percent of the Bay Area's dental offices are now participating; the target is 85.

Bay Area publicly owned treatment works metal loads, 1995–2010



Bay sediments. Our assessment also included qualitative consideration of exotic species and trash—two important forms of pollution that are difficult to quantify. We examined concentrations of six contaminants in fish tissue to evaluate whether Bay fish are safe to eat and examined bacteria concentrations in water at beaches where people swim to determine whether the Bay is safe for swimming. Other contaminants in Bay water and fish tissue that meet established goals were also considered and briefly summarized.

BENCHMARKS

To assess water quality, we compared monitoring results for parameters measured in water (dissolved oxygen, copper, silver, bacteria) to goals established by the state for each constituent. We compared concentrations of methylmercury in small fish to a target set in the state’s mercury control plan for the Bay. We evaluated the frequency of occurrence of sediment toxicity relative to the state’s goal of no toxicity.

To assess whether fish are safe to eat, we compared concentrations of contaminants (PCBs, methylmercury, dioxins, legacy pesticides, selenium, and PBDEs) in sport fish tissue to specific goals for each of these contaminants that were established by the state to protect public health.⁹ For more details, please see the on-line [Technical Appendix \(www.sfestuary.org\)](http://www.sfestuary.org).

To evaluate whether the Bay is safe for swimming, we used a statewide system for evaluating the safety of bathing beaches that compares bacteria concentrations to state goals. Heal the Bay, a Santa Monica-based non-profit, provides comprehensive evaluations of over 400 California bathing beaches in both Annual and Summer Beach Report Cards as a guide to aid beach

users’ decisions concerning water contact recreation. These report cards, which use the familiar “A to F” letter grade scale, provide a valuable and accessible assessment of how safe Bay waters are for swimming and were used as benchmarks.

■ KEY RESULTS AND TRENDS

IS THE BAY SAFE FOR AQUATIC LIFE?

Enforcement of the Clean Water Act and other environmental laws as well as technological improvements in treating wastewater have resulted in tremendous improvements in overall Bay water quality (see “Taking Action to Reduce Metal Pollution” and Table 2). These improvements have

solved serious threats to aquatic life related to reduced dissolved oxygen and elevated concentrations of silver. Many other pollutants are also routinely monitored and found at concentrations below water quality goals, and are considered to pose very low risk to Bay aquatic life. However, several pollutants still pose a substantial threat to the health of aquatic life in the Bay. Methylmercury, exotic species, toxic sediments, and trash are the principal concerns.

Methylmercury, largely a legacy of historic mercury mine operations (see photo and caption), continues to be a significant risk for Bay wildlife. Researchers find that elevated levels of methylmercury are leading to high mortal-

Table 2. Is the Bay safe for aquatic life?

	HIGH CONCERN	MODERATE CONCERN	LOW CONCERN	GOALS ATTAINED
Rapid Progress Likely	Exotic Species**	Trash	Copper	Dissolved Oxygen Silver Other Priority Pollutants: arsenic, cadmium, chromium, nickel, lead, zinc, alkytin; diazinon, chlorpyrifos, dachtal, lindanes, endosulfans, mirex, oxadiazon; cyanide
Rapid Progress Unlikely	Methylmercury	Sediment Toxicity	*	

*No contaminants fall in this category. **Progress expected by reducing the rate of new introductions.

The Senador Mine reduction works, circa 1900, where miners separated quicksilver, aka mercury, from slag. Mercury comes from the red ore called cinnabar. Mexicans began mining the New Almaden district just before the Gold Rush. In its heyday, the district contained hundreds of miles of mining tunnels, several small towns, and 1,800 homes for miners—all working to produce and export flasks of liquid mercury. The creek pictured in the photo was one of more than 80 miles of streams that drained the mining area into the Guadalupe River watershed and San Francisco Bay.



COURTESY HISTORY SAN JOSE

ity in embryos and chicks of some fish-eating birds. Methylmercury concentrations in the Bay food web have not changed perceptibly over the past 40 years, and we anticipate that they will decline very slowly in the next 30 years. It may be possible to tackle at least some facets of this problem. One of the species at greatest risk in the Bay, the Forster's tern, forages primarily in salt ponds. Agencies that manage these habitats may be able to manipulate factors, such as water flow through the ponds, in ways that reduce the production and accumulation of methylmercury.

Exotic species pose the greatest threat to aquatic life in the Bay by displacing native species, disrupting communities and the food chain, and altering habitat. Scientists consider San Francisco Bay the most invaded estuary in the world, and the ecological impacts of exotic species in the Bay have been immense. Successful invasions by exotic species are essentially irreversible, so efforts are best focused on reducing the rate of introductions. Many exotic species arrive in the Bay in ships' ballast water. If implemented rigorously, state and federal ballast water regulations could greatly reduce this major pathway of introduction. Several other pathways (aquaculture activities, imported live bait, aquarium organisms, ornamental plants, live educational or research organisms, and live seafood) could also be managed better by thoughtful regulation.

The frequent and continuing toxicity of Bay sediments in standard tests is another indicator of the impacts of pollution on aquatic life. Since routine sampling began in 1993, at least 26 percent of each year's sediment samples have been found to be toxic. In 2009, 67 percent of the samples were toxic. These results indicate that pollutant concentrations in Bay sediments

are high enough to affect the development and survival of aquatic invertebrates. This problem will persist into the future until the chemicals (or mix of chemicals) causing this toxicity can be identified and remediated.

Trash in the Bay also continues to threaten aquatic life. Plastic trash in particular persists for hundreds of years in the environment and threatens wildlife when they eat it or become

entangled. Larger pieces of trash degrade into fragments that can harm fish and other aquatic animals when they eat these fragments and when animals are exposed to chemicals that leach from (or accumulate on) the plastic particles. Aggressive new regulatory requirements adopted in 2010¹⁰ should significantly reduce the amount of trash and other urban pollutants entering the Bay in the next 30 years (see "Taking Action to Improve Stormwater Quality").

CONTROLLING A NEW, POTENTIALLY INVASIVE MARINE INVERTEBRATE

The European periwinkle (*Littorina littorea*), an edible marine snail, features in European and Asian cuisines and can be purchased live in local markets. The species is getting into San Francisco Bay, likely with human assistance.

Recent research indicates the periwinkle is native to Europe and was introduced to North America. The small algae-grazers have altered New England intertidal ecosystems and are a host for marine black spot disease, transmissible to fish and seabirds.

European periwinkles have turned up sporadically in the Bay over the years. A population was discovered at the Dumbarton Pier in the South Bay in 2002, and more were found at Ashby Spit in the East Bay in 2007. Both populations were removed.

Biologists suspect *Littorina* has been introduced intentionally in an attempt to start a local fishery. Andrew Chang of UC Davis and the Smithsonian Environmental Research Center and colleagues reported that genetic analyses indicate an East Coast origin for the snails in San Francisco Bay. All the Ashby and Dumbarton periwinkles were reproductively mature adults. Biologist Andrew Cohen cautions that the planktonic larval stage could spread over a wide area. But no one has found a possible daughter population elsewhere in the Bay, despite intensive surveys.

Dumbarton remains a hot spot. Last August another 400 snails were found there, and removed. In February, a much larger population, at least 5,000, was discovered; eradication efforts were resumed. This requires collecting all visible snails along a gradient from large boulders to mud. Chang anticipates that removal will require repeated visits over the course of several years.

Again, only adult snails have been detected. Chang speculates that water temperatures constrain their reproduction. Their southern limit on the East Coast and in Europe occurs where water temperatures reach 21 degrees Celsius. Conditions might be more favorable in the cooler North Bay. There's also concern that larger numbers make successful reproduction more likely.

Biologists agree that the ideal solution would be to cut off the source, focusing on prevention rather than eradication. But detecting surreptitious releases will be a challenge.



CHRIS KAY



Several other pollutants appear to pose risks to Bay aquatic life, but definitive goals for their concentration in the Bay have not yet been developed. A few of the most prominent examples include selenium, polycyclic aromatic hydrocarbons (PAHs), and perfluorooctanesulfonate (PFOS). Efforts to evaluate these pollutants and develop appropriate goals are in progress.

ARE BAY FISH SAFE TO EAT?

Pollutants in fish from the Bay pose a health concern to people (Table 3), mainly from polychlorinated biphenyls (PCBs), methylmercury, and dioxins, which are generally found in Bay fish at moderate concentrations. Consumers can exercise caution and reduce their exposure to these contaminants by following safe eating guidelines for the Bay, which have just been updated this year (see oehha.ca.gov/fish/). Many other toxic pollutants (e.g., arsenic, cadmium, chlorpyrifos, diazinon, dieldrin, DDTs, PAHs, PBDEs, and selenium) are found at very low concentrations and do not pose concerns for consumers of Bay fish.

The degree of contamination in Bay fish varies by species. Striped bass have relatively high concentrations of methylmercury while

TAKING ACTION TO IMPROVE STORMWATER QUALITY

A new era in regional stormwater management began in 2009 when the Municipal Regional Permit (MRP) replaced county-based stormwater discharge permits previously issued to municipalities in Alameda, Contra Costa, San Mateo, and Santa Clara counties, and three cities in Solano County. Covering 76 cities, counties, and flood management districts, the MRP provides a robust framework for controlling pollutants entering San Francisco Bay. Its development was a collaborative effort between the San Francisco Bay Regional Water Quality Control Board and municipalities, creek advocacy groups, and other stakeholders.

Water quality monitoring is a key element, with new requirements beginning October 2011. Monitoring was inconsistent in the past; MRP sets a regional playing field and encourages collaborative efforts. Cities and counties must now track creek water quality trends using physical, biological, and chemical indicators and provide data to calculate pollutant loads to the Bay.

One immediate effect of the MRP was the implementation of TMDLs (Total Maximum Daily Loads) for pesticide-related toxicity in urban creeks. Since the Water Board anticipated problems with replacement pesticides, the MRP covers newer products like pyrethroids and fipronil.

The MRP requires cities to implement Integrated Pest Management (IPM) policies and ensure that city employees and contractors follow IPM procedures. Local governments can't regulate pesticides but can control what happens on city-owned property. Outreach to pest-control professionals, including support of IPM-certified contractors, is mandated.

Covered cities are required to identify trash hot spots in urban creeks and along shorelines, clean them up annually, and report on the amount and types of trash collected. Trash capture devices to treat runoff from an area of 30 percent of land used for retail and wholesale businesses must be installed by 2014. The Estuary Partnership has received a \$5 million state grant to provide such devices to municipalities. Targets are a 40 percent reduction in trash loading by 2014, 70 percent by 2017, and 100 percent by 2022.



JAY DAVIS

In December 2011, MRP requirements for low-impact development (LID) will take effect. For new development and redevelopment projects resulting in 10,000 square feet of impervious surface, builders must ensure that stormwater infiltrates, evapotranspires, or is harvested on-site. If those measures aren't feasible, bioretention and biofiltration will be allowed. LID tools include rain barrels and cisterns, green roofs, permeable pavement, rain gardens, planters, and tree well filters.

According to Tom Mumley of the Water Board, the MRP creates a comprehensive and uniform approach with flexibility and adaptability built in. He considers it a significant step forward in a 20-year effort to manage urban stormwater runoff.

Table 3. Are Bay fish safe to eat?

	HIGH CONCERN	MODERATE CONCERN	LOW CONCERN	GOALS ATTAINED
Rapid Progress Likely	*	*	*	DDT Dieldrin Chlordane selenium Other Priority Pollutants: PAHs, chlorpyrifos, endosulfan, endrin, lindane, mirex, toxaphene
Rapid Progress Unlikely	PCBs	Methyl-mercury Dioxins	*	

*No contaminants fall in this category.

jacksmelt are relatively low in this contaminant. Shiner surfperch have relatively high concentrations of PCBs, and California halibut have relatively low concentrations. The safe eating guidelines for the Bay highlight the key differences among species to allow fish consumers to reduce their exposure. For example, the OEHHA guidelines indicate that PCB concentrations in one group of species—surfperch—are high enough that they not be eaten at all.

Moderate levels of contamination are generally found in fish in all parts of the Bay. However, shiner surfperch in the Central Bay have higher levels of PCBs than the same species in San Pablo Bay or South Bay. This is due to the tendency of this species to inhabit nearshore areas, many of which are contaminated with PCBs in the Central Bay. This finding suggests that identifying and cleaning up contaminated hotspots along the Bay’s edges could reduce fish contamination in local areas.

IS THE BAY SAFE TO SWIM IN?

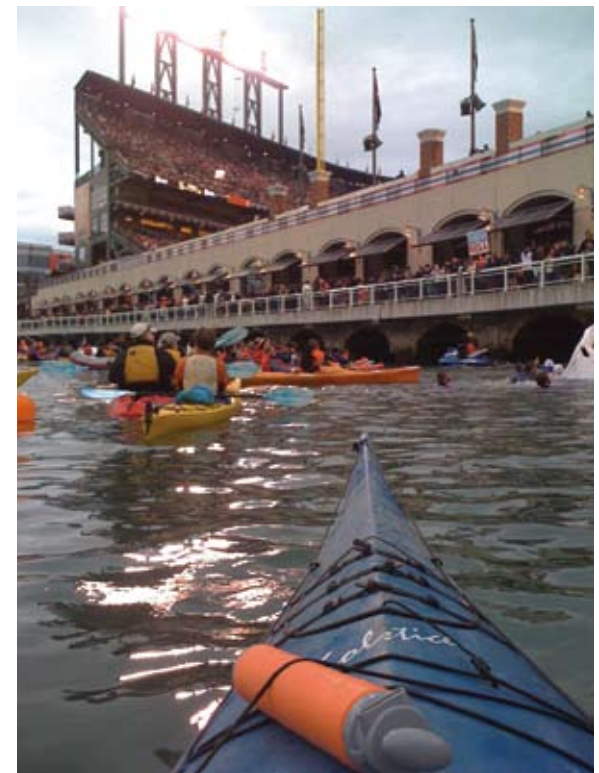
The most recent data indicate that most Bay beaches are safe for swimming, but bacterial contamination is a concern at a few beaches in the summer and at most beaches in wet weather.

For the 2010 summer beach season, 19 of the 27 monitored beaches received an A or A+ grade from Heal the Bay, reflecting that standards were rarely exceeded. Ten of these beaches received an A+: Coyote Point, Alameda Point South, Bath House, Windsurf Corner, Sunset Road, Shoreline Drive, Hyde Street Pier, Crissy Field East, Crissy Field West, and Schoonmaker Beach. Most Bay beaches are therefore quite safe for swimming in the summer (see Map 2).

Seven of the 27 monitored beaches had grades of B or lower, indicating that they exceeded bacteria standards by varying degrees. One beach, Keller, received an F grade. Five beaches received a D, including Aquatic Park and Lakeshore Park in San Mateo County, Keller Beach South in Contra Costa County, and CPSRA Windsurfer

Circle and Sunnydale Cove in San Francisco County. These low grades indicate that swimmers could have an increased risk of becoming ill or infected through contact with the water. Overall, the average grade for the 27 beaches monitored from April through October was a B.

During wet weather (usually November through March), recreational activities in which people come in contact with the water are less popular but are still enjoyed by a significant number of Bay Area residents. Bacteria concentrations are considerably higher in wet weather, making the Bay less safe for swimming. This pattern is evident in Heal the Bay’s report card



BETH HUNING

grades for wet weather. In wet weather, only five of 22 beaches with data received an A. Six of these 22 beaches, on the other hand, received an F grade. The average grade for these beaches in wet weather was a C.

■ SUMMARY

Overall, thanks to the considerable investment that has been made in wastewater treatment infrastructure and the diligent efforts of water quality managers, the Bay is much safer for aquatic life and for people to fish and swim in than it was in the 1960s. Substantial control efforts that began in the 1970s solved most of the obvious problems of the 1960s and set the Bay on a course for gradual recovery for many pollutants (Table 4).

The risks people and wildlife face today are in large part a legacy of unregulated discharges of pollutants in the past. For example, even though sale and production of PCBs were banned in 1979, these persistent chemicals have become thoroughly spread across the Bay watershed and mixed throughout the Bay, creating a widespread pool of contamination that will dissipate very slowly. After examining data on contaminants in sport fish from 1994 to the present, we found no declines in PCBs, methylmercury, and dioxins. Reducing these pollutants to a level at which all Bay fish are safe to eat will take decades.

Although these pollutants present challenges for resource managers, continued progress can be achieved in reducing trash inputs to the

Map 2. Bay Beaches Monitored for Bacteria

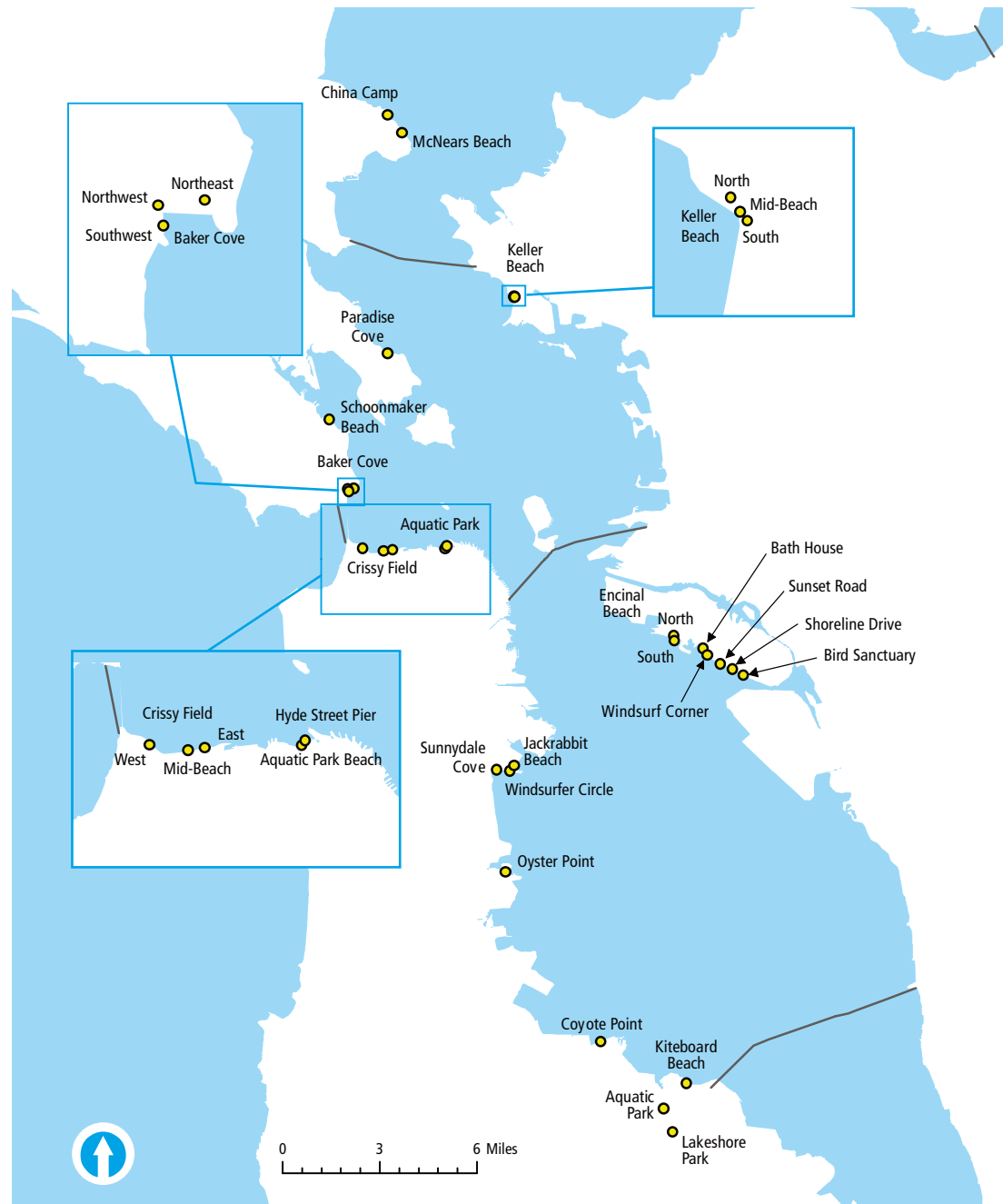


Table 4. Water quality summary

SAFE FOR AQUATIC LIFE		SAFE TO EAT		SAFE FOR SWIMMING	
Methylmercury	•	PCBs*	•	Beach Bacteria (Summer)	••••
Exotic Species	••	Methylmercury	••	Beach Bacteria (Wet)	•••
Sediment Toxicity	••	Dioxins	••		
Trash	•••	Legacy Pesticides	•••••		
Copper	••••	Selenium	•••••		
Dissolved Oxygen	•••••	PBDEs*	•••••		
Silver	•••••	Other Priority Pollutants*	•••••		
Other Priority Pollutants	•••••	Emerging Contaminants	?		
Selenium	?				
PAHs*	?				
PBDE*	?				
PFOS*	?				
Emerging Contaminants	?				

KEY:	
poor	•
poor to fair	••
fair	•••
fair to good	••••
good	•••••
goals not established	?

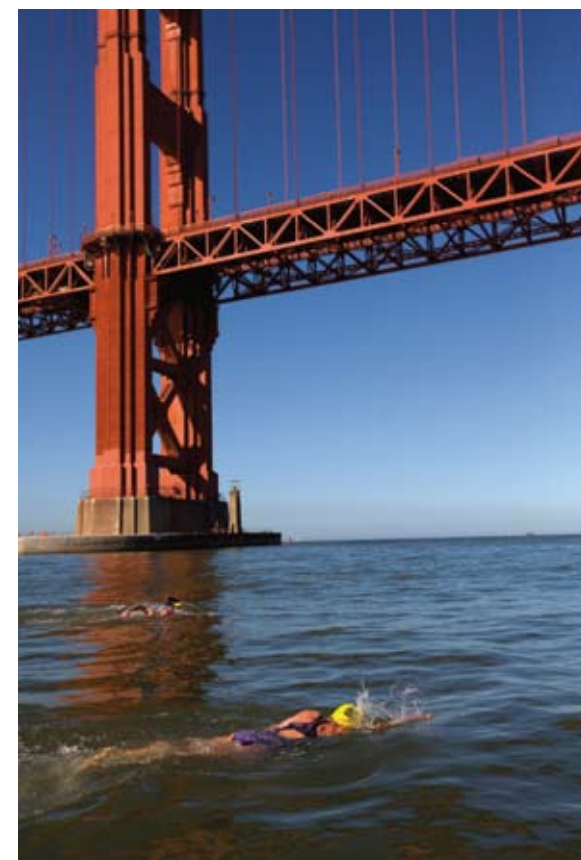
*PAHs Polycyclic aromatic hydrocarbons
 PBDEs Polybrominated diphenyl ethers
 PFOS Perfluorooctanesulfonic acid
 PCBs Polychlorinated biphenyls

Bay, stemming the influx of exotic species, and reducing methylmercury production in specific habitats.

A variety of approaches can be taken to make the Bay safer for people to swim in. Surveys can be conducted to identify and mitigate sources of bacterial contamination where possible. Low impact development (LID) treatment measures could be used at many sites throughout the Bay Area to retain and treat stormwater to prevent many pollutants from reaching the Bay. Repairing and replacing defective and

aging sanitary sewer systems will be necessary in many instances before human fecal sources are controlled.

Every day, we use thousands of chemicals (in a plethora of industrial and consumer products, including personal care products, pesticides, herbicides, and fungicides, just to name a few) at home and at work; many of these chemicals end up in the Bay. A lack of information on the exact chemicals present in these products, their movement in the environment, and their toxicity hinders efforts to track and manage the



SWIM ACROSS AMERICA

risk posed to people and aquatic life by these contaminants of emerging concern (CECs). Numeric goals for assessing CECs are not yet available but should be part of future assessments of Bay health. The occurrence of CECs also underscores the importance of “green chemistry” efforts to prevent potentially problematic chemicals from entering the Bay in the first place. Such measures would help prevent new legacy pollutants that could threaten the health of future generations of Bay wildlife and Bay Area residents.

TAKING ACTION TO CLEAN UP THE FLEET

After years of effort by regulators and environmentalists, information from investigative reporters, and ultimately a lawsuit, a federal court judge ruled last year that the 57 ships in the mothball fleet sitting in Suisun Bay constitute a “point source” under the Clean Water Act and are discharging pollutants without a permit. The judge ordered the federal Maritime Administration (“MARAD”) to clean the ship decks and hulls in a way that does not pollute San Francisco Bay.

The problem with the ships was first discovered in 2006 when *Contra Costa Times* reporter Thomas Peele advised the San Francisco Bay Regional Water Board that MARAD was scraping invasive species from the sides and bottoms of ship hulls—along with large flakes of steel and paint containing heavy

metals—into the Bay, says the Water Board's David Elias. “Most marine bottom paints even today contain heavy metals designed to kill anything that tries to live on the paint,” says Elias. The U.S. Coast Guard had ordered MARAD to clean the ships of invasives before sending them to Brownsville, Texas for dismantling. At that time, MARAD claimed that cleaning the ships in dry docks in San Francisco—which would have prevented discharging invasives and paint into the Bay—was too costly, according to Elias.

A report obtained at the time by the *Contra Costa Times* through a Freedom of Information Act request to the Coast Guard showed that a consultant hired by MARAD to evaluate the impacts from exfoliating paint had found that around 20 tons of copper and other heavy metals was missing, and that lots

more—as much as 65 tons—was about to fall off (in paint chips) or was lying around on the ships' decks. When MARAD finally tested the stormwater collected from the ships in 2009, the samples contained high concentrations of heavy metals including lead, zinc, cadmium, mercury, chromium, and copper, says Elias. In response, the Water Board ordered MARAD to deal with the problem by scraping, sweeping, shoveling, and containing the

flaking paint. The Water Board also ordered MARAD to come up with a plan to safely remove the invasives on the remaining ship bottoms and to test the sediments around the ships (a subsequent limited study by NOAA revealed that the sediments were not statistically more contaminated than Bay sediments in the vicinity). When MARAD did not comply with the orders, NRDC, BayKeeper, and Arc Ecology sued; the Water Board then decided to become a co-plaintiff.

“The Water Board had never sued the federal government before or partnered with environmental organizations as co-plaintiffs,” says Elias. But the end result was a good one for the Bay: the settlement that was ultimately reached after the Obama administration took over mandated that 25 of the most polluting mothball ships be removed from the fleet and scrapped by 2013, and 32 more by 2017. The battleship USS Iowa will be re-used as a museum ship. “This case demonstrates that we can work side-by-side with NGOs to achieve the kind of compliance we otherwise might not be able to achieve,” says Elias. “It’s a potential road map for other state agencies to regulate the federal government.” And last but not least, says Elias, the simple act of sweeping the ships' decks works: when MARAD tested stormwater from the decks after sweeping them this past winter, concentrations of heavy metals were greatly reduced. The other positive outcome, says the Water Board's Bruce Wolfe, is that the Water Board facilitated, by expediting numerous permits, the re-opening of the Mare Island dry docks where some of the ships will be dismantled, “providing an ecologic and economic win-win.” The reopening of the Vallejo shipyard, which was closed in 1995, is expected to create 100 to 120 jobs when it is fully operational.

A slightly different version of this article first appeared in ESTUARY NEWS, June 2011.



DAVID ELIAS

Quantity (Freshwater inflow)

The amount, timing, and patterns of freshwater inflow to the Bay define the quality and quantity of its estuarine habitat. As it mixes with salt water, inflowing fresh water creates brackish water (or low salinity) habitat in the Bay's open waters and shoreline marshes. Freshwater inflows also drive key ecological processes. The amount of inflow determines how much and where in the Bay this habitat is located (see also the Estuarine Open Water Habitat section). The variability, or changes in inflows over time, trigger reproduction and migration of many species, and high flows transport nutrients and organisms to and through the Bay, and flush contaminants.

Most of the fresh water that flows into the Bay comes from the Sacramento and San Joaquin Rivers. Smaller waterways around the Bay, like the Napa and Guadalupe rivers, and Alameda, San Francisquito, Coyote, and Sonoma creeks, and many smaller tributaries, contribute the balance. All of these streams have large seasonal and year-to-year variations in flow, reflecting California's seasonal rainfall and snowmelt patterns, and cycles of floods and droughts. During the past century, freshwater flows into the Bay have been greatly altered by dams and water diversions. These changes have affected the Estuary and the plants and animals that depend on it.

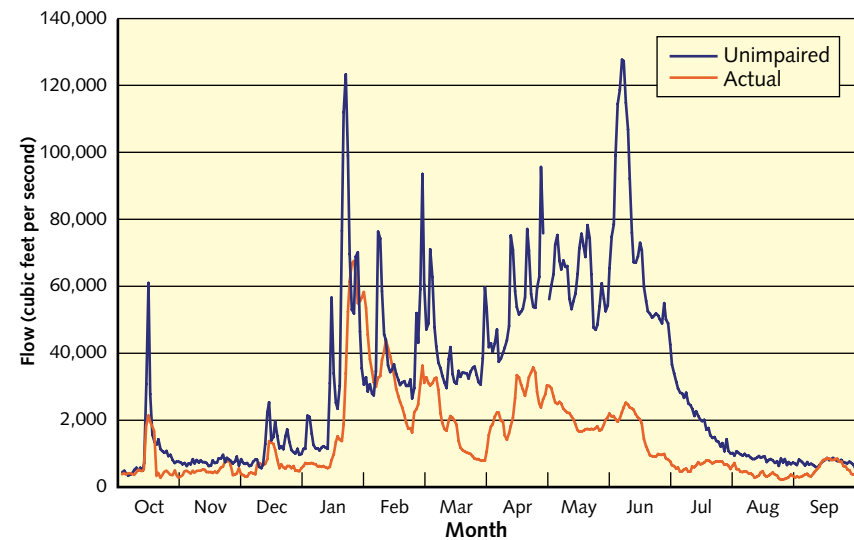
HEALTH INDICATORS

The Freshwater Inflow Index uses six indicators to assess the amounts, timing, and patterns of freshwater inflow to the Bay from the Sacramento-San Joaquin watershed, which provides 90 percent of total inflow in most years. In order to account for the system's natural seasonal and year-to-year variability, each of the indicator measurements was made in comparison to what the freshwater inflow condition would have been if there were no dams or water diversions, referred to as "unimpaired" conditions (Figure 2). Two indicators measure how much water flows into the Bay annually and during the ecologically important spring period. Two other indicators measure the variability of freshwater inflows, both between years and the seasonal



PETER BAYE

Figure 2. For Water Year 2010, this graph compares freshwater inflow conditions that would have occurred if there were no dam and water diversions, referred to as "unimpaired" conditions, with actual freshwater inflows.



variability within each year. The fifth indicator measures how frequently the Bay receives high inflows, which are usually driven by flood conditions in the watershed. The final indicator measures how frequently the Bay experiences inflow conditions similar to what would have occurred during the driest years on record. For each year, the results of the six indicators are combined into a single score (0–4) to calculate the Freshwater Inflow Index.¹¹

BENCHMARKS

Regulatory requirements for minimum freshwater inflows into the Bay have been in place for several decades. However, the State Water Resources Control Board (SWRCB) recently determined that, in order to protect public trust resources like fish and wildlife in the Estuary, 75 percent of unimpaired runoff from the Sacramento–San Joaquin watershed should flow into the Bay during the winter and spring (SWRCB 2010). The benchmarks used to evaluate the Freshwater Inflow indicators were developed based on this recommendation. Measured inflow conditions that exceeded this benchmark were considered to be good conditions; inflows that were lower were considered to be fair, poor, or very poor conditions.

■ KEY RESULTS AND TRENDS

Flow conditions degraded over the last half century (see Figure 3).

All of the key characteristics of freshwater inflow—amounts, variability, peak flows and dry year frequency—were adversely affected. Since the 1970s, overall flow conditions have been mostly poor and, in the past two decades,

occasionally very poor. During the 2000s, annual inflows were reduced by more than 50 percent on average and springtime inflows by nearly 60 percent compared to historic levels. In 2010, only 31 percent of estimated springtime unimpaired runoff from the Bay’s watershed actually flowed into the Bay. Both seasonal and year-to-year variability have been reduced and, in 2010, the frequency of peak flood flows was reduced by 90 percent (see also Flood Events in the Ecological Processes section of this report). In effect, based on the amounts and patterns of actual freshwater inflow, the Bay is being subjected to chronic drought conditions: 2010 was the eighth year out of the past ten in which the total annual amount of freshwater flow into the Bay was the same (or less) than what it would have been under unimpaired conditions in a “critically dry” year. Despite above average runoff in the watershed, inflow conditions in

2010 were very poor, and the Freshwater Inflow Index was the lowest on record (Figure 3).

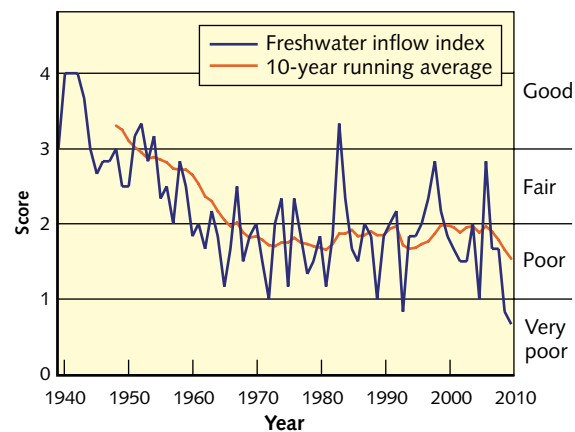
Based on results of the Freshwater Inflow Index, the health of the San Francisco Estuary is critically impaired. Reductions and alterations in freshwater inflow have their greatest impacts in the upstream regions of the Estuary and Suisun and San Pablo Bays where the mix of fresh and salt water creates productive open water estuarine habitat. Scientists now consider poor freshwater inflow conditions to be one of the major causes for the ongoing declines of fish populations observed in the upper Estuary (see also the Fish Index in the Living Resources section of this report).

■ SUMMARY

Since 1993, when the San Francisco Estuary Partnership’s CCMP called for increasing freshwater availability to the Estuary and restoring healthy estuarine habitat, overall inflow conditions have not improved but rather generally declined. Similarly, new water quality and flow standards established by the SWRCB in 1995 have not had a detectable effect on the Freshwater Inflow Index.

Recently, after reviewing new research and hearing testimony from scientists, fishermen, water managers and water users, the SWRCB determined that freshwater inflows needed to be increased substantially in order to protect the public trust values of the Bay.¹² This finding and the results of the Freshwater Inflow Index underscore the importance of and urgent need for greater efforts to improve freshwater inflow conditions as part of a comprehensive program to improve the health of the Bay.

Figure 3. The amounts and variability of freshwater inflows to the San Francisco Bay declined during the 1950s and 1960s, after large dams were constructed on most of the Bay’s tributary rivers. Since then, freshwater inflow conditions have been poor in most years.

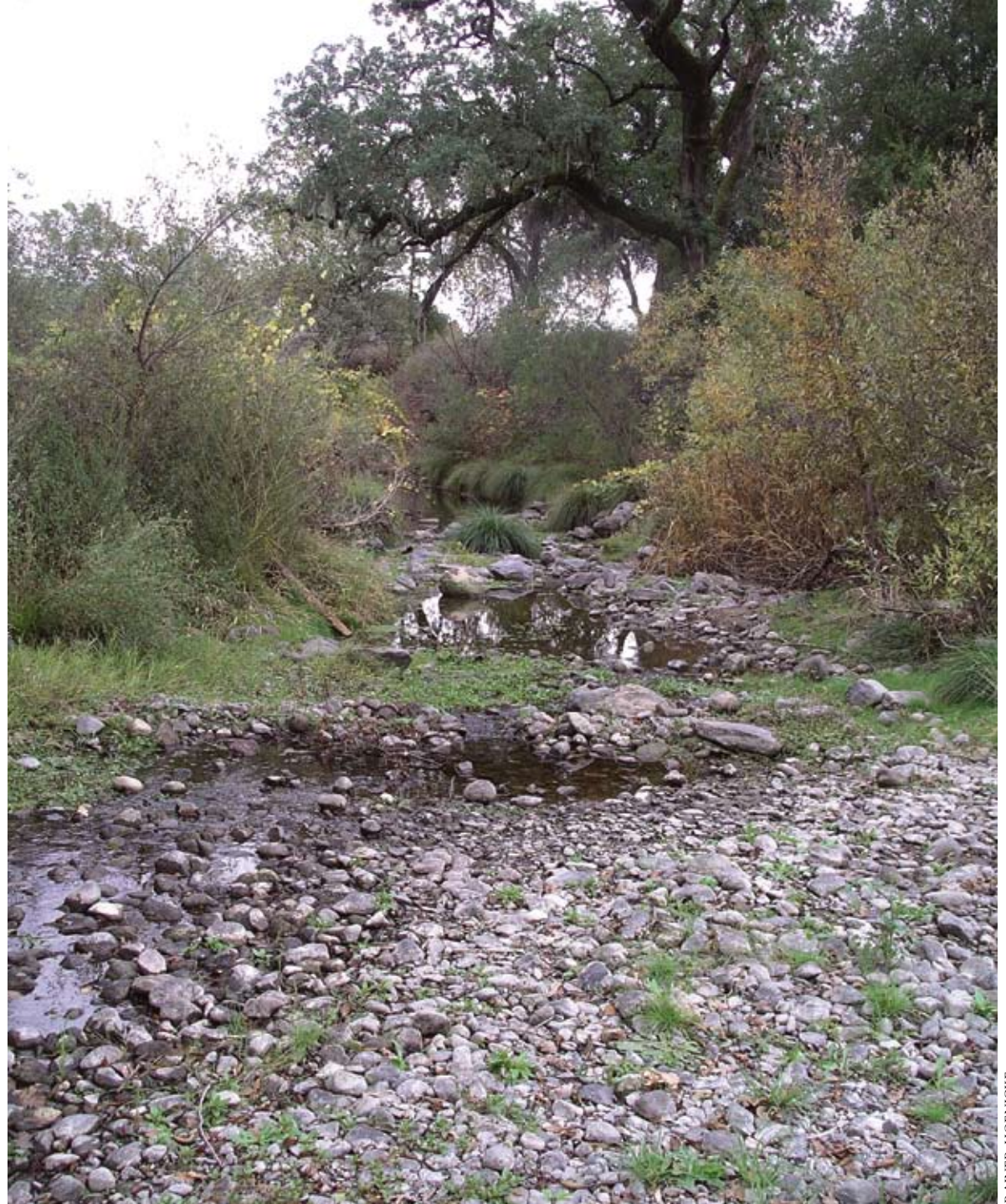


Habitats

The physical habitats of the Bay include tidal marshes and tidal flats—baylands, estuarine open water, managed ponds, subtidal habitat, and the local watersheds that drain to the Bay. The health of these habitats is assessed in the following sections. Subtidal habitat—the submerged area beneath the water surface of the Bay—is another very important type of habitat in the Estuary, but it is not evaluated in this report since a major analysis of this habitat was completed in December 2010. For more information see www.sfbaysubtidal.org.

Estuarine open water

The mixing of fresh water from rivers and saltwater from the ocean creates important open water habitat unique to estuaries. In the Bay, most of this brackish (or low salinity) habitat is formed by freshwater inflow from the Sacramento and San Joaquin rivers. The amount of inflow determines where in the Bay fresh and salt water first mix, a location known in scientific shorthand as “X2”, the place where the salinity of the water near the bottom is two parts per thousand (about six percent of the saltiness



RAINER HOENICKE

of seawater), measured in kilometers from the Golden Gate.¹³ When inflows are high, brackish water habitat is found farther downstream, closer to the Golden Gate, than when inflows are low. Because of the Bay's shape, the location of X2—whether in the wide open reaches of Suisun Bay or in the narrow channels where the Sacramento and San Joaquin Rivers enter the Bay—determines the amount (or area) of this important habitat. For a number of Bay fish and invertebrate species, each 10-kilometer upstream shift in X2 during the spring corresponds to a two- to five-fold decrease in abundance or survival.



Map 3.

The benchmark for healthy estuarine open water habitat was defined as X2 (the place where salinity is two parts per thousand) located downstream of 65 kilometers from the Golden Gate—see dashed line above—for more than 100 days between February and June.

HEALTH INDICATORS

Freshwater inflow to the Bay varies dramatically from year to year, a function of California's Mediterranean climate and the natural occurrences of droughts and floods. However, since the 1940s, large dams on the Bay's major tributary rivers have captured and stored the majority

of their springtime flows in most years, with the result that less fresh water flows into the Bay (see also Freshwater Inflow Index). Reduced spring inflows produce more upstream locations of X2, reducing the quality and quantity of estuarine open water habitat and impacting the plants and animals that use it. The Estuarine Open Water Habitat indicator uses three measurements to assess the occurrence of high quality estuarine open water habitat in the Bay during the spring:

- frequency (how often?)
- magnitude (how much?) and
- duration (how long?)

BENCHMARKS

Current regulatory standards for freshwater flows into the Bay were designed to prevent extreme low inflows during the spring, but these minimum requirements still do not produce healthy estuarine conditions. Therefore, we developed a benchmark for evaluating estuarine open water habitat conditions based on the population and survival responses of many Bay fish and invertebrate species and defined high quality estuarine open water habitat as X2 located downstream of 65 kilometers (or X2 less than 65) for more than 100 days during the February through June period. Frequency was measured as the number of years in the past decade that this high quality habitat occurred. Magnitude was measured as the average springtime value for X2, and duration as the number of days in which X2 was downstream of 65 kilometers from February through June. Measured conditions that exceeded the benchmark were considered to indicate good conditions while those that were lower were considered to indicate fair or poor conditions.

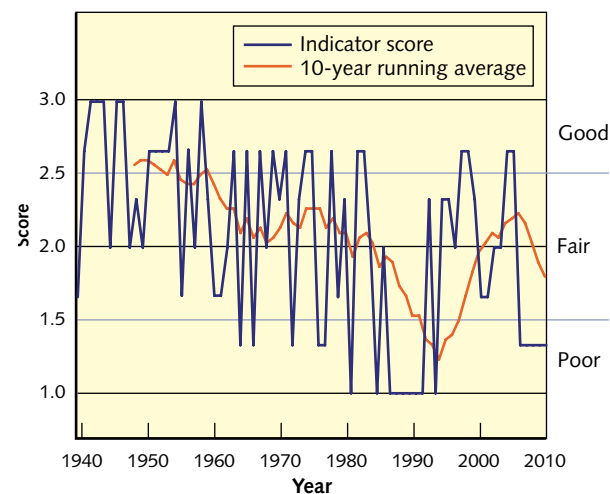
For each year, the Estuarine Open Water Habitat indicator was calculated by combining the results of the three measurements into a single score (1–3).

KEY RESULTS AND TRENDS

Results of this analysis reveal a steady decline in springtime estuarine open water habitat, from consistently good or fair conditions prior to the 1960s to mostly poor conditions by the 1990s (Figure 4).

Conditions improved during the late 1990s, during a sequence of unusually wet years but declined again in the 2000s. Declining habitat conditions were driven by reductions in all three component measurements of the indicator. In the 1940s and 1950s, high quality open

Figure 4. The quality and quantity of low salinity, open water habitat in the San Francisco Estuary in the spring has declined during the past 50 years.

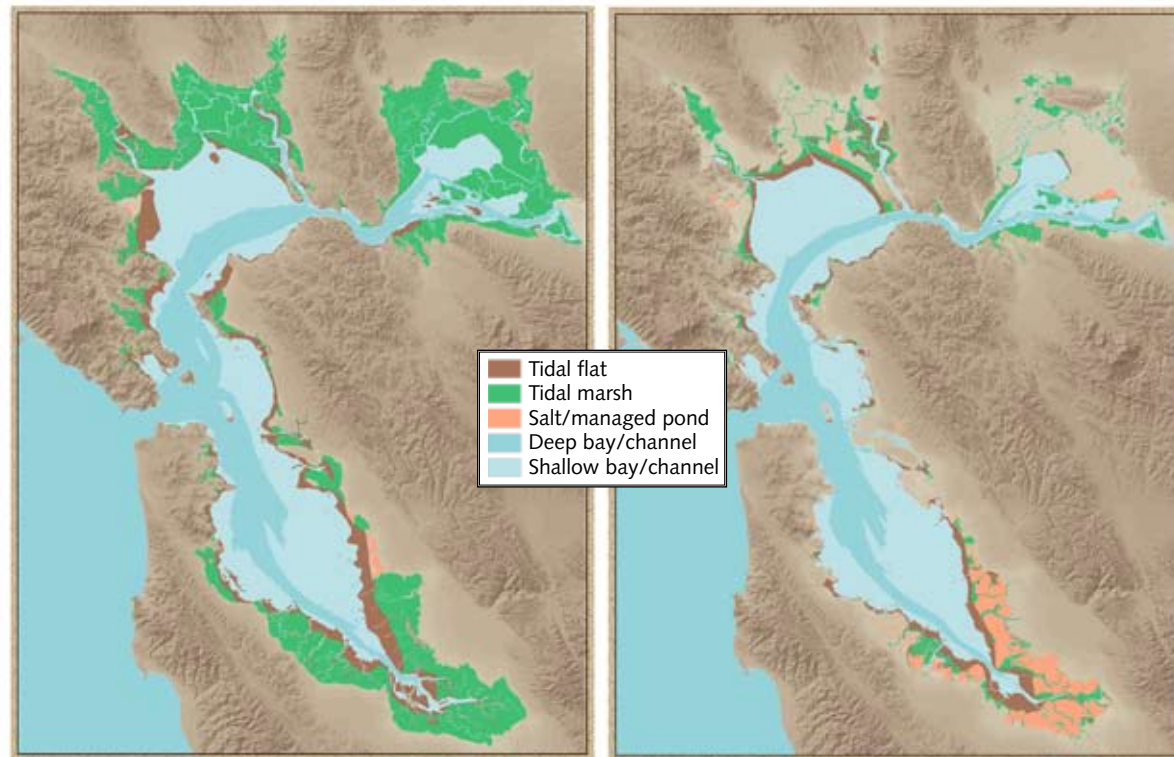


water habitat occurred on average in 70 percent of years. By the last decade, it occurred in just 37 percent of years, with the average location of springtime X2 shifting upstream nearly 7 kilometers. The number of days with good habitat conditions during the spring has declined by two thirds, from an average of 100 days per year in the 1940s and 1950s to just 43 days per year in the most recent decade.

■ SUMMARY

Reduced quantity and quality of springtime estuarine open water habitat impairs the health of the Bay. The availability of this habitat is closely linked to the abundance and survival of many of the Bay's native fish and shrimp species (see also the Fish Index, Living Resources section). This seasonal estuarine habitat is also often associated with (and created by) high flow "flood events," an ecological process that transports nutrients to the Bay, promotes productivity, and improves food availability for Bay fish and wildlife (see the Flood Events Index, Ecological Processes section). The connection of this habitat attribute with both ecological processes and living resources underscores the importance of acting to improve freshwater inflow conditions during the spring if we are to achieve the CCMP goals of increasing freshwater availability to the Estuary and restoring healthy estuarine habitat.

Figure 5. Historical (ca 1800 on left) and present-day (2009) baylands.



Tidal marshes and flats

Baylands are the tidal flats and marshes subject to regular inundation by the Bay's tides, plus the lowlands around the Bay that would be tidal if not for levees, dikes, tide gates, and other water control structures. Whereas tidal marshes support abundant vegetation, tidal flats are intertidal areas that lack rooted vegetation. Tidal flats and tidal marshes form in relatively calm areas along the margins of the Bay where fine sediments carried by the Bay currents and waves tend to accumulate.

Baylands have many important ecological and hydrological functions that contribute to the

health of the Bay. The healthiest flats support dense colonies of shellfish and other invertebrates that serve as food for fish, birds, and other wildlife. Tidal marshes support many species of Bay fishes and water birds, while serving as water quality filters, trapping fine sediment and breaking down some of the contaminants that enter the Bay from local watersheds. Storage of fine sediment in tidal marshes helps reduce the need for expensive dredging in ports, marinas, and shipping channels.

Since the Gold Rush era there has been a dramatic decline in the amount of tidal baylands (Figure 5) as dikes and levees were constructed to separate tidal baylands from the waters of the Bay.



A diked marsh used for hay farming

These diked baylands were drained and converted to agricultural, industrial, or urban uses. Although undeveloped diked baylands do provide a variety of important wildlife habitats, the significant historical loss of tidal marsh and tidal flats has caused the health of the Bay to deteriorate.

■ HEALTH INDICATORS

Since baylands provide important ecological and hydrological functions, indicators of their condition can help assess the overall health of the Bay. Specifically, baylands are evaluated here by assessing:

- regional extent
- parcel size
- physical/biological condition

The extent of tidal flats and marshes matters because the ecological and hydrological benefits they provide increase as extent increases. The size of existing bayland parcels matters because when larger areas are fragmented into smaller ones, their value as wildlife habitat tends to decrease—few very large parcels close together are better

for Bay wildlife than many small parcels farther apart. Lastly, measuring the condition of baylands helps assess how well they are providing their intrinsic ecological and hydrological functions.

BENCHMARKS

REGIONAL EXTENT

In the late 1990s a science-based public process identified a long-range goal of establishing 100,000 acres of tidal marshes in the Bay, or about 50 percent of the acreage of tidal marsh that existed historically. This process culminated in the 1999 *Baylands Ecosystem Habitat Goals* report. Here we assess progress toward that goal by evaluating the current extent of tidal marshes in the Bay.

No quantitative goal exists for tidal flats, so we derived a benchmark from the 1993 California Wetlands Conservation Policy. That policy calls for “no net loss” and a net overall gain in the state’s wetlands, which implies that the number of acres of tidal flat that existed in 1993 is the minimum acceptable amount.¹⁴ The 1993 figure represents a little more than 50% of the tidal flat that existed historically, making this bench-

mark consistent with the tidal marsh goal of 100,000 acres.

PARCEL SIZE

To evaluate bayland size, we compared historical and present-day distributions among six different size categories.¹⁵ We developed a benchmark for both tidal marsh and tidal flat size by assuming that the historical distribution of bayland parcel size is an appropriate measure today for a healthy Bay (*i.e.*, the relative abundance of different sizes of bayland parcels should be the same as historical, even if the total area they cover is less).¹⁶ Given this assumption, we set the benchmark for parcel size of baylands as the percent similarity between their historical and present-day distribution among size categories ($\pm 25\%$ due to the range of sizes in each category).¹⁷

PHYSICAL/BIOLOGICAL CONDITION

There are no regional data for setting a benchmark for tidal flat condition. The few existing data only represent a handful of points scattered around the Bay.¹⁸ Tidal flats are an under-studied component of the Bay ecosystem. Their ecological importance for migratory shorebirds and other wildlife warrants a comprehensive approach to assessing their condition. The condition of tidal marshes has recently been comprehensively surveyed using the California Rapid Assessment Method (CRAM). This standardized method has been widely used to assess California wetlands and wadeable streams. Because goals for tidal marsh condition have yet to be established, we set the benchmark for marsh condition in the Bay by comparing their CRAM score for *physical structure* (one of the four CRAM attributes—see description, page 29) to that for the less impacted marshes along the North Coast of California.

■ KEY RESULTS AND TRENDS

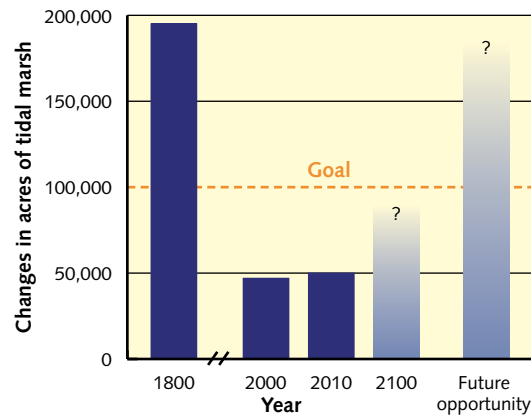
REGIONAL EXTENT

Our evaluation indicates that the region is half-way to the established goal of 100,000 acres of tidal marsh (Figure 6).

For tidal flats, the existing acreage is 10 percent less than the 30,000-acre benchmark adopted for this report (Figure 7).

Over the last decade, tidal marsh habitat in the Bay has gradually increased. Based on the marsh restoration projects now funded or likely to be funded in the foreseeable future, the total acreage of marshland will increase but is not likely to meet the acreage goal for 2100.

Figure 6. Change in acres of tidal marsh from 1800 to present, plus forecasts of future acreage due to anticipated restoration (year 2100) and combinations of restoration and sea level rise (Future Opportunity). The South Bay Salt Pond Restoration Project represents about 20 percent of the expected gains in tidal marsh acres by 2100. Sea level rise creates uncertainties about the survivability of existing and restored marshes.



WHAT IS CRAM?*

CRAM is a rapid health check-up tool for wetlands and wadeable streams (www.cramwetland.org). Two or more trained practitioners can use CRAM in the field over a period of 1-3 hours to score a wetland or stream based on a standard set of visual health indicators.

Habitats with good scores are likely to provide high levels of ecological and hydrological functions, based on the habitat type, location within its watershed, and its surrounding landscape. CRAM is part of a comprehensive monitoring plan in three levels:

- Level 1 (landscape assessment) uses aerial photography and other remote sensing data to inventory wetlands and streams.
- Level 2 (rapid assessment) uses visible field indicators of condition in the field to assess the overall health of wetlands and streams. CRAM is an example of a Level 2 assessment method.
- Level 3 (intensive assessment) uses quantitative methods in the field to measure particular aspects of wetland or stream health, and to understand the causes of health conditions. Counts of fish, birds, and plants are examples of Level 3 data.

There are different versions of CRAM for different kinds of wetlands and streams. All the versions are based on the same basic method. CRAM produces a site score that ranges up to 100 (100% of good health based on statewide surveys). The site score is the average of 4 attribute scores; each attribute score is the sum of 3-4 metric scores. The metric scores and attribute scores can be used to identify ways to improve the site scores. All the scores are maintained in a statewide database (www.cramwetland.org).

How is CRAM Being Used?

CRAM is being used to help assess wetland and stream projects, and to assess the average condition of streams and wetlands for watersheds, regions, and statewide. Over time, CRAM will help land managers and scientists understand how projects can be planned to maximize their benefits to people and ecosystems.

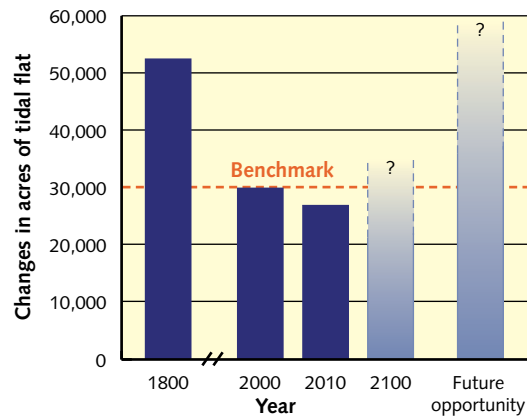
*Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas (website). www.cramwetlands.org

ATTRIBUTES		METRICS
Buffer and Landscape Context		Landscape Connectivity Percent of Assessment Area with Buffer Average Buffer Width Buffer Condition
Hydrology		Water Source Channel Stability Hydrologic Connectivity
Structure	Physical	Structural Patch Richness Topographic Complexity
	Biological	Number of Plant Layers Present Number of Co-dominant Species Percent Invasion Horizontal Interspersion and Zonation Vertical Biotic Structure

For tidal flats, the existing acreage is a little less than the 30,000-acre benchmark developed for this report (Figure 7). Since 1993, some tidal flats have been diked, dredged, or eroded by Bay currents and waves, or colonized by marsh vegetation. Some new flats have formed in the early stages of marsh restoration projects. Both seasonal and annual variations in the amount of tidal flat have been observed in some locations, but there has been a slight net decrease in the overall acreage of tidal flat since 1993.

Scientists are uncertain about the future extent of tidal flats and marshes in the Bay. We expect that sea level rise associated with climate change will cause the Bay to rise faster than it has since the oldest flats and marshes were formed. This deeper Bay might generate stronger currents and waves that prevent fine sediment from being deposited at the Bay's edges—a prerequisite for plant colonization. We also expect that there is

Figure 7. Change in acres of tidal flat from 1800 to present, plus forecasts of future acreage due to anticipated restoration (year 2100) and combinations of restoration and sea level rise (Future Opportunity). Sea level rise creates uncertainties about the survivability of existing and restored flats.



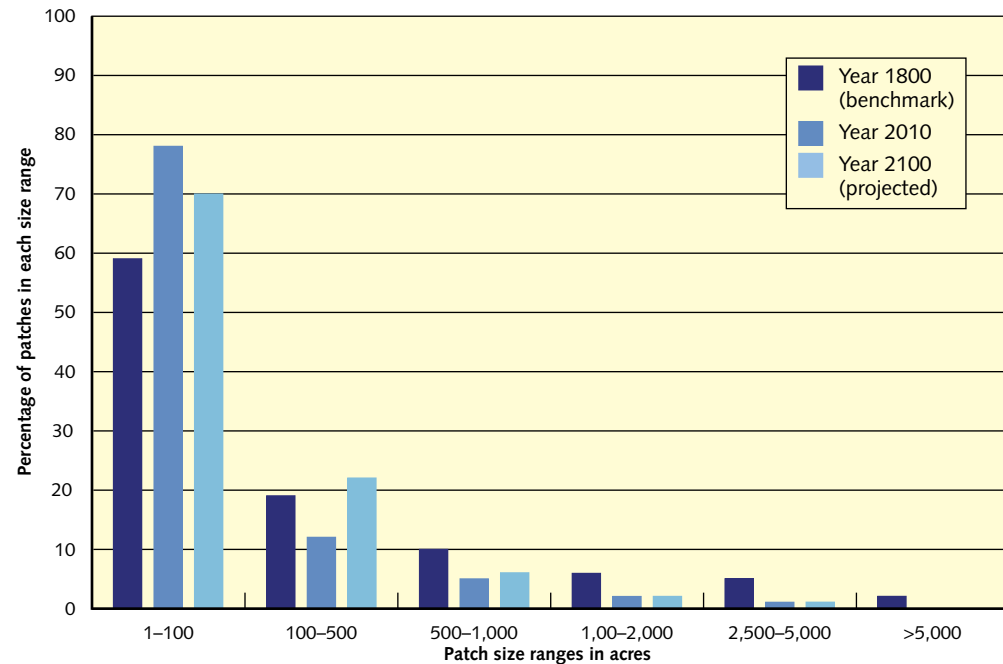
less sediment coming into the Bay for the tides to deposit onto the marshes—less of the fine silts and clays that marshes need to build upwards as the Bay rises. Plants help build marshes by adding debris and roots. Whether or not sedimentation and plant growth will keep up with the rising Bay is not known. Studies are being conducted to help forecast the effects of climate change, including that of the rising Bay on tidal marshes. However, even with a rapidly rising Bay, some new marshes can result from allowing the tides to return to suitable diked baylands and uplands. Such efforts, in addition to the marsh restoration projects that are already being planned, could help us meet the goal of 100,000 acres of tidal marsh.

PARCEL SIZE

Our benchmark for tidal marsh size (± 25 percent) is only being met for two of the six size categories. We are meeting our benchmark for the two smallest sizes, and farthest from our benchmark for the largest size category (Figure 8). While critically important restoration efforts are now underway at several large sites around the bay, they will not restore continuous marshes in the two larger categories (see [Technical Appendix](#) for more information).

In general, the proportion of small marshes has increased, and the proportion of large marshes has decreased. None of the existing marshes are nearly as large as the largest historical marshes.

Figure 8. Historical (ca 1800), present-day (ca 2010), and plausible future (ca 2100) distribution of tidal marsh patches among size classes ranging from less than 100 acres to more than 5,000 acres.



BLACK RAIL NEEDS SHALLOW WATER, STEPPING STONE WETLANDS TO CONNECT TO MARSHES

The secretive, seldom-seen, marsh-dwelling black rail—often described as a “chunky robin”—may find itself in trouble as sea level rises and also because the Bay’s marshes have become so fragmented. The threatened rail, with its stubby legs, needs very shallow water—less than 1.2 inches—and wetlands that are connected to one another, possibly by smaller, “stepping stone” wetlands, says UC Berkeley’s Steve Beissinger, who has been studying rail populations around the Bay and in the Sierra foothills in the hope that science can help inform conservation strategies for this threatened species as the climate changes and Bay waters rise.

In a poster at the 2010 Bay–Delta science conference, Beissinger described his recent research finding a genetic link between black rails in wetlands in the Sierra foothills and San Francisco Bay—a surprise since rails are thought to be poor fliers, making it difficult for them to disperse long distances. “The study is preliminary, and we’re just opening the book here, but the genetic connectivity we found going on between the foothills and the Bay was surprising—we didn’t expect that. It looks to be recent, within the lifetime of the birds we captured,” says Beissinger. In other



STEVE BEISSINGER

words, at least one individual must have interbred with one from the population around the Bay, probably a foothills rail visiting the Bay. “They must be finding some sites where they can stop over—maybe the Yolo Bypass? That’s the paradox of rails—they don’t appear to be very good flyers; they’re walking around under the vegetation all the time. They fly like butterflies; they wobble around and try to go right down into the vegetation.” Yet rails have somehow reached islands in the middle of oceans, so “they got there somehow,” says Beissinger.

The foothills population was discovered 15 years ago by Beissinger’s colleague, Jerry Tecklin, when he found rails at the Berkeley research station and then started poking around on state-owned land and private ranches (with owner permission). Tecklin found rails in natural, spring-fed wetlands throughout the foothills in the oak woodland belt through which Bay-feeding streams flow. But he also found them in small wetlands that had been created accidentally. “There’s a fair amount of water held back for irrigation purposes,” says Beissinger. “And the rails have benefited from that.” The wetlands are typically found a little above the valley floor up to about 2,000 feet above sea level, says Beissinger, in Placer, Yolo, Butte, and Nevada counties.

Beissinger and colleagues’ genetics analyses revealed another surprise. “It suggests that the interchange of individuals within the Bay is less frequent than in the foothills—that the sites around the Bay, even though they are larger wetlands, are more isolated from each other. What we’ve learned from our foothill rails studies is that the more isolated the wetlands, the less likely they are to be colonized.” Beissinger says the genetics also show that the foothill population may have existed historically.

For now, he hopes to get more genetic material from Bay rails and to expand his study to the South Bay. He and his doctoral student Laurie Hall are also planning to analyze the DNA of museum specimens in to better understand rail gene flow around the Bay prior to the large-scale landscape changes that occurred with development. “That will give us clues as to the original population size as well as whether genetic diversity has been lost with all of the changes to the Bay’s wetlands over the past century.”

Possibly most urgently, the studies will help resource managers plan for sea level rise. “As sea level rises, distances between wetland sites in the Bay will likely increase and they will become more isolated and reduced in sized. We want to get a better handle on the dispersal ability of these rails so we can look at the role of different configurations of sites. As certain places are restored in the Bay, it will be very useful to think about creating shallow water areas that don’t get inundated.” This could mean possibly creating “stepping stone” wetlands both within the Bay and east of the Delta, for example. The Department of Fish and Game has already created artificial marshes for the rails in some state game management lands in the Sierra foothills that have been very successful, says Beissinger. Whatever happens, rails will feel the squeeze at both ends—around the Bay with its rising waters, and in the foothills, one of the fastest growing regions in the state. “It’s possible that they will survive sea level rise in the Bay by distributing themselves further inland,” says Beissinger. “It may be that they can get around better than we had been thinking. But there is also a need to better plan for the location and connectivity of the sites we are restoring.”

A slightly different version of this article first appeared in ESTUARY NEWS, December 2010.

The average size of marshes within each size category has become smaller over time. This decrease, along with the absence of marshes in the largest size class, indicates continuing marsh fragmentation.

Unlike tidal marshes, tidal flats meet the benchmark (± 25 percent) for each size category, as they haven't changed significantly from their historic distribution. We expect that the proportion of flats in the smaller size classes will fluctuate as areas restored to tidal action evolve from tidal flats to tidal marshes.

PHYSICAL/BIOLOGICAL CONDITION

Based on the regional survey of tidal marsh condition using CRAM, the median overall score for marshes in the Bay is 78 on a scale of 100. This is lower than the overall score for North Coast marshes, mainly because Bay marshes tend to have lower scores for physical structure (Table 5). Using the CRAM *physical structure* median score for North Coast marshes as a benchmark for evaluating Bay marshes, the condition of Bay marshes is about 65 percent of the benchmark.¹⁹

Table 5. Median (50th percentile) scores for tidal marsh condition in different regions of the coast, based on the California Rapid Assessment Method (CRAM).

COASTAL REGION	MEDIAN CRAM SCORE physical structure
SOUTH COAST	59
CENTRAL COAST	57
SF BAY	56
NORTH COAST	86

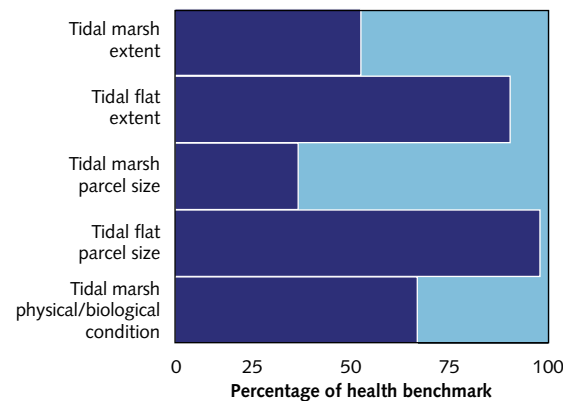
The lack of physical complexity in Bay marshes probably relates to their relatively young age. Few of the ancient marshes that are physically and ecologically complex have survived the land use changes since the Gold Rush. Completed restoration projects around the Bay are generally not old enough to have developed the natural complexity that characterizes ancient marshes.

SUMMARY

If we regard the tidal marsh and tidal flat indicators to be equally important and plot them together for the region as a whole, the overall health status of baylands is about 65 percent of excellent health (the dark blue area of Figure 9). If we exclude tidal flats from this analysis we find that the overall health status of tidal marshes is about 49 percent. Based on these few indicators, tidal marshes are not as healthy as tidal flats.

To reach the health goals for tidal baylands we will need to restore physically complex parcels of

Figure 9. Assessment of the health status of tidal baylands. Based on all five indicators, the overall health of the tidal baylands has a score of 65 on a scale of 100 (65 percent of the graph is dark blue).



tidal marsh that are larger than the projects currently planned. This means that tidal marsh restoration projects should be adjacent to or located very near one other, and they should be designed to develop the natural drainage networks, levees, pannes, and other features that contribute to physical complexity. Ancient, high-elevation marshes such as those at China Camp and the Petaluma River provide models for future restoration projects.

The increasing rate of sea level rise due to climate change will be a challenge and an opportunity for tidal baylands. The main challenge will be to maintain sufficient flats and marshes so they can serve their critically important roles for water quality, navigation, habitat, recreation, and aesthetics. Meeting this challenge may involve accepting the conversion of high marshland to low marshland, which means lowering our expectations for the physical complexity of Bay marshes. We may also need to nurture the continued evolution of marshes and flats by increasing the availability of sediment from local watersheds that is essential for sustaining tidal baylands—e.g., by re-using sediment from flood control projects or by restoring appropriate creek hydrologic functions—and by adding structures to tidal flats that reduce the ability of Bay waves to erode marsh shorelines.

Remaining undeveloped lands around the Bay could in time become healthy tidal baylands through careful planning and designs that accommodate sea level rise. Both the challenges and opportunities involved in such a process highlight the need to consider tidal baylands—marshes and mudflats—as integral parts of local watersheds.

Watersheds

A watershed is defined as all the lands and waters that drain to a common place.²⁰ Everyone lives in a watershed, and healthy watersheds are essential for the well-being of people. They are the primary source of fresh water, which can be captured by dams or extracted from groundwater. Watersheds are also managed to assure adequate flood control, pollution control, wildlife protection, and recreation. Yet some of these management actions can degrade watersheds and streams. For example, riprapping of stream and river banks for flood or erosion control purposes can destroy habitat and cause erosion upstream and downstream. If not managed properly, recreational activities—off-road vehicles, dog walking, mountain biking, to name a few—can also degrade stream habitat. But the biggest problem related to watershed health is urbanization. As our cities have grown and we have paved over the landscape, many watersheds have lost their permeability and resilience. During the rain, pollutants now race across a landscape of concrete and asphalt and straight into our rivers and streams. As a result of all of these activities, over 40 streams in the Bay watershed are now listed as “impaired” under the Clean Water Act.

■ HEALTH INDICATORS

While many possible watershed health indicators exist, the data required to analyze them are not available for most of the Bay’s watershed areas. The State Water Resources Control Board is proposing that the three-level assessment framework described earlier (see Mudflats and marshes) should be used to characterize the

STORMWATER SOLUTIONS: PERMEABLE PLAZA

In downtown San Francisco, a former derelict alley has been transformed into a popular pedestrian plaza that removes as much as a half million gallons of stormwater runoff per year from the city’s sometimes overwhelmed combined sewer/stormwater system. The project designers divided the plaza—just off of Fifth Street between Market and Mission—into three “mini” watersheds, explains CMG Landscape Architecture’s Scott Cataffa. Two of the “watersheds” flow into and through stormwater planters at either end of the plaza; one flows into an almost invisible slot drain. From there the stormwater goes into an underground infiltration basin, where it slowly percolates into the native soil, which is sand and rubble from the 1906 quake, according to Sherwood Design’s Bry Sarte. The new plaza, funded by a special tax assessment district facilitated by the Association of Bay Area Governments in which local businesses agree to increase their property taxes over the next 30 years, has spurred redevelopment all around it. Historic warehouses have been converted to condos, high-end coffee shops, and restaurants, while the plaza, in addition to treating stormwater, hosts concerts, farmers’ markets, and dance performances.

“It’s a win-win-win,” says the city’s Michael Yarne, who spearheaded the project while working for Martin Development Company. “The city got a beautiful public space for pretty much nothing, and the designers used an urban landscape to recreate some of the functionality of the original natural landscape.” According to Yarne, the San Francisco PUC chipped in \$150,000 from its depaving fund; that contribution plus \$200,000

from a local hotel seeking an open space mitigation site downtown, helped offset the \$3.2 million total cost. The project won the EPA’s 2010 National Award for Smart Growth Achievement, Civic Places category. In an interesting twist of fate, the Old Mint, a Greek Revival building built in 1874, survived the big quake because rainwater had been captured in underground cisterns. Today the plaza “harvests” rainwater in a different way, says Sarte, by putting it back into the ground, helping avoid sewage overflows into San Francisco Bay.

A slightly different version of this article first appeared in ESTUARY NEWS, June 2011.



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health of watersheds. The assessments would be based on the extent of aquatic habitats, their overall condition (CRAM or another Level 2 method), and the condition of particular aspects of health, such as contamination, flood control, and biological community integrity. This is the approach used here. Currently there are regional data on habitat extent, but the data for overall condition and biological integrity are restricted to a few watersheds. We evaluated the health of two large Bay Area watersheds, Coyote Creek in Santa Clara County and the Napa River in Napa County, as an example of Bay Area watershed

health. Three indicators of watershed health were assessed:

- width of riparian areas
- stream habitat condition
- stream biological integrity

WIDTH OF RIPARIAN AREAS

Riparian areas connect aquatic areas with their adjacent uplands. Healthy riparian areas transport surface and subsurface flows of water and other materials, maintain stream water quality, shade aquatic habitat, stabilize shorelines, store flood

waters, and provide other ecological and physical functions depending on topography and vegetative structure. These beneficial functions are affected by the width of riparian areas.

BENCHMARK

The current riparian width assessment adopts a benchmark similar to that used for tidal marsh patch size by using historical condition as a reference.²¹ According to this benchmark, riparian areas should be distributed among categories of width according to their historical distributions. This benchmark assumes that this historical distribution protects beneficial uses of watersheds. Each width category has its own benchmark (based on the historical distribution of widths), and riparian width is assessed as the percentage of these benchmarks that are being met. Given the range of widths in each width class, a 25 percent departure from the benchmarks was still considered to meet the benchmark.

STREAM HABITAT CONDITION

Streams are an important feature of our Bay Area watersheds, and the ability of stream habitat to support the invertebrates, fish, and wildlife that live in and use stream channels and riparian areas is considered by regulatory agencies to be a “beneficial use.”

CRAM provides a cost-effective measure of stream health consistent with the state’s proposed framework. CRAM was used in 2008 and 2010 to assess the health of wadeable streams in the Bay Area, and the survey results are used here to evaluate the health of Coyote Creek and the Napa River.

BENCHMARK

No goal for stream health has been set, and there are no historical data suitable for inferring a goal based on existing policies. Examination of the regional CRAM data revealed that many of the low scores were due to a lack of physical structure. This finding is similar to that for tidal marshes. The low physical structure scores are mainly due to a lack of natural floodplains. Based on this finding, a benchmark for stream health was set as 75 percent of the physical structure score for the highest scoring streams in the region.

STREAM BIOLOGICAL INTEGRITY

Benthic macroinvertebrates are aquatic insects

and other non-vertebrate organisms that live in streams. The biological integrity of a stream can be assessed using the Benthic Macroinvertebrate Index (BMI) as excellent, good, fair, or poor, based on the degree of difference between its benthic community and that of reference streams.

BENCHMARK

No regional goal for stream biological integrity has been set. However, a reasonable assumption is that the goal should reflect an increase in the relative abundance of streams in excellent or good health, based on the BMI. In this report we established a benchmark for biological integrity by assuming that at least 75 percent of the stream assessments for all watersheds should be ranked as having either excellent or good health.

KEY RESULTS AND TRENDS

Our evaluation of stream riparian width in the two example watersheds indicates that their riparian areas have narrowed substantially relative to historical conditions, despite a net increase in their overall length (Figures 10 and 11).

The narrowing is due to two main causes: riparian areas have been encroached upon by agriculture and other land uses, and in places, converted into ditches with only narrow fringes of riparian vegetation. The narrowed riparian widths mean that these streams cannot provide their intrinsic ecological and hydrological functions and cannot be considered healthy. Two of the five categories of riparian width represent the same proportion of the stream ecosystem as

Figure 10. Distribution of riparian area widths for Coyote Creek, Santa Clara County.

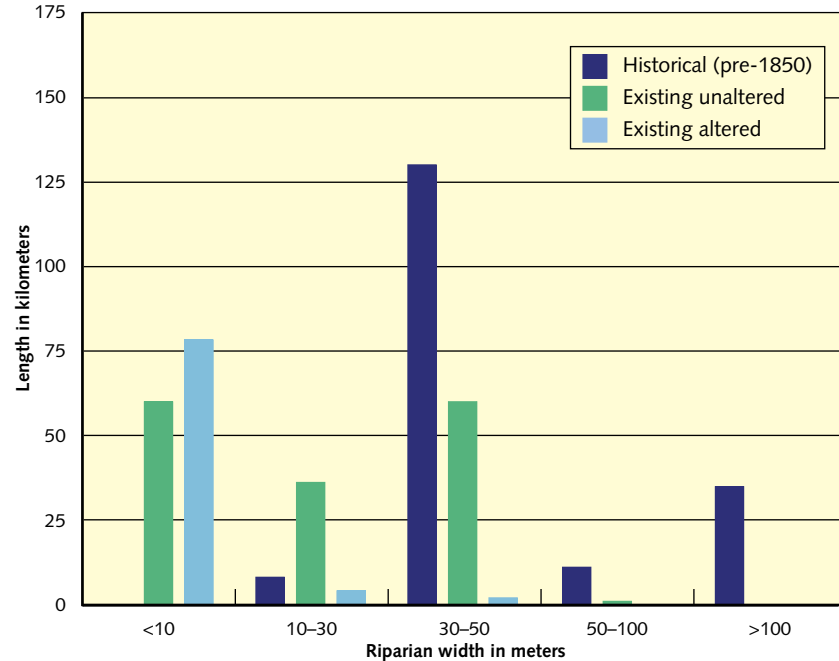
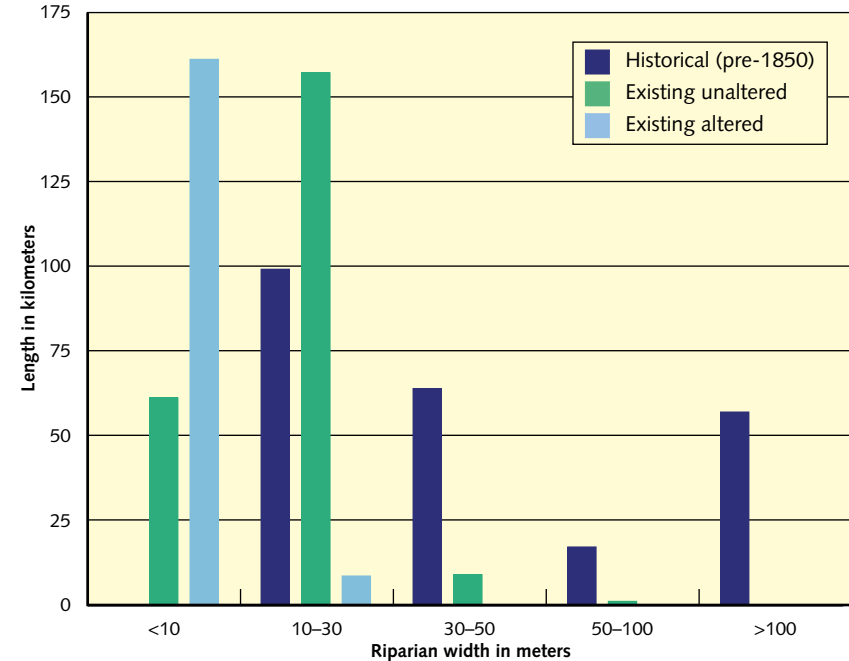


Figure 11. Distribution of riparian area widths for Napa River, Napa County.





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Soil bioengineering—using plants and plant parts to stabilize creek banks—is an effective alternative to riprap and provides good riparian habitat.

they did historically. So we have reached 40 percent of the benchmark. However, these are the narrowest categories. These very narrow riparian areas provide fewer ecological and physical functions than the broader areas.

The average physical attribute CRAM score for the Coyote Creek and Napa River watersheds is 57, which is about 76 percent of the benchmark for this score (Table 6). A close examination of the CRAM survey results for these two stream networks indicates that low physical structure scores relate to stream entrenchment. Historical land use changes that

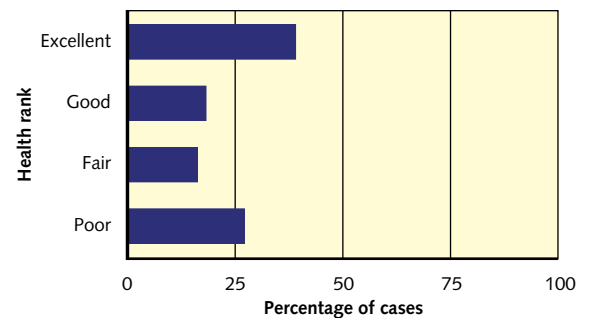
have increased runoff have caused the streams to cut down until their beds are far lower than their natural heights, relative to their valleys. This means that the channels lack floodplains and complex riparian plant communities. It also means that the streams contain higher, flashier flows that wash away woody debris and other structures that contribute to the physical complexity of the stream ecosystem. The streams are physically much less complex than they were under more natural conditions, which reduces their ability to provide many of their natural functions.

Table 6. Average scores for the four attributes of the California Rapid Assessment Method (CRAM) for the wadeable streams of the Coyote Creek and Napa River watersheds combined.

CRAM ATTRIBUTE	MEAN SCORE
LANDSCAPE AND BUFFER	81
HYDROLOGY	79
PHYSICAL STRUCTURE	57
BIOLOGICAL STRUCTURE	72

Only about 57 percent of the stream assessments in the Bay Area indicate either excellent or good condition (Figure 12), which is about 76 percent of the benchmark. The condition of Bay Area streams is a result of many interacting processes and events affecting water chemistry, temperature, light, aquatic vegetation, flow regimes, and sediment characteristics. Despite these compli-

Figure 12. Relative abundance of stream assessments indicating excellent, good, fair, or poor health based on the benthic macroinvertebrate index. Assessments ranked as either excellent or good represent 57 percent of the total number of assessments.



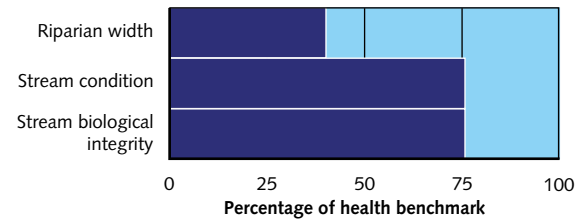
cations, a review of the regional distribution of assessments reveals a strong tendency for streams in the most urbanized settings to be in the poorest condition.

■ SUMMARY

We combined the watershed health indicators into a simple bar graph as a sample watershed health evaluation. Based on this approach, the status of these watersheds is about 64 percent of good health (Figure 13, dark blue area).

Achieving the health goals for our watersheds will require providing the streams with enough room to develop functional floodplains with wide and naturally complex riparian areas. This is especially challenging in urban and densely industrialized settings. Where adequate space is available, we recommend that stream restoration efforts focus on increasing the overall complexity of the stream ecosystem. This can involve

Figure 13. Assessment of the health status of Bay Area streams based on example watersheds. Based on all three indicators, the overall health of the streams is 64 on a scale of 100 (64% of the graph is dark blue).



creating channels with multiple floodplains at different heights that provide different functions. The highest floodplains that are designed to accommodate the larger and less frequent floods may be suitable for some land uses, especially agriculture and recreation. Riparian width can be increased in some areas by adding suitable vegetation along the banks and floodplains of

streams that run through urban and industrial landscapes.

The future health of our watersheds will depend on how we manage them as the climate changes. At this time, precise local effects of climate change on watersheds and streams are very difficult to forecast. Generally, we can expect to see more intense rainstorms and a shorter wet season. This will likely cause our watersheds to discharge larger amounts of water faster, which will increase the need for flood control (which itself can impact stream health as discussed above) and erosion control. The general solution will probably be to redesign our watersheds so that they retain more rainfall. This will require creative uses of groundwater recharge, flood water bypasses, local detention basins, floodplain and wetland restoration, and universal water conservation practices.

Living Resources

The Bay is important spawning, nursery and rearing habitat for a host of fishes and invertebrates, a migration corridor for anadromous fishes like salmon, steelhead, and sturgeon, and breeding and nesting habitat for waterfowl and shorebirds.

Invertebrates

The Bay is important habitat for several shrimp and crab species, including Bay shrimp, which once supported an extensive commercial fishery in the Bay, and Dungeness crab, an icon of San Francisco's Fisherman's Wharf. California's commercial crab fishery relies heavily on crabs that rear in the Bay, feeding and growing in the Bay's brackish waters and tidal marshes for the first year or two of their lives before migrating to the ocean to mature and breed.

■ HEALTH INDICATORS

Abundance and distribution of shrimp and crabs in the Bay are affected by environmental conditions both within the Bay and in the nearby ocean, and different species use different regions of the Bay. Estuarine species like the Bay



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shrimp, which prefers low salinity waters, are strongly influenced by the amounts and timing of freshwater inflows. Other species restricted to higher salinity habitats closer to the Golden Gate may be more affected by environmental conditions in the nearby ocean. While measures of shrimp and crab abundance, distribution, and species composition within the Bay can be useful biological indicators for the Bay's health, they must be interpreted carefully.

The condition of the Bay's shrimp and crab communities was assessed using several indicators. The simplest ones measure abundance—or, how many shrimp and crabs does the Bay support? For shrimp, this measurement is also made for the different regions of the Bay, from Central Bay near the Golden Gate (essentially a marine environment), to Suisun Bay, just downstream of the Sacramento and San Joaquin rivers.

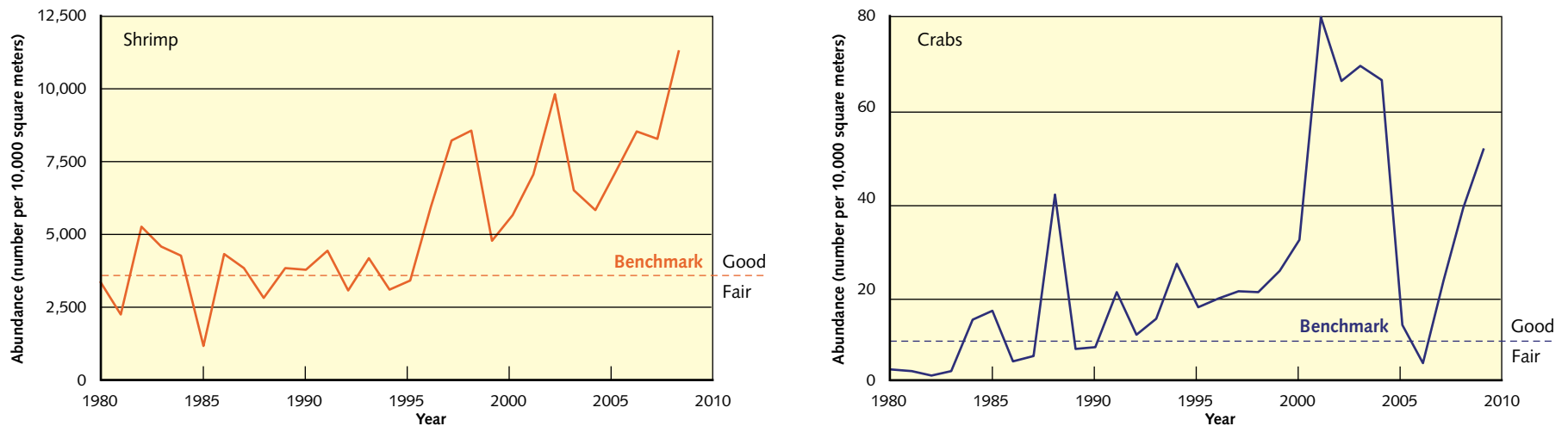
Another indicator for shrimp compares the abundance (how many?) and distribution (where are they?) of species that prefer low salinity waters to those that prefer saltier waters. The final two indicators measure the prevalence of non-native species in the shrimp and crab communities in the Bay.

BENCHMARK

There are no quantitative goals for shrimp and crab populations in the Bay. In addition, there is good evidence that abundance of many shrimp and crab species in the Bay is affected by environmental conditions in the ocean rather than the Bay. Therefore, high abundance of crab and shrimp does not necessarily indicate healthy environmental conditions in the Bay. However, to evaluate the measured values for the shrimp and crab abundance indicators, we

used the 1980–89 average levels, the earliest period for which comparable data were available, as the benchmark. For evaluation of the species composition indicators, the benchmark was set at 85 percent native species based on established ecological principles and the relationship between the presence of non-native species and community and ecosystem health (see [Technical Appendix at www.sfestuary.org](http://www.sfestuary.org) for additional information). Measured conditions that exceeded the benchmarks were interpreted to indicate good conditions while lower measurements were interpreted to indicate fair or poor conditions. As noted in the introductory section of the report, these benchmarks are references for comparison with measured values of the indicators, not recommendations for policy.

Figure 14. Abundance of shrimp and crabs has increased in the San Francisco Bay during the last 15 years.





■ KEY RESULTS AND TRENDS

The indicators show a shellfish community in good condition as the Bay supports larger numbers of shrimp and crabs than it did during the 1980s (Figure 14), and over 85 percent of those populations are native species.

However, for shrimp, increased abundance was driven by five to tenfold increases in the abundances of four shrimp species that prefer saltier waters and which, during the past three decades, have progressively extended their range into the upstream region of the Bay, particularly in years with low freshwater inflows. In contrast, abundance of the Bay shrimp, which lives in low salinity waters and is found most commonly in San Pablo and Suisun Bays, showed no increase and, in years with low freshwater inflows, was lower.

Regionally, shrimp abundance increased in all parts of the Bay except Suisun Bay. Increases in crab abundance reflected a sevenfold increase in rock crabs and periodic large increases in Dungeness crab numbers, most likely a response to improved ocean conditions rather than environmental conditions within the Bay.²² Two non-native shrimp species, which both prefer low salinity waters, are present in the Bay but their numbers are low and relatively stable at about two percent, another indication that conditions in the Bay are good for the native shrimp community. The Bay's crab community is similarly dominated by native species although, for a brief period during the late 1990s, the non-native Chinese mitten crab flourished, comprising 25 percent of the Bay's crab community in 1990.

■ SUMMARY

Based on the shrimp and crab indicators, the health of the San Francisco Bay has improved, but only for species that use the more saline regions of the Bay. While the CCMP goal of recovering and reversing the declines of these estuarine species has been met, the results illustrate the Bay's complexity and its close connections and interdependence with adjacent ecosystems.

Upstream, chronically low freshwater inflows degrade estuarine conditions (see Freshwater Inflow Index and Estuarine Open Water Habitat section), and species like Bay shrimp that rely on these habitats are, at best, holding steady. Downstream, variable ocean conditions influence marine species' reproductive success and seed the Bay's rich nursery habitats with diverse wildlife communities.

RETURN OF THE NATIVES

As shorebirds and waterfowl have begun using newly modified salt ponds in the South Bay, so have fish. The first year of monitoring by the UC Davis Fisheries Research Team led by Jim Hobbs detected a high diversity of fish species in the ponds, with a strong preponderance of natives.

Hobbs' team monitored fish populations in the Eden Landing, Alviso, Ravenswood, and Bair Island areas, including restoration ponds like Ravenswood's SF2 and flooded "island ponds" like Alviso's A19, A20, and A21 from July through December 2010. Shallow sloughs and intertidal creeks were also surveyed.

An impressive 98 percent of all fish caught by trawling the sloughs were native species. Of 30 species, three-spined sticklebacks accounted for more than half (1,678 of over 3,300) of the captures, followed in abundance by northern anchovy (549), topsmelt (392), staghorn sculpin (253), arrow goby (142), and longfin smelt (61). "That's comparable to the open

Bay," Hobbs explains. "Environmental conditions in the South Bay are a little saltier. Most invasive fish species are more freshwater tolerant, and are more common in the North Bay." The presence of small fish like sticklebacks and anchovies is good news for cormorants and other fish-eating birds.

The assemblage varied seasonally, with more sticklebacks, anchovies, sculpins, and gobies in summer and more smelt, herring, shad, and silversides in winter. "The anchovies came in late summer and fall and spawned," says Hobbs. The Pacific herring followed: "We're now seeing young herring all over the South Bay."

Hobbs also found that larger predators, notably leopard sharks and bat rays, are foraging at the outlets of the "island" ponds like A19. Like human anglers, the sharks wait for smaller fish exiting the ponds as the tide recedes. "We caught at least half a dozen sharks and rays per hour," he recalls.

One result that caught his attention was the relative abundance of longfin smelt (*Spirinchus thaleichthys*), a species involved in the Pelagic Organism Decline phenomenon: "Longfin smelt abundance has collapsed in the pelagic ecosystem of the North Bay and Delta. They had been intermittently collected in the South Bay during various surveys, but there hadn't been enough studies using appropriate gear this far up into the sloughs. We caught quite a few up Coyote Creek and in the island ponds. During late fall, they're coming back from the nearshore ocean and either turning right and going into the South Bay or left into the North Bay and Delta. I've looked at some of the data before and during the POD, and there's a correlation between their decline in the North Bay and increase in the South Bay. If they hang out until January and February in the South Bay, they're not likely moving into the North Bay to spawn."

Hobbs was also looking for a small unprepossessing goby called the longjaw mudsucker (*Gillichthys mirabilis*.) Although it currently has no conservation status, it's a sentinel species for the Bay's much-reduced pickleweed marsh habitat. "It's the only fish species that lives intertidally in these marshes," he says. "It's an important prey species. It used to be used heavily as bait, but stopped showing up in bait shops in the 1980s. We're trying to get an assessment of what its distribution formerly was like." In much of its intertidal habitat in the Bay, the mudsucker has been displaced by the non-native yellowfin goby.

Monitoring will continue on a monthly basis for the next four years. New approaches will include a mark/recapture study of mudsuckers to determine population size and mortality and an analysis of fish otoliths (ear bones) for heavy metal contaminants like mercury and copper. The researchers will also look at the distribution and abundance of zooplankton and benthic fauna like the overbite clam (*Corbula amurensis*).



JIM HOBBS

Fish

The San Francisco Bay is important habitat for more than 100 fish species, including commercially important Chinook salmon and Pacific herring, popular sport fishes like striped bass and sturgeon, and delicate Estuary-dependent species like Delta smelt. Environmental conditions in the Bay—the amounts and timing of freshwater inflows, the extent of rich tidal marsh and brackish water habitats, ecological processes that drive productivity, and pollution—affect the numbers and types of fish the Bay can support. A large, diverse fish community distributed broadly throughout the Bay and dominated by native species is a good indicator of a healthy Estuary.

HEALTH INDICATORS

The Fish Index uses 10 indicators to assess the condition of the fish community within the Bay. Four of the indicators measure abundance (how many fish?), and two others measure the diversity of the fish community (how many species?). Another pair of indicators assesses the composition of the fish community (what kind of fish?) by measuring the percentage of fish that are native rather than invasive or introduced. The final two indicators examine the distribution of native fish within the Estuary (where are the fish?). Because the Bay is so large and its environmental conditions so different in different areas—for example, Central Bay near the Golden Gate is essentially a marine environment while Suisun Bay is dominated by freshwater inflows from the Sacramento and San Joaquin Rivers—each of the indicators and the index

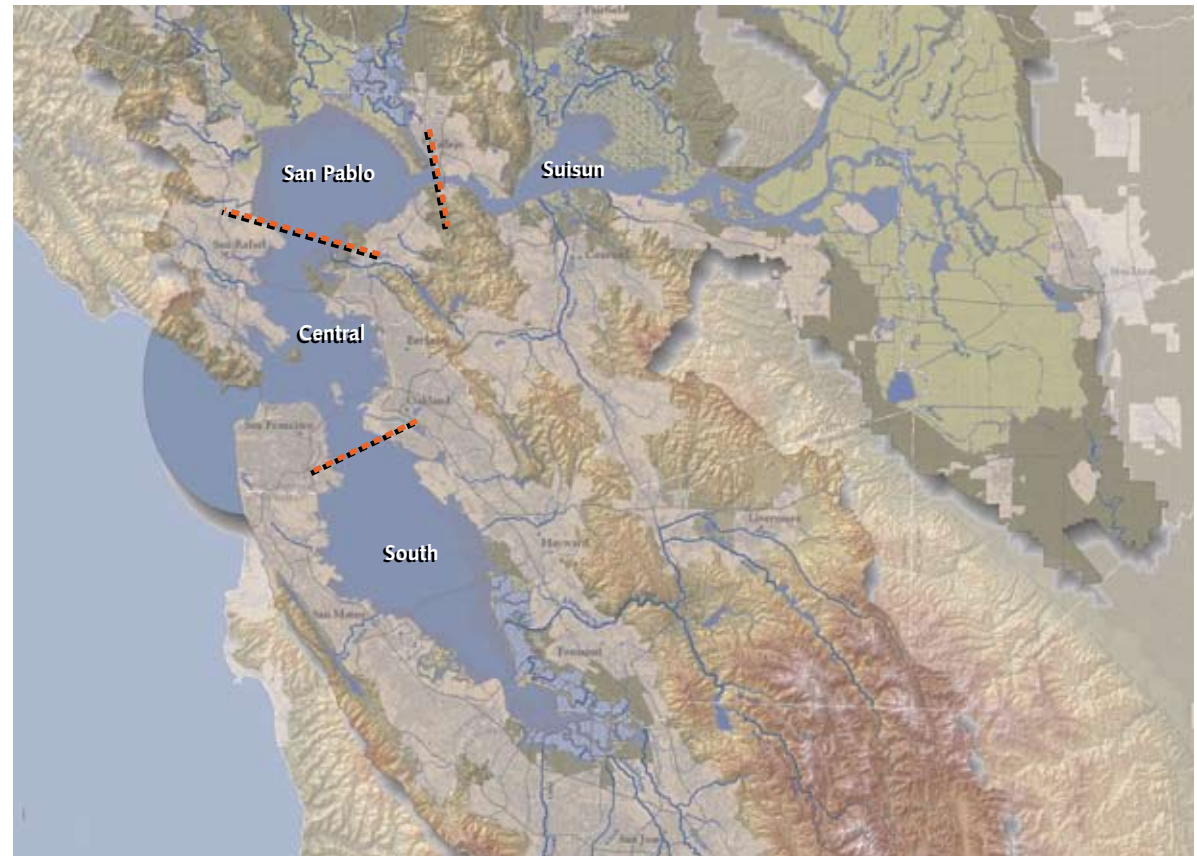
was calculated separately for four regions (Figure 15). For each year, the results of the 10 indicators were combined into a single score (0–4) to calculate the Fish Index.

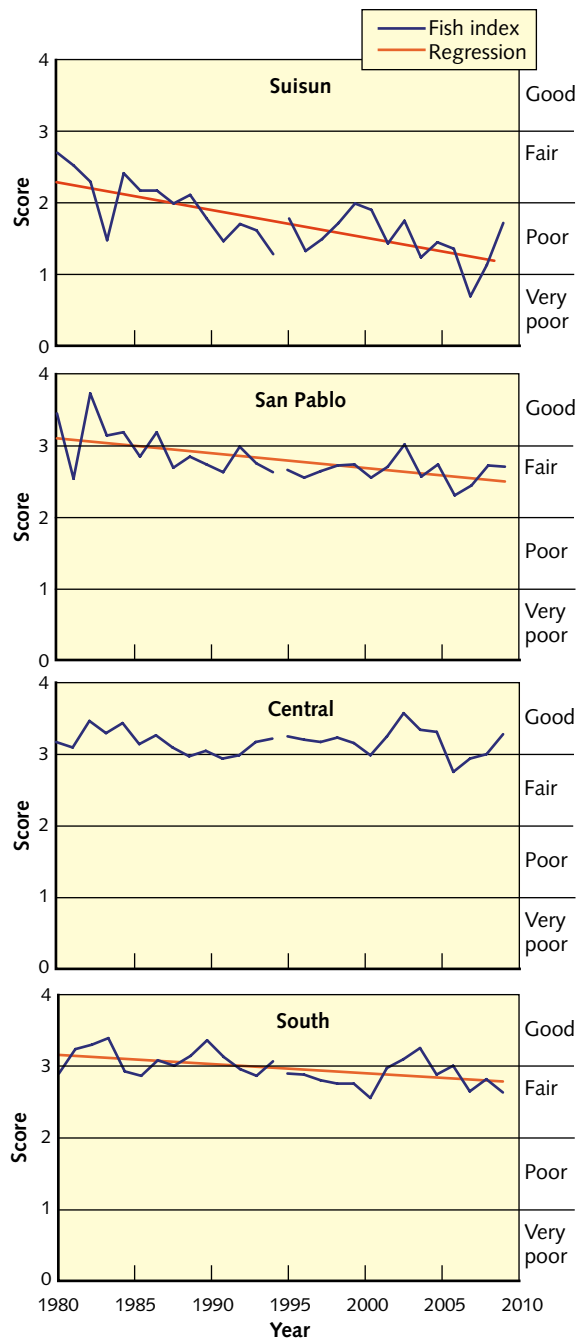
BENCHMARK

There are no established quantitative goals or standards for fish populations in the Bay. Therefore, for each indicator we established a bench-

mark based on either 1980–89 average levels, the earliest period for which comparable data were available, or established ecological principles such as the relationship between the presence of non-native species and community and ecosystem health. Measured conditions that exceeded the benchmark were interpreted to indicate good conditions while lower measurements were interpreted to indicate fair, poor, or very poor

Map 4. *Because San Francisco Bay is so large and its environmental conditions so different in different areas, the Fish Index was calculated separately for four regions: Suisun, San Pablo, Central, and South Bays.*





conditions. As noted in the introductory section of the report, these benchmarks are references for comparison with measured values of the indicators, not recommendations for policy.

KEY RESULTS AND TRENDS

Results of the Fish Index show that the health of the Bay’s fish communities is different in different regions of the Bay (Figure 15).

Conditions in the Central Bay are generally good and have been mostly stable for the past 30 years. In contrast, the condition of the fish community in Suisun Bay, which was already poorer at the start of the survey, declined quickly during the 1980s and has remained poor to very poor ever since. The condition of the fish community in San Pablo Bay has declined from good to fair during the past three decades and in the South Bay a similar trend is emerging.

Declines in the Fish Index largely reflect declines in fish abundance: in the 2000s, the Bay supported far fewer fish than it did just two decades earlier. Abundance of pelagic fishes

(those that live in open water habitat away from the shore) declined in all regions except the Central Bay. Compared to the abundance during the 1980s, abundance of pelagic fishes in the last five years was 88 percent lower in Suisun Bay, 68 percent lower in San Pablo Bay, and 55 percent lower in South Bay.

Abundance of sensitive Estuary-dependent species like longfin smelt, starry flounder, Pacific herring, and striped bass declined in all regions of the Bay, and abundance of bottom-dwelling fishes declined in both Suisun and San Pablo Bays. Northern anchovy, by far the most common fish in the Bay, virtually disappeared from Suisun Bay and fell by 60 percent in San Pablo Bay. Diversity, measured as the numbers of native species present, declined in San Pablo Bay and, for native Estuary-dependent species, in the South Bay as well.

As a percentage of species in the fish community, native species declined in all regions of the Bay except the Central Bay: in Suisun Bay, clearly the region with the fish populations in the poorest health, almost 30 percent of the fish species collected during the 2000s were non-native species, compared to 13 percent in the South Bay and 7 percent in the Central Bay. However, on the basis of total numbers of fish, native fishes predominate in all regions of the Bay except for Suisun Bay, where more than 60 percent of all fish caught are non-native species. The distribution of native fishes in Suisun Bay also declined. Compared to the 1980s when natives were regularly collected at all sampling stations, in recent years native fish have disappeared for much of the year from more than a third of the stations.

Figure 15. The condition of the San Francisco Bay’s fish community has declined in all areas of the Bay except near the Golden Gate. The decline is worst in Suisun Bay, the eastern, upstream region of the Bay.

■ SUMMARY

Based on the Fish Index and its component indicators, the health of San Francisco Bay has declined since the 1980s in all regions except Central Bay, near the Golden Gate. The decline is most severe in Suisun Bay, the upstream region of the Estuary heavily influenced by the amounts, timing and quality of freshwater inflows from the Bay's Sacramento-San Joaquin watershed.

Since 1993, when the CCMP called for recovery of and reversing the declines of estuarine fish and wildlife species, none of the Bay fish communities in any part of the Bay have improved. Instead, six native fish species that rely on the Bay have been listed under the federal and/or state Endangered Species Acts.²³

Decades of scientific research have identified the causes for these declines: degraded open water and marsh habitats, impaired water quality, reduced food availability, and increasing prevalence of harmful non-native species.

The Fish Index results underscore the need to improve Bay health and function by improving freshwater inflow conditions, restoring open water estuarine habitat and tidal marshes around the Bay's perimeter, re-establishing key ecological processes that increase productivity, and reducing pollution (see also the Freshwater Inflow Index, Water Quality Indices, Estuarine Open Water Habitat indicator, and the Flood Events section).

Birds

San Francisco Bay provides critical habitat for a wide variety of bird species. Birds are an ecologically diverse group, and this diversity is reflected in the broad spectrum of bird species dependent on different parts of the Bay ecosystem. Birds are found in tidal marshes, tidal flats, salt ponds, diked wetlands, open water, and rocky areas. Some are present year-round, while others are migratory. Many bird species feed on fish and invertebrates, using specialized hunting techniques to exploit particular prey species.



GARRETT SCALES

■ HEALTH INDICATORS

Five distinct indicators of bird populations were used to reflect the health of the Bay:

- abundance of breeding tidal marsh dependent birds (i.e., song sparrow, common yellowthroat, and black rail)
- tidal marsh bird reproductive success (specifically salt marsh song sparrows)
- heron and egret breeding populations
- abundance of winter waterfowl (dabbling ducks and diving ducks)

With these indicators it is possible to evaluate the degree to which the CCMP goal of stemming and reversing the decline in the health and abundance of estuarine biota (indigenous and desirable non-indigenous) and restoring healthy natural reproduction is being achieved. The benchmarks for these indicators are described below along with the key results and trends.

■ KEY RESULTS AND TRENDS

Our evaluation of bird-related indicators finds distinct patterns of change in the subregions of the Bay. The question that can be answered is not “how are birds (or a group of bird species) doing in the Bay?” but “how are birds (or a group of bird species) doing in each region of the Bay?” Differing results among regions are due to marked differences in species composition—not just birds, but plants, invertebrates, and other living resources—that in turn are driven in part by differences in salinity, with the Suisun region the least saline, San Francisco Bay (including Central and South Bays) region the most saline, and the San Pablo Bay region intermediate in salinity.

TIDAL MARSH BIRD ABUNDANCE

This indicator reflects density of subspecies that are especially adapted to tidal marsh habitat: the Alameda, San Pablo, and Suisun subspecies of song sparrow, the salt marsh common yellowthroat, and the California black rail. Tidal marsh bird populations, combining data across the three species, have demonstrated increases since 1996: in San Francisco Bay, the increase was in the late 1990s, but not more recently; in Suisun, increases are observed only since 2000; and in San Pablo Bay tidal marsh birds have shown a gradual increase over the entire period, 1996 to 2008 (Figures 16 and 17).

However, only San Pablo Bay tidal marsh birds demonstrate a significant increase in population density during this period (a cumulative increase of 31 percent over a 12-year period). Increases in tidal marsh bird density, such as have

been observed for San Pablo Bay, are likely due in large part to better habitat quality, especially the maturation of restored habitat, which can support a higher bird density than more recently restored sites. While the recent increase in Suisun Bay is heartening, the recent decline in San Francisco Bay is cause for concern.

BENCHMARK

We evaluated change in the density of tidal marsh birds with respect to the following benchmark: the upper quartile value observed for mature tidal marsh, averaged over the three target species. Averaging over all Bay regions provided a rough benchmark of 0.93 birds per hectare. Assuming that the same benchmark can be applied to all Bay regions, we observed that for the two most recent years, San Francisco Bay (including South and Central Bay) tidal marsh

birds are at 70 percent of this value, San Pablo Bay birds at 54 percent, and Suisun Bay birds at 94 percent.

TIDAL MARSH BIRD REPRODUCTIVE SUCCESS

Reproductive success of tidal marsh birds, as indicated by two subspecies of song sparrow that live exclusively in tidal marsh habitat, has been increasing in Suisun Bay since 2000, but decreasing in San Pablo Bay (Figure 18).

The level of reproductive success throughout the Bay (including information from Central and South San Francisco Bay) appears to be too low to sustain these populations over the long-term, let alone support their growth. The two most important pressures on tidal marsh birds accounting for low success are predators (especially

Figure 16. Combined species, Suisun Bay

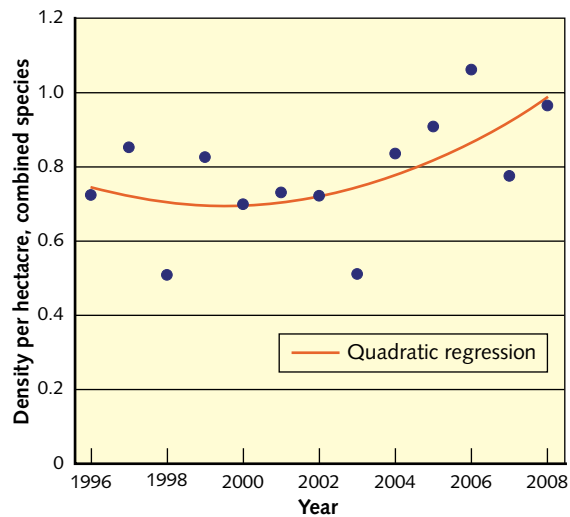


Figure 17. Combined species, San Pablo Bay

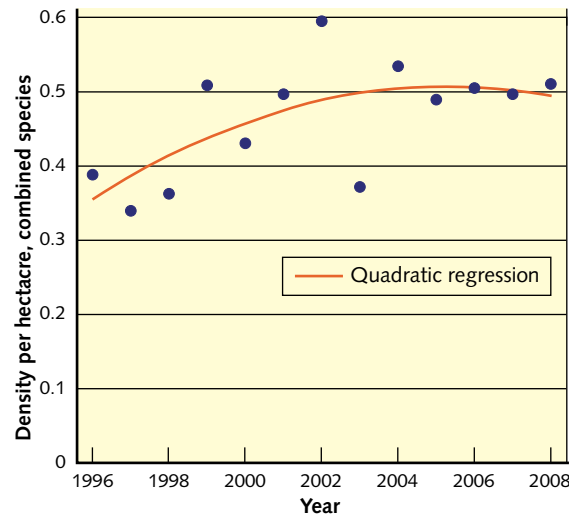
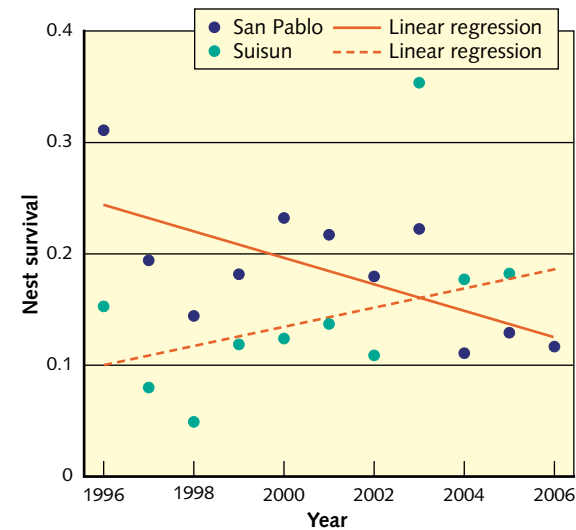


Figure 18. Reproductive success indicator, San Pablo and Suisun Bays





mammals and snakes) and nests being flooded. The impact of flooding is worse when song sparrows nest in the invasive-hybrid smooth cordgrass (*Spartina alterniflora*). Native marsh vegetation is not found at such low elevations relative to tides as is smooth cordgrass.

BENCHMARK

We used a nest success rate of 20 percent as the benchmark, the minimum success rate needed to sustain populations of tidal marsh song sparrows based on demographic analysis. Below this value, song sparrow populations are expected to exhibit long-term declines in breeding numbers. For the two most recent years, San Pablo song sparrows are at 61 percent of this value and Suisun song sparrows at 69 percent.

HERON AND EGRET BREEDING POPULATIONS

This indicator provides a measure of the breeding population size of herons and egrets, as exemplified by two species: great blue heron and great egret. The number of nests per 100 square kilometers of wetland habitat showed strong increases in San Pablo Bay (on average, 8.8 percent per year) but decreases in Central San Francisco Bay (on average, 3.8 percent per year) (Figures 19 and 20).

In fact, the San Pablo Bay nesting population has increased more than nine-fold since 1991. Nesting populations in Suisun Bay and overall in the San Francisco Bay have remained relatively stable. The increase in San Pablo Bay likely reflects increases in the amount and quality of habitat for herons and egrets.

Figure 19. Heron and egret nest density, Central San Francisco Bay

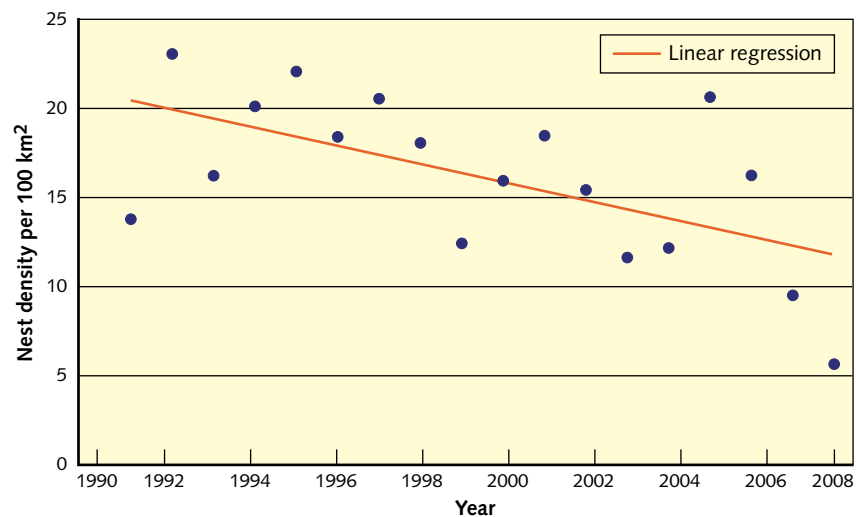
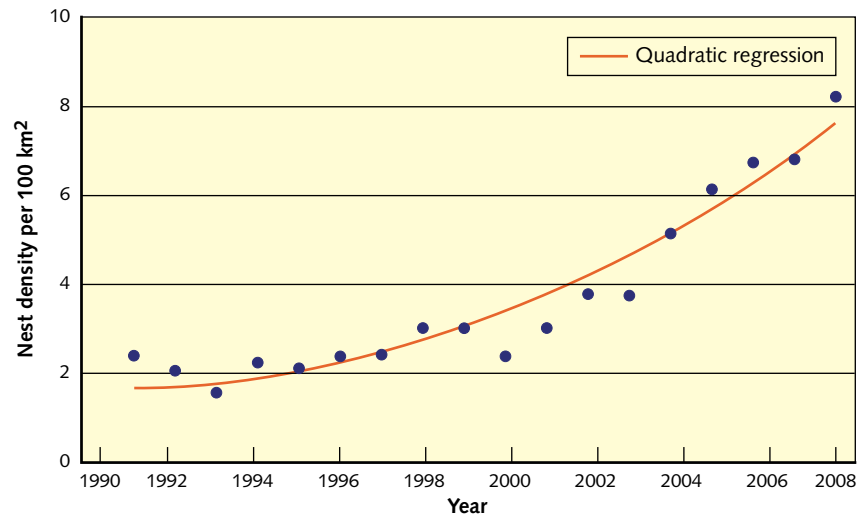


Figure 20. Heron and egret nest density, San Pablo Bay



HOPE FOR HERRING

It must have seemed like old times to Point Richmond residents as the Pacific herring came inshore to spawn. At its peak, February 2011's run attracted an estimated 20,000 gulls and an uncounted number of diving ducks. "California sea lions and harbor seals, their fur covered with herring eggs, were joining in the feast," reported birder Eric Lichtwardt.

The run brought the last urban fishery in the United States back into action for the first time in two years. Thirty boats went after the fish, whose roe is prized in Japan. "This is a year unlike any I've seen," Ernie Koepf of the *Ursula B* told the *Contra Costa Times*. "This is an epic year for harvesting." The 1,900-ton quota was filled early.

California Department of Fish and Game biologists agree that this was a good season. Most of this year's spawners were hatched in 2008, just after the *Cosco Busan* spill that contaminated many spawning sites. "Our feeling is that it was such a strong year class that it can support a fishery if managed properly for several years," says the agency's John Mello.

Some herring fishers reported the fish were avoiding oiled sites. Mello says he has heard this anecdotally, but hard data is lacking; "I don't think we've had enough spawning events since the spill to judge that this is the case. The herring do jump around. They don't hit all the known spawning areas every year."

Along with rocky substrates and man-made structures like piers, female herring deposit their eggs on eelgrass and *Gracilaria* algae. The health of

the fishery clearly depends on that of the subtidal and intertidal ecosystems.

"We're quite happy we're seeing a rebound in the population," says Fish and Game's Ryan Bartling.

A slightly different version of this article first appeared in ESTUARY NEWS, April 2011.



A gull discovers herring roe on a piling.

MICHAEL BUKAY

Nesting success of great blue herons and great egrets (one of two important components of reproductive success, the other being number of young reared) displayed a modest decline between the mid 1990s and the most recent years, especially in San Pablo Bay (see the [Technical Appendix, www.sfestuary.org](#), for more details). The observed decline in success of nesting attempts suggests that disturbance to breeding herons and egrets (whether due to humans or other sources) has increased in recent years.

BENCHMARKS

The benchmark value for heron and egret breeding populations as indicated by nest density is the average density observed from 1991–1995, calculated for each region separately: 19.1 nests per 100 square kilometers of historic tidal wetland habitat for Central San Francisco Bay; 2.09

nests per 100 square kilometers in San Pablo Bay; and 15.5 nests per 100 square kilometers in Suisun Bay. For the three most recent years, the combined heron and egret nest density for Central San Francisco Bay was 43 percent below the benchmark; San Pablo heron and egret nest density was about 250 percent above the benchmark; and Suisun heron and egret nest density was 12 percent higher.

The benchmark value for heron and egret breeding populations is the average value observed during the earliest five-year reference period, 1994 to 1998, 0.812. Applying this benchmark to all subregions indicates that heron and egret nesting success was 12 percent below this value in Central San Francisco Bay; 9.1 percent below this value for San Pablo Bay; and 4.7 percent below this value for Suisun Bay.

WINTERING WATERFOWL ABUNDANCE

Waterfowl population trends differ depending upon feeding behavior of the species and among Bay regions (Figures 21 and 22, note log scale). Ducks that feed at or just below the surface in shallow water (“dabbling” ducks) such as pintail, shoveler, and mallard, have shown healthy increases in Suisun and San Pablo Bay, increasing by 11 to 12 percent per year in both regions, but not in the Central and South San Francisco Bay, where there are no clear-cut trends. Diving ducks, which feed in deeper waters, have declined in San Pablo Bay in recent years but have been fairly stable in Suisun Bay. In particular, in San Pablo Bay, between the early 1990s and the mid-2000s, diving ducks decreased 41 percent while dabbling ducks increased 295 percent. The difference between the two types of duck species reflects the relative availability of

Figure 21. Dabbling ducks, North Bay

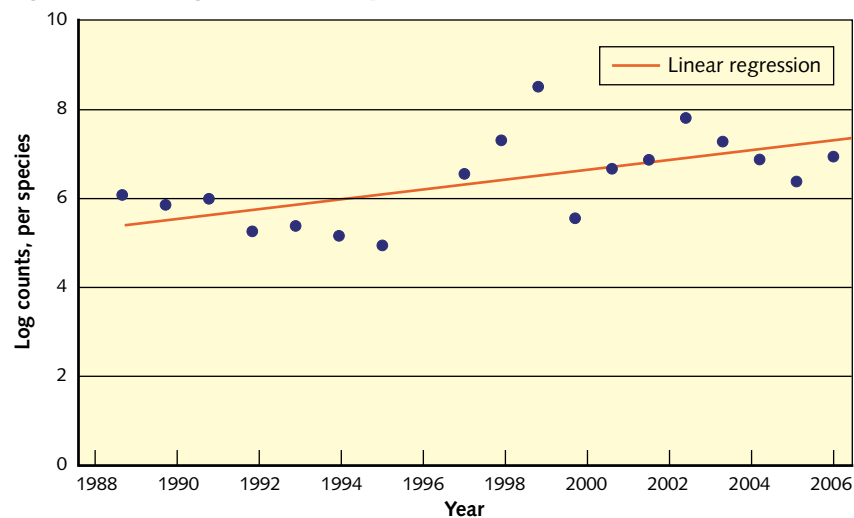
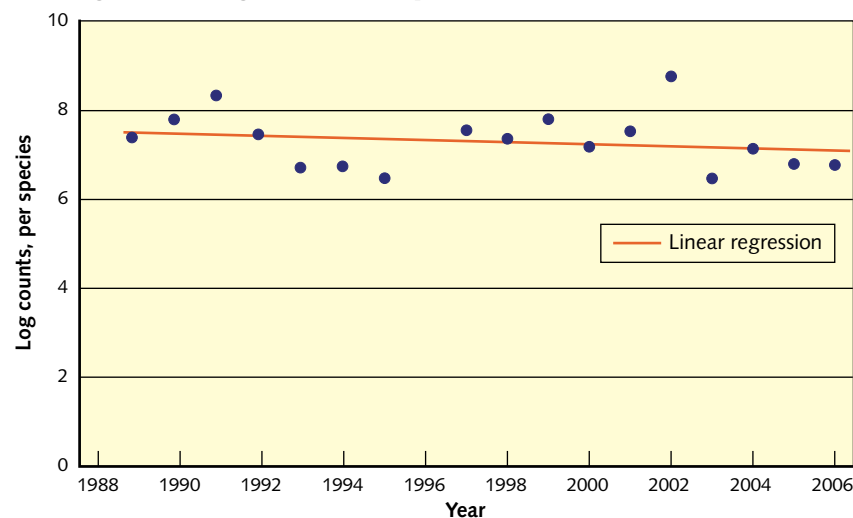


Figure 22. Diving ducks, North Bay





their different prey resources, with diving ducks feeding on large invertebrates such as clams, and dabbling ducks feeding on very small invertebrates and plant material. In addition, dabbling ducks are able to take advantage of the conversion of former salt evaporation ponds to tidal marsh habitat if it contains pannes and associated intertidal flats, whereas diving ducks are not able to use tidal marsh habitat for foraging.

BENCHMARK

For each of four regions, South San Francisco Bay, Central San Francisco Bay, North Bay (comprised mainly of San Pablo Bay), and Suisun Bay, the benchmark is the mean, per species, for the two groups of waterfowl (dabbling ducks and diving ducks).²⁴ For the three most recent years, this translated into percent changes in counts (after back-transforming from log values) for dabbling ducks of a 58 percent increase in South

San Francisco Bay, 21 percent decrease in Central San Francisco Bay, 295 percent increase for North Bay, and 680 percent increase in Suisun Bay: the predominant pattern was a strong increase. For diving ducks, the percent change in counts comparing the most recent three years to the reference period was a 49 percent increase in South San Francisco Bay, 17 percent decrease in Central San Francisco Bay, 41 percent decrease in the North Bay, and 20 percent decrease in Suisun: the predominant pattern was a decrease in winter populations.

■ SUMMARY

With respect to the CCMP goal of stemming and reversing the decline in the health and abundance of estuarine biota (indigenous and desirable non-indigenous), and restoring healthy natural reproduction, the results for birds are mixed. Though some populations demonstrate

increases in density, others have not shown any material gains in population during this time. Reproductive success has generally remained low or decreased since 1993.

Tidal marsh bird populations overall have increased since 1993. This is the case for common yellowthroats and black rails; however for song sparrows this is only true for San Francisco Bay, and not for Suisun or San Pablo Bay (see [Technical Appendix](#)). For great blue herons and great egrets, nesting numbers have increased in San Pablo Bay, but overall, the number of nesting herons and egrets has been fairly stable. For dabbling ducks, most Bay regions demonstrate an increase in numbers, especially San Pablo and Suisun bays. Several groups of birds have increased in part due to habitat restoration and enhancement, including tidal marsh birds (especially black rails), herons and egrets nesting in San Pablo Bay, and dabbling ducks.

Significant declines have occurred in the abundance of diving ducks and in nesting success, however, particularly for great egrets and San Pablo Bay song sparrows. Diving ducks have declined in numbers in all regions except South San Francisco Bay, possibly due to declines in prey. Increases in predator access, predator populations, or disturbances to breeding birds may be the root cause of declines in nesting success. Overall, substantial decreases in the indicators measured can be linked to excessive predation (tidal marsh bird reproduction), disturbance (heron and egret nesting success), and reduced prey availability (as suggested for diving ducks). The impact of invasive species altering wetland habitats remains a concern.

Ecological Processes

The Bay is composed not only of physical, biological, and chemical components but also active processes that link them to produce a functioning ecosystem. Examples of these processes include the movement of nutrients in the food chain as predators consume their prey, decomposition of dead animals and plants, sediment being transported to nourish wetlands and maintain channels, and freshwater flows mixing fresh and salt water to create aquatic habitat of varying salinity.

This section of the report identifies and evaluates indicators of two key ecological processes in San Francisco Bay: flood events and food availability to breeding birds. Identifying indicators that track ecological processes over time is a scientific challenge. We expect that in the future the indicators described here will be further refined, and more will be developed.

Flood events

Following winter rainstorms and during the height of the spring snowmelt in the San Francisco Bay's vast watershed, Bay tributary rivers may flood, spilling over their banks to create ecologically important floodplain habitat and high



MICHAEL BUKAY

flows of fresh water into the Bay. These high seasonal flows transport organisms, sediment, and nutrients to the Bay, increase mixing of Bay waters, and create productive brackish water habitat in the Suisun and San Pablo regions—conditions favorable for many native fish and invertebrate species. Flood events trigger reproduction and migration for many estuarine fishes and for anadromous species like salmon that migrate between the ocean and rivers through the Bay.

■ HEALTH INDICATORS

Freshwater flows into the Bay have been greatly altered by dams built on most of the Bay’s tributary rivers in the Sacramento–San Joaquin watershed (see Freshwater Inflow Index, Water Quantity Section). Many of these dams were built for the purpose of reducing damaging flood events and to store mountain runoff for later use and export to other regions in the state. However, these upstream water management operations have interrupted an important

ecological process—regular seasonal flooding—that we now know is critical to the health of the Bay, its watershed, and the plants and animals that depend on these habitats. The Flood Events Index uses these measurements to assess the frequency (how often?), magnitude (how much?), and duration (how long?) of flood events and high inflows into the Bay.

BENCHMARKS

The benchmarks for the three measurements that comprise the Flood Events Index were based on review of historical flow data for the years before most of the major storage dams were completed on the Bay’s largest tributary rivers. This showed that flows in excess of 50,000 cubic feet per second corresponded to inundation of floodplain habitat upstream of the Bay and that these high flows occurred in half of all years, with average duration of about 90 days. Flood frequency is measured as the number of years in the past decade in which inflows

exceeded 50,000 cubic feet per second for a total of 90 days during the year.

Magnitude is measured as the average flow during the 90 days of highest flow in the year, and duration as how many days during this period flows exceeded the 50,000 cubic foot per second flood threshold. Measured conditions that exceeded the benchmarks were considered to indicate good conditions while those that were lower were considered to indicate fair or poor conditions. For each year, the Flood Events Index was calculated by combining the results of the three measurements into a single score (1–3).

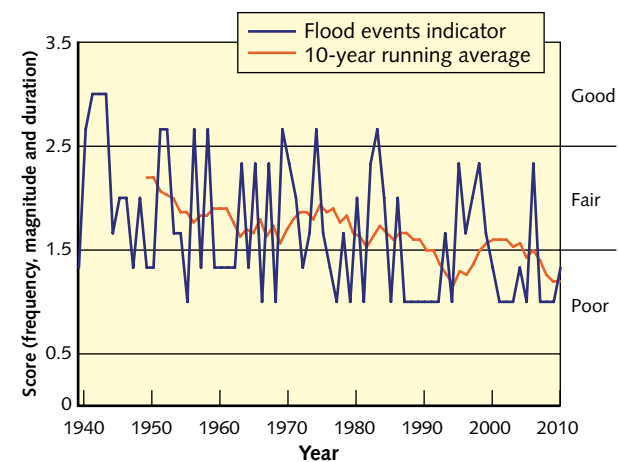
■ KEY RESULTS AND TRENDS

Results of the Flood Events Index (Figure 23) track the steady decline in the occurrence of this key ecological process, from good to fair and, by the 1980s, mostly poor. During the last 20



RICHTURNER

Figure 23. The frequency and duration of flood events in the San Francisco Estuary’s watershed has declined during the past 60 years.



THE YOLO BASIN AS REARING HABITAT FOR SENSITIVE FISH SPECIES

The law of unintended consequences has been known to work in nature's favor. The Yolo Bypass, a natural floodplain reengineered to convey floodwaters around Sacramento, is one case in point. UC Davis fish scientist Peter Moyle has observed that the Bypass was entirely a flood control area in concept, with the floodplain graded to facilitate draining; yet it has become increasingly important for fish and wildlife. In winter, the floodplain teems with waterfowl. It is also recognized as prime habitat for sensitive native fish species at a critical stage in their life histories. Fifteen native species and 27 non-natives, including popular game species like striped bass, use the Bypass.

The Sacramento splittail, a California-endemic cyprinid, spawns in the flooded Bypass. Young splittail rear there and move out to river channels as the floodwaters recede. Although it is not currently on the federal endangered species list, the splittail is still considered by some wildlife advocates to be of conservation concern.

Biologists have also documented the floodplain's importance to Chinook salmon. Juveniles move into the floodplains during high-flow events, seeking out low-velocity areas. Research by Ted Sommer of the California Department of Water Resources and others indicates that juvenile salmon grow faster in the Bypass than in the adjacent Sacramento River, in part because of the seasonal abundance of a recently described species of chironomid midge on the floodplain and the warmer water and greater habitat complexity of the Bypass. The dispersal of the fish over the extensive flooded area limits the impact of predation by wading birds. The juveniles move out during later flood events or when the inundated portion of the floodplain drains. Historical grading for agriculture enhances drainage, which may help the young salmon make their way out.



USGS

years there were no years with good conditions, and fair conditions occurred in only seven years during a particularly wet sequence of years in the late 1990s and in 2006. Most of the decline is driven by reductions in the frequency of flood events. In the 1940s, floods and high flows into the Bay occurred in more than half of all years (an average of 56 percent of years). For the last 20 years, flood frequency averaged less than two flood events per decade (14 percent of years). Magnitudes of the maximum flows measured during the year were also lower, averaging more than 80,000 cubic feet per second in the 1940s but just 48,000 cubic feet per second in the last decade. And flood durations were lower. In the 1940s, flows into the Bay exceeded 50,000 cubic feet per second for an annual average of 82 days, but these high flows occurred for only an average of 27 days per year by the 2000s.

■ SUMMARY

Reductions in the frequency and intensity of flood events over the past several decades have impaired the health of the Bay, reducing its productivity and dampening the year-to-year and seasonal variability that help native species thrive and restrain expansion of invasive non-natives. As with the changes in other aspects of the freshwater flows into the Estuary (measured by the Freshwater Inflow Index), declines in this important ecological process probably have their greatest effect on the upstream regions of the Bay, which directly receive the flood flows. However, the effects of periodic flood flows are also important in the downstream regions of the Bay, as well as in coastal environments outside the Golden Gate. For example, success-

ful restoration of tidal marshes along the Bay's perimeter depends on deposition of sediment, most of which is transported to the Bay during floods. Therefore, achieving the CCMP goal of restoring healthy estuarine habitat will take more than improving minimum freshwater inflows, it will require restoration of some larger flow events calibrated so as not to threaten people and property along the affected river corridors. Such carefully managed events would greatly help to nourish habitats and drive the ecological processes of a healthy estuary.

Food web

The food web of the estuary represents an important ecological process. Since fish-eating birds need a functioning food web so they can feed themselves and their young, the reproductive success of these birds is an indicator of the health of the aquatic food web of the Estuary.

■ HEALTH INDICATORS

Two indicators reflect the availability of food to breeding birds:

- the number of young reared per great blue heron and great egret successful breeding attempt, based on a large number of breeding colonies in the wetlands of San Francisco Bay
- the number of young reared per Brandt's cormorant breeding pair on Alcatraz Island, inside San Francisco Bay

Both of these indicators reflect the availability of food (specifically, fish) in the Estuary's baylands (for great blue herons and great egrets) or in open water (Brandt's cormorants), and thus assess the functioning of the food web.

The time series for the great heron and great egret brood size began in 1991, and is based on observations of those species at numerous breeding colonies distributed throughout Central San Francisco Bay, San Pablo Bay, and Suisun Bay. The time series for Brandt's cormorant began in 1995 and comes from the only breeding colony of this species within San Francisco Bay at Alcatraz Island. All three species forage widely when rearing young, and thus the indicators reflect the food web beyond the immediate vicinity of the breeding colony.

BENCHMARKS

The benchmark for the number of young reared per heron and egret brood is the average value observed during the earliest five-year reference period, 1991 to 1995, calculated across all regions of the Estuary, combining data for great blue heron and great egret: 2.17 young per brood. Compared to the benchmark value, the number of young per brood for the most recent three years (2006 to 2008) was reduced by 5.4 percent in Central San Francisco Bay, by 1.8 percent in San Pablo Bay, and by 7.7 percent in Suisun Bay.

The benchmark for the number of young reared per breeding pair of Brandt's cormorants is the long-term average value obtained at a reference site for this species (Southeast Farallon Island, 1991–2005) of 1.69 chicks fledged per pair (PRBO, unpublished). While prior to 2008,

12 out of 13 years were above this value, from 2008 to 2010, the three-year average was only 39 percent of the long-term benchmark.

■ KEY RESULTS AND TRENDS

Great blue heron and great egret brood sizes have shown declines since 1991 (Figure 24), but the pattern differs somewhat depending on the region of the Bay. The decline in brood size is more pronounced for great egrets, whose brood size has declined 17 percent in the Bay as a whole, when comparing the most recent three years (2006–2008) to 1991–1995. Combining results from the two species reveals no decline in the Central Bay, but a pronounced decline in



PETER LA TOURETTE

Suisun Bay of more than 15 percent over the 17-year period. In San Pablo Bay, a decline in brood size during the mid to late 1990s was followed by an increase from 1998 to 2006. These results suggest declines in the availability of prey, particularly in Suisun Bay, a result consistent with observations of fish populations in the same regions and time period (see the Fish Index, Living Resources section).

In marked contrast, Brandt's cormorants on Alcatraz Island demonstrated relatively high and relatively stable reproductive success between 1995 and 2007, comparing favorably to the long-term reproductive success of this species on the Farallon Islands. This healthy performance changed during 2008–2010, when reproductive success was severely impaired (Figure 25).

Whereas such low reproductive success is unprecedented for the Alcatraz population, it is

not unusual on the Farallon Islands, where reproductive failure (or near-failure) is a definitive sign of prey shortage for breeding cormorants.

■ SUMMARY

The two indicators of reproductive success, brood size of great blue herons and great egrets, and chicks fledged per breeding pair of Brandt's cormorants, both demonstrate some reduction in prey availability. The brood size indicator reveals a consistent long-term population decline in one of the three Bay regions, while the fledgling indicator reveals high prey availability in the aquatic food web up to 2007, and then a drop beginning in 2008 and accelerating in 2009 and 2010. The years 2009 and 2010 may represent only a two-year anomaly, but if this extremely low production of cormorant young continues, it will be of grave concern.



Figure 24. Heron and egret brood size, Suisun Bay

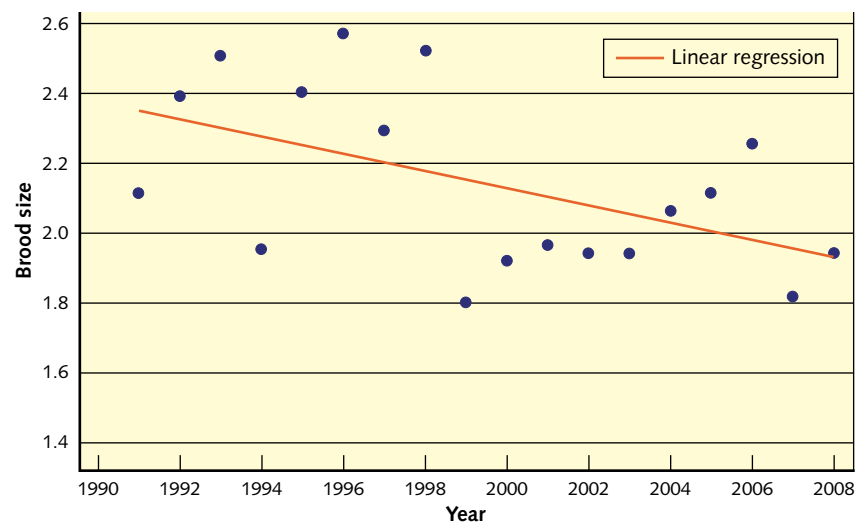
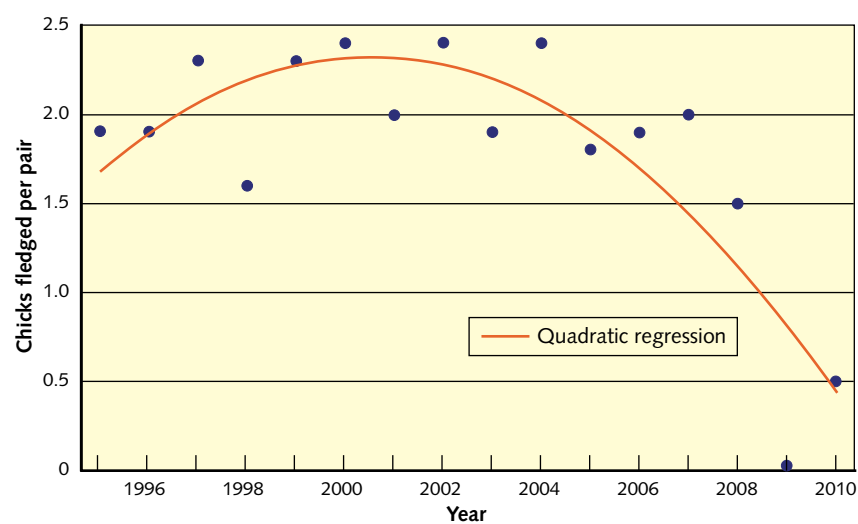


Figure 25. Brandt's cormorant reproductive success, San Francisco Bay



Stewardship

Humans, as part of the ecosystem, can act as stewards by taking individual and community actions that reduce adverse impacts on valued attributes of the Bay. Stewardship activities can include both volunteer efforts as well as the work of regulatory and management agencies or permittees—like cities and counties—pursuant to laws and regulations. Examples of good stewardship actions include individuals and communities using water more efficiently, participating in cleanup efforts in their local beaches and watersheds, or planting marsh vegetation. Examples of stewardship actions by management and regulatory agencies include programs to reduce water pollution, increase vital wetland habitat, or reduce disposal of dredged material into the Bay.

This section of the report highlights and evaluates indicators of a few key stewardship activities involving water use, volunteers, and public access efforts. Many important programs and efforts could have been evaluated as part of this stewardship analysis. The indicators below should be viewed as pilot indicators, and we recognize that some of the selected measures may not represent



NORTH BAY CONSERVATION CORPS

the broad category of activities from which they are drawn. As with other portions of this document, we intend for these indicators to begin a dialog about how to refine and improve stewardship indicators in future assessments and, most importantly, about which actions and activities citizens and committed resource managers should support, expand, or begin.

Urban water use

About 90 percent of the 1.1 million acre-feet per year of water used in the Bay Area is for urban uses. Most of that water is imported from outside the Bay Area, mainly from the Delta watershed with smaller amounts from the watersheds of the Russian River and Tomales Bay. Some local watersheds provide groundwater to urban users in the Santa Clara Valley, Fremont area, and in the North Bay.

Bay Area residents have the opportunity to demonstrate stewardship by using water more efficiently, leaving more water to maintain the habitats, living resources, and ecological processes that contribute to a healthy Bay. Efficient use of water can also reduce the vulnerability of our supplies to disruption by earthquakes, droughts, floods, and rising sea level, and help meet regulatory requirements to protect endangered species; reduce the need for transporting and storing water and developing new sources; relieve competition for limited supplies; and reduce pollutant loads from irrigated lawns, gardens and crops.

HEALTH INDICATOR

This indicator measures water used annually by urban users in Bay Area watersheds from 1986 to 2009. It also examines residential water use specifically as this use directly reflects decisions by individuals and families, whose choices to use water more efficiently in and around the home can collectively create large-scale benefits.

BENCHMARK

A recently adopted state law (The Water Conservation Act of 2009) establishes a goal of reducing urban per-capita water use by 20 percent by 2020 with an interim goal of a 10 percent per-capita reduction by 2015. The 2020 goal, interpreted by the California Department

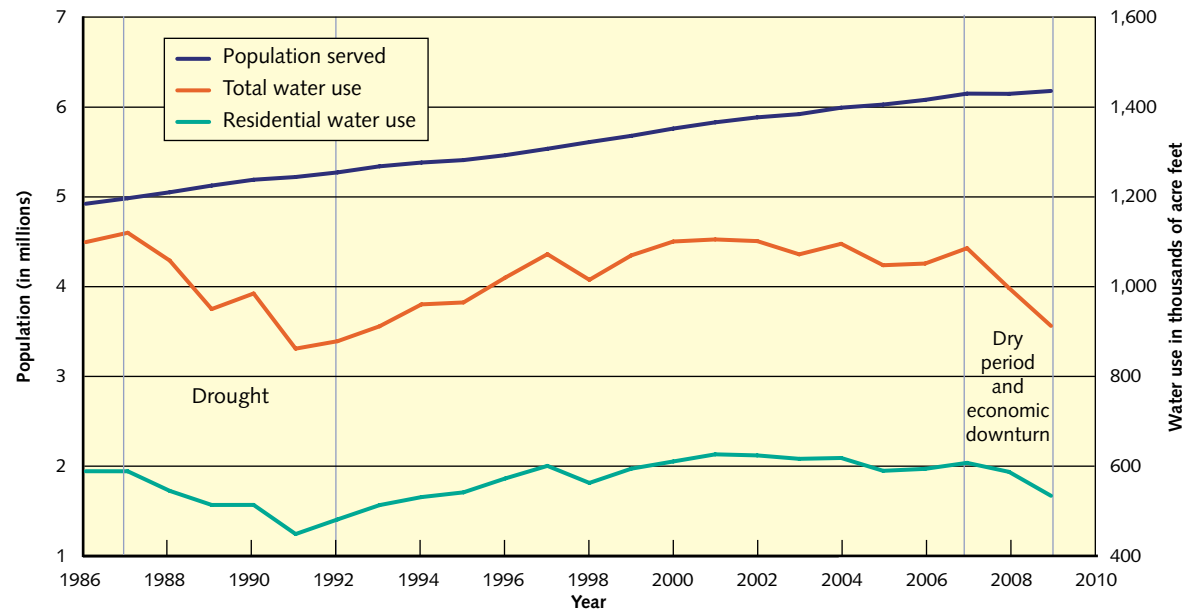
of Water Resources as 124 gallons per day per person in the Bay Area, is used to evaluate this indicator of stewardship activity in our region.

KEY RESULTS AND TRENDS

Total urban water use in the Bay Area is 20 percent less today than it was 25 years ago, a remarkable achievement given that the population has increased by 20 percent (Figure 26).

This accomplishment is primarily due to greater efficiency of use, combined more recently with a dampening of water demand due to the economic downturn. The increased efficiency has been achieved through mandates for more efficient water-using appliances, and by Bay Area residents and businesses reducing

Figure 26. Urban water use in the San Francisco Bay Area. Data from the regional water agencies (see [Technical Appendix](#) for details).



their use in response to requests for conservation during dry periods (Figure 27). Although data for the entire Bay Area is only available through 2009, data from selected suppliers for 2010 and 2011 indicates that usage is continuing its downward trend as cooler and wetter springtime weather suppresses demand. Given these recent factors, Bay Area water agencies have already made significant progress toward meeting their urban water use targets. A rebounding economy and years with less precipitation are factors that will likely increase urban water use at some point in the future. However, if recent per-capita usage can be maintained or improved, the legislative mandate for a 20 percent reduction should be easily achieved by 2020.

SUMMARY

The Bay Area is using less water today than it did 25 years ago even though the population has increased by well over a million people. While conservation practices deserve much of the credit, the economic downturn and climate variation are also significant factors. Additional efficiency improvements will be needed in the future if Bay Area water users are to continue this trend. These improvements can be achieved by greater adoption of water-saving appliances and drought-tolerant landscapes, and increasing the use of recycled water.

Reduced water demand by Bay Area residents and businesses will increase freshwater inflows to the Bay and flows in streams and rivers only if upstream users do not increase their diversions.

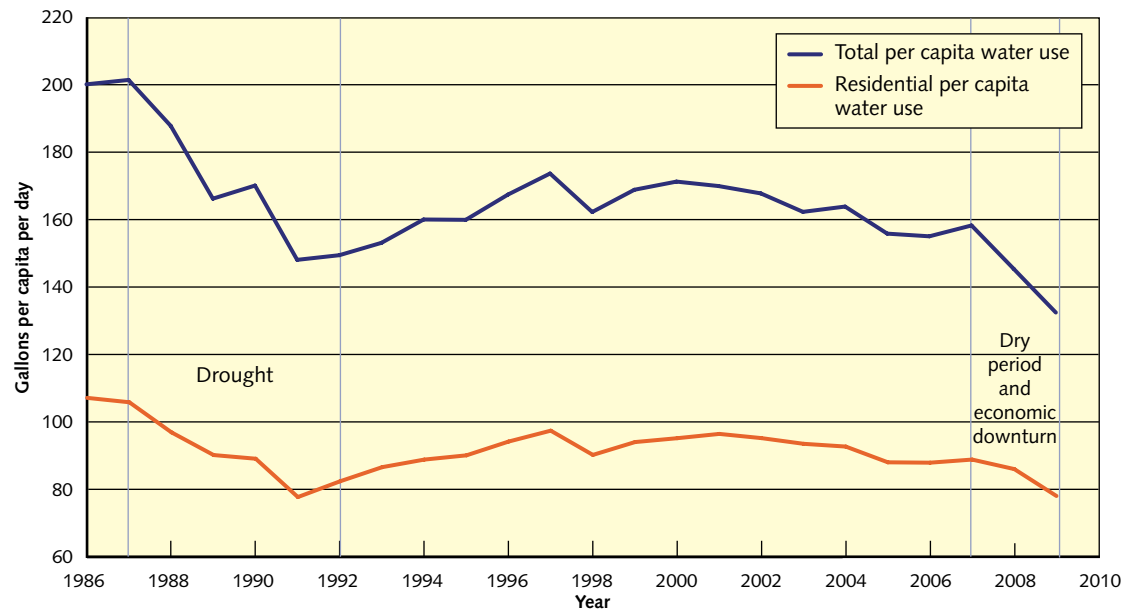
Recycled water use

Nearly all of the high quality water consumed in the region is used once, treated, and discharged to the Bay from wastewater treatment plants. There has been a small amount of intentional recycling or reuse for over 50 years, but the amount and uses of recycled water have grown substantially over the past decade.

Recycled water use demonstrates stewardship because it allows limited local and imported water supplies to be used more efficiently, with the potential to reduce the need for new water diversions from the Bay's watershed. Using recycled water increases the region's sustainability by providing a local and available source of water. The use of recycled water also reduces the amount of treated wastewater discharged into the Bay.

Recycled water is used in our region to irrigate landscapes (including golf courses), and crops; for process water, including power plant and refinery cooling water and washdown water at commercial and industrial facilities; and to augment freshwater flow to wetlands. Proposed new uses of recycled water include toilet flushing in commercial buildings, heating and cooling, and for groundwater recharge.

Figure 27. Water Use Per-capita in the San Francisco Bay Area. Data from the regional water agencies (see [Technical Appendix](#) for details).



■ HEALTH INDICATOR

Recycled water is quantified as either the recycled water produced at wastewater treatment plants (WTPs), or the water supply that it replaces or creates.²⁵ The amount of recycled water being used is analyzed here by examining the type of water use that it replaces or offsets. This helps us understand the ecological benefits of this stewardship activity. Recycled water that replaces water that otherwise would be delivered by a municipal supplier is considered a “potable offset.” Recycled water can also be used in a way that does not offset potable water, such as for creating and enhancing freshwater marsh habitat at Hayward Marsh, Peyton Slough, Palo Alto Marsh, and several North Bay streams.

Vineyards and dairies can also use recycled water instead of pumping groundwater or withdrawing surface water from a nearby stream. A WTP may also treat its wastewater to recyclable standards but not have a market for the water and will apply it to formerly non-irrigated land to grow grass or forage crops instead of discharging it into the Bay. In all of these cases, the recycled water is providing a local water resource, expanding our region’s available water portfolio, and providing economic, environmental or social benefits. For public utilities that normally discharge effluent to the Bay, any reuse will reduce the amount of that discharge.

BENCHMARK

We evaluated water recycling success by comparing the amount recycled to the amount of wastewater flowing into treatment plants and to recycled water use targets and projections, or the potential demand for recycled water.

■ KEY RESULTS AND TRENDS

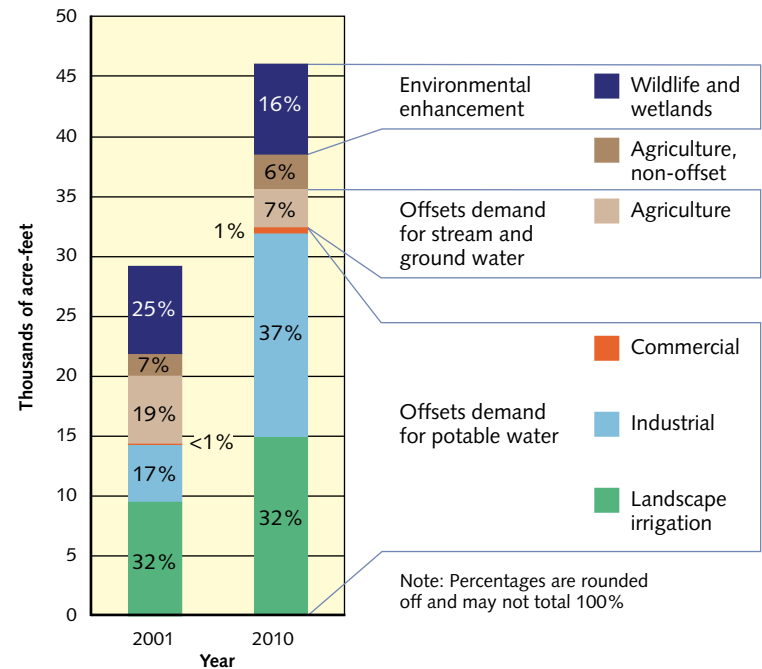
From 2001 to 2010, total recycled use in the Bay Area increased more than 50 percent to 46.1 thousand acre-feet (TAF) (Figure 28). The most significant increase was in use by refineries and power plants for process and cooling water.

Over 35 TAF of recycled water now replaces potable use and stream and groundwater use (nearly four percent of the total urban and agricultural water demand in the Bay Area), more than doubling the 2001 potable offset. (See 2010 column, Figure 29.) Most of the 35 TAF offsets potable supplies previously used for landscape irrigation and industrial uses, with a small offset for groundwater and surface water use by North

Bay agriculture. The remaining recycled use does not offset potable uses but instead is used to sustain freshwater marshes around the Bay and to grow forage crops in the North Bay.

Recycled water use in 2010 fell considerably short of the projected 2010 target of 125 TAF established in 1999 by the Bay Area Regional Water Recycling Program (BARWRP). This is primarily due to project costs and funding limitations, reduced market demand, and customer/public acceptance. Currently, 27 project proposals (120 TAF/YR of yield) are in different phases of planning or funding procurement. This is still short of the 270 TAF of the potential market for recycled water that the BARWRP and North Bay Reuse Study identified for the year 2025.

Figure 28. Recycled water use volumes in the San Francisco Bay Area in 2001 and 2010, in thousands of acre-feet (TAF). Total use increased from 29.1 TAF in 2001 to 46.1 TAF in 2010. (Source: personal communication with treatment plant operators and Regional Water Quality Control Board staff, 2010 Urban Water Management Plans (draft), 96-011 reports from wastewater plant operators to the Regional Board)



The 46.1 TAF of currently recycled water is only seven percent of wastewater production from the WTPs, meaning there is plenty of potential supply. A portion of the wastewater stream may never be economically feasible to develop for recycling given the current mismatch between wastewater discharge locations and recycled water market locations.

Benefits for the Bay from recycled water use include increasing available habitat, reducing effluent discharge, and reducing water diversions from the watershed. However, as with urban water use reduction, the net benefit to the Bay and its watershed from recycled water use could be diminished by new freshwater diversion projects and extractions in the future.

■ SUMMARY

Recycled water use is becoming an increasingly important part of the Bay Area's water portfolio. Hopefully this will help offset increased potable uses and replace enough existing potable uses to reduce our reliance on imported supplies and increase freshwater outflows to the Bay from the Delta. If the potential market for recycled water is fully realized, demand for imported water could be significantly reduced and the region's water supply would be far more reliable. To fully realize this potential, Bay Area residents and businesses will need to overcome their concerns about the perceived risks of recycled water and embrace it as one of the most viable means of achieving a more sustainable water future.



STEVENS & PERMANENTE CREEKS WATERSHED COUNCIL

Volunteer efforts

The success of local environmental conservation and restoration efforts relies in large part on public interest and involvement. Bay Area residents volunteering their time in local restoration or cleanup activities is an expression of stewardship aimed at improving the health of the Bay. There are many ways that citizens can be involved, both directly and indirectly, in such stewardship activities. One example is Coastal Cleanup Day, an annual event organized by the California Coastal Commission, in which volunteers collect debris from the state's marine environments, including the Bay's shoreline and watersheds.

■ HEALTH INDICATOR

The number of volunteers participating in the annual Coastal Cleanup Day event in the nine-county region (Marin, Sonoma, Napa, Solano, Contra Costa, Alameda, Santa Clara, San Mateo, and San Francisco) is presented as an indicator of stewardship that improves the health of the Bay. This indicator does not represent all categories of volunteer activities, as there are many possible ways for Bay Area residents to volunteer their



ADRIENNE MILLER

HANDS IN THE MUD

Everyone knows that the Estuary needs enough fresh water rumbling in from its rivers to keep it alive and healthy. But its health is also increasingly tied to the hard work of the thousands of volunteers who clean trash and invasive plants from its shores, test its water quality, and restore its watersheds.

In Marin County, STRAW (Students and Teachers Restoring a Watershed) program—begun in 1992 by fourth graders as a classroom project to save the endangered California freshwater shrimp—has grown to rely on 2,000 teachers, students, parents, and other community members to put over 30 stream restoration projects in the ground every year, according to STRAW's Laurette Rogers. To date, more than 28,000 students have participated in over 300 restorations on rural and urban creeks, restoring over 21 miles of creek banks, says Rogers.

Save The Bay's community-based restoration program was created in 2000 and has used more than 50,000 youth and adults in hands-on restoration projects at 8 sites around the Bay, according to the group's Jessica Castelli. This year, over 5,000 volunteers will donate 20,000 hours to restore 120 acres of Bay habitats by hand. "That's the equivalent of 10 full-time employees," says Castelli. Save The Bay also has a huge contingent of citizen volunteers who regularly tackle trash "hot spots" in creeks.

"Most of our annual budget goes to pay one part-time person," says Femke Oldham of the San Pablo Watershed Neighbors Education and Restoration Society (SPAWNERS). "Otherwise our activity completely relies on volunteers. Lots of grants are contingent on using volunteers. We have contracts with cities and the county for big cleanups. They save money because we do the community organizing and supply the volunteers. It would be more expensive if city or county staff or a professional source did it." She says school groups, retirees, and corporate

groups—490 participants last year—help with creek cleanups, weeding invasive plants, and planting natives. "We're guided by a volunteer steering committee, including native plant experts, that creates planting plans."

Berkeley's Codornices Creek Watershed Council hasn't had a paid coordinator for several years. "It's all volunteer now," says the San Francisco Bay Regional Water Board's Dale Hopkins, who volunteers for the Council. One focal point is a reach of the creek where steelhead have been observed in recent years: over 130 of them, many 18 inches or longer.



STEVENS AND PERMANENTE CREEKS WATERSHED COUNCIL

"A lot of what's going on now involves removing barriers to the steelhead," she adds. Volunteers have also weeded and planted along the creek as part of a stewardship project, developed in conjunction with a city-sponsored restoration. Hopkins says future directions may include an all-volunteer GPS mapping project.

In Oakland, Kimra McAfee of Friends of Sausal Creek says over 2,300 volunteers, the largest component from high school community service groups, pitched in during the last fiscal year (July through June) to propagate and plant native vegetation and remove invasives. That amounts to 6,140 service hours.

In the South Bay, on Alameda Creek, volunteers have donned hip waders every year to help carry threatened steelhead past barriers in the stream when needed (under permits from regulatory agencies), and to conduct regular creek cleanups. Farther west, the Stevens & Permanente Creeks Watershed Council relies on volunteers to monitor water chemistry, collect benthic macroinvertebrates for assessing aquatic habitat, map riparian areas, remove invasive plants and revegetate with natives, lead nature walks, and conduct community outreach, among many other tasks. Says the Council's Joanne McFarlin, "I have over 50 different volunteers working with me in an average month, with many of those volunteers working several hours several times during the month. Our volunteer hours totaled more than 3,700 last year. We would cease to exist without volunteers."

Some groups have brought in skilled specialists for tasks inappropriate for volunteers. SPAWNERS, for one, has hired heavy equipment operators in the past and has also worked with a documentary filmmaker, a professional environmental engineer, and a water-quality specialist. Friends of Sausal Creek paid an irrigation specialist last year. Still, volunteers are

the heart and soul of these non-profits. "Where's the community spirit if you pay people to work on Earth Day?" asks Sausal Creek's McAfee.

For her masters' thesis at the University of San Francisco, Rachel Spadafore surveyed representative Bay Area organizations, including public agencies and nonprofits, on their use of volunteers in urban watershed restoration projects. Although the responses to her questionnaire pointed toward both challenges and strengths in reliance on volunteers, the overall sense was strongly positive.

Small watershed groups tapped several volunteer sources: 91 percent used short-term ("convergent") volunteers, 83 percent long-term volunteers, and 83 percent school students. Two-thirds of the groups worked with a combination of the three types. All of the larger organizations (e.g. Save The Bay) used all three categories.

"One of the biggest things large and small groups alike struggled with was recruiting and retaining volunteers," says Spadafore. "That surprised me. I expected it would be lack of ecological knowledge or training. It's difficult to build a set of long-term volunteers. The advantage to developing a set of skilled long-term volunteers is that they can then take more responsibility for future projects. Watershed groups without a lot of money or staff can benefit from having a core of volunteers who can train younger or less experienced volunteers in technical tasks." She singled out Contra Costa County's Department of Conservation and Development for its exemplary model for developing long-term volunteers.

Volunteers are typically used for basic tasks like removing invasive plants and planting natives that are nonetheless essential to the function of a restoration program, she says. Most organizations provided brief onsite training with oral instruction. "A few groups have volunteers doing technical work like

water quality testing, benthic macroinvertebrate sampling, and irrigation installation. Friends of Sausal Creek, for one, has a program set up to train lay people in these technical tasks. Even school students can do it. In one group, long-term volunteers participated in the project initiation and design phases of restoration."

Apart from the free labor, the groups Spadafore surveyed saw the educational function of volunteer work as its most compelling rationale: "It's a perfect opportunity to educate a large group of people about the issues involving their watershed." Admittedly, large school groups can be a mixed blessing: "They're not necessarily there by choice, and there can be discipline problems, lack of interest, and distractions. On the other hand, you're cultivating understanding and experience with restoration at a really young age."

A slightly different version of this article first appeared in ESTUARY NEWS, April 2011.



STEVENS & PERMANENTE WATERSHED COUNCIL

time in stewardship activities (see "Hands in the Mud").

BENCHMARK

We used the number of Coastal Cleanup Day volunteers in 1998 as this stewardship benchmark.

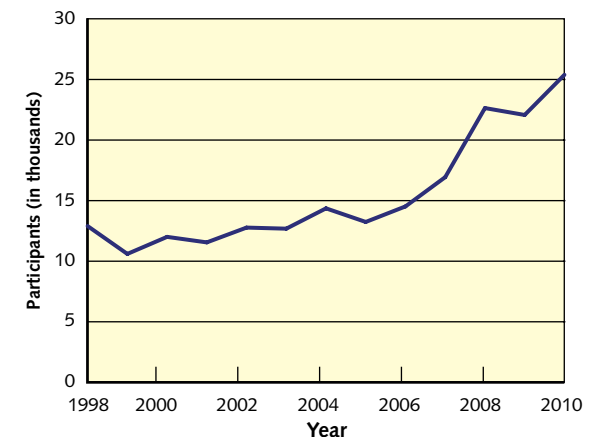
KEY RESULTS AND TRENDS

Based on data from the California Coastal Commission, Coastal Cleanup Day participation has increased steadily, with a near two-fold increase in volunteers since 1998 (Figure 29).

SUMMARY

Volunteer participation in stewardship activities, as represented by Coastal Cleanup Day, has increased steadily over the last decade. The interest shown by Bay Area residents in volunteering

Figure 29. Coastal Cleanup Day Participation in the nine county region, 1998–2010. Source: California Coastal Commission.



their time to take part in stewardship activities is an important outcome of public outreach and education efforts by many organizations and agencies around the region. Continued outreach and education efforts, combined with stewardship opportunities, will likely strengthen volunteer participation in the future, which will contribute to the ecological health of San Francisco Bay.



ABAG

Public access

Access to the Bay and its surrounding watershed provides the public with the opportunity to appreciate these natural resources, which in turn helps to promote active involvement in protection and restoration efforts.

HEALTH INDICATORS

The public access indicator assesses the extent to which access to the Bay is being provided by evaluating the increases in mileage of the San Francisco Bay Trail and the Bay Area Ridge Trail over time.

BAY AREA-WIDE TRASH CAPTURE DEMONSTRATION PROJECT

In 2009 the Estuary Partnership received \$5 million in federal stimulus funds (the American Recovery and Reinvestment Act of 2009) to assist Bay Area towns, cities, and counties in reducing the amount of trash reaching local waters, the Bay, and the Pacific Ocean. The project is designed to facilitate municipalities' efforts to comply with the San Francisco Bay Regional Water Board's Municipal Regional Permit, which requires significant reductions in trash by 2014. The funding was made available by U.S. EPA, through the State Water Resources Control Board's Clean Water State Revolving Fund.

Working in concert with the Water Board, the Partnership contracted with 12 suppliers of "full-capture" trash control devices—both small catch basin inserts and much larger devices installed at storm sewer junctions. The Partnership made those devices available to participating municipalities, allocating project resources based on population and commercial/retail zoned areas since commercial areas are known to generate the most trash. As this report went to press, 66 towns, cities, and counties had joined the project and were ordering and installing devices.

The Estuary Partnership's contribution to trash cleanup is considered a "demonstration project" because \$5 million is only a small downpayment on the ultimate cost of solving the Bay Area's trash problem. The goal is to provide tools to help municipalities understand the types of trash collection strategies and trash control devices that will work best in specific situations. The project website allows municipal staff to upload both land use and maintenance data, and download it in ways that will help them compare the utility of devices and generate reports documenting permit compliance.



CITY OF SAN LEANDRO

BENCHMARK

In 1989, the Association of Bay Area Governments (ABAG) established the goal of building a 500-mile regional hiking and bicycling trail around the perimeter of San Francisco and San Pablo Bays. In 1987, the Bay Area Ridge Trail Council established the goal of building 550 miles of trail for recreational use along the ridgelines surrounding San Francisco Bay. In 2006, the Council identified the near-term goal of completing 400 miles of trail by 2010. The indicators in this report were assessed by measuring the percentage of these goals that is currently being met.

■ KEY RESULTS AND TRENDS

Our analysis shows a steady increase in public access to the Bay. At the time of the Bay Trail Plan adoption, 130 miles of the Bay’s shoreline were accessible to the public, up from just 4 miles in 1965. Currently, 310 of 500 planned miles of the Bay Trail are complete, or 62 percent of the goal for the entire system (Figure 30).

Since the dedication of the Ridge Trail’s first segment in 1989, 330 of 550 miles of trail have been completed, or 60 percent achievement of the goal for the entire system and 82 percent achievement of the near-term goal set for 2010 (Figure 31).

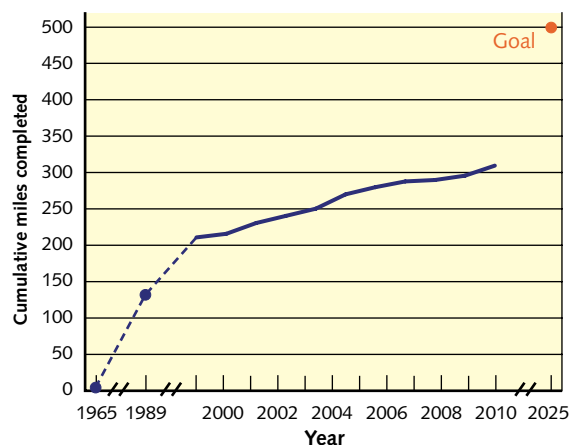
■ SUMMARY

Public access plays an important role in promoting stewardship activities that improve the health of the Bay. Comprehensive planning efforts by a wide range of stakeholders over the past four decades have led to a significant



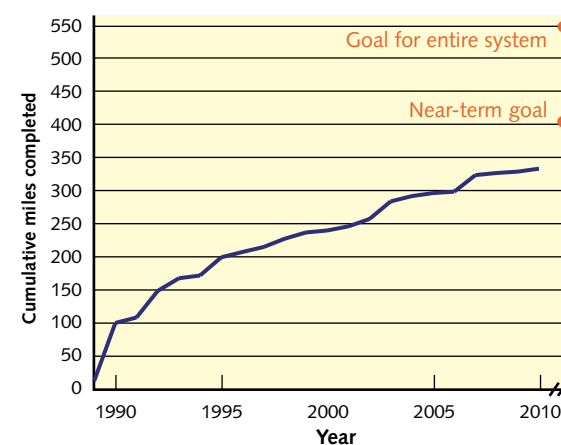
ABAG

Figure 30. Cumulative miles of San Francisco Bay Trail completed 1965–2010. * Data from Association of Bay Area Governments.



*Data for miles completed between 1966–1988 and 1990–1998 are interpolated.

Figure 31. Cumulative miles of Bay Area Ridge Trail completed 1989–2010. Data from the Bay Area Ridge Trail Council.



increase in the extent of the Bay accessible to the public. A framework for completion developed by ABAG in 2005 estimates that approximately \$150 million is needed to complete the entire Bay Trail by 2025. Continued success at attaining the goals for access will rely on adequate funding and the continued collaboration of individuals, agencies, and organizations.

Successful stewardship through management: the LTMS

A broad array of regulatory and management programs are designed to improve the health of the Bay, including programs that will expand and enhance habitat, improve water quality and adjust freshwater inflow, and protect living resources. All of these programs can be considered an aspect of stewardship—people working to improve the health of the Bay.

It was not possible to review indicators for all of these programs in this report. Below is one example of stewardship through regulatory effort, the work done to improve management of material dredged from the Bay.

The Bay supports a thriving maritime industry that is critical to the region's economy. Navigational channels and ports must be dredged for safe navigation. Until the late 1980s, most dredged material was disposed of at three sites in the Bay. After environmentalists, the fishing community and resource managers raised concerns about the impacts of this practice on the Bay's ecosystem, the Long Term Management Strategy for the Placement of dredged material in the San

Francisco Bay region (LTMS) was established by the San Francisco Bay Conservation and Development Commission, the San Francisco Bay Regional Water Quality Control Board, the San Francisco District of the U.S. Army Corps of Engineers, and the U.S. Environmental Protection Agency (EPA). The LTMS Management Plan includes goals for reducing the amount of dredged material disposed of in the Bay, and for maximizing the “beneficial reuse” of dredged

material for projects such as wetlands creation and levee restoration.

In 1994, the EPA established the San Francisco Deep Ocean Disposal Site (SF-DODS) as the first major alternative to in-Bay disposal. To date over 15 million cubic yards of dredged material that would have been dumped back into the Bay have been diverted to SF-DODS. Under the LTMS, resource managers also began using dredged material in wetland restoration and



MASTER OF TOWING VESSELS ASSOCIATION

landfill cover projects. Nearly 20 million cubic yards of dredged material have now been reused beneficially for such purposes. The LTMS program has also continued to reduce the effects of dredging itself, by strengthening sediment testing standards and instituting a variety of impact avoidance measures ranging from Environmental Work Windows to Essential Fish Habitat protection requirements. Together, these management actions are good examples of stewardship: industry and government agencies taking action to improve the health of the Bay.

■ HEALTH INDICATORS

The success of the LTMS's management actions to reduce the negative impacts of dredging on Bay health can be measured by examining the annual volume of in-Bay disposal of dredged material and the relative amount of disposal directed toward beneficial reuse.

BENCHMARK

These indicators are evaluated using the goals of the 2001 LTMS Management Plan:

- In-Bay disposal is to be reduced over a 12-year period to approximately 1.25 million cubic yards per year, to be implemented with annual in-Bay disposal volume targets reduced by approximately 387,500 cubic yards every 3 years.
- Beneficial reuse is to increase, with a long-term goal of achieving a minimum of 40% and up to 80 percent reuse per year by 2012 (with ocean disposal at SF-DODS making up any shortfall in this percentage).

■ KEY RESULTS AND TRENDS

Results of this analysis show that LTMS management actions have significantly reduced in-Bay disposal of dredged material (Figure 32) and increased beneficial reuse of dredged material (Figure 33) compared to pre-LTMS volumes. The annual individual in-bay disposal site limits and the interim total in-Bay limits have been met for every three year period, and the long-term goal of reducing in-Bay disposal to 1.25 million cubic yards per year by 2012 is on track to being met. In fact, since 2000, the long-term goal of disposing no more than 20 percent of dredged material in-Bay was already met in one year and was close to being met in three other years. Similarly, although

annual beneficial reuse volumes have fluctuated as large-scale projects have come on line and been completed, since 2000 the long-term goal of achieving a minimum of 40 percent reuse of dredged material has already been met in five of the years evaluated.

Less dredging being needed in the Bay has assisted in achieving these goals, since less sediment is being deposited in the Bay from its tributaries. In the early 1990s, resource managers projected that the annual volume of sediment dredged from the Bay between 1995 and 2035 would be 6 million cubic yards, but from 2000 to 2010, the annual average has only been half of this amount.

Figure 32. In-Bay Disposal of Dredged Material 1985–2009. Data from: BCDC Road Map (1998 and 1999); LTMS Management Plan (2001); DMMO annual reports (2000–2002, 2004, 2008); USACE database (tables from 2006–2009)

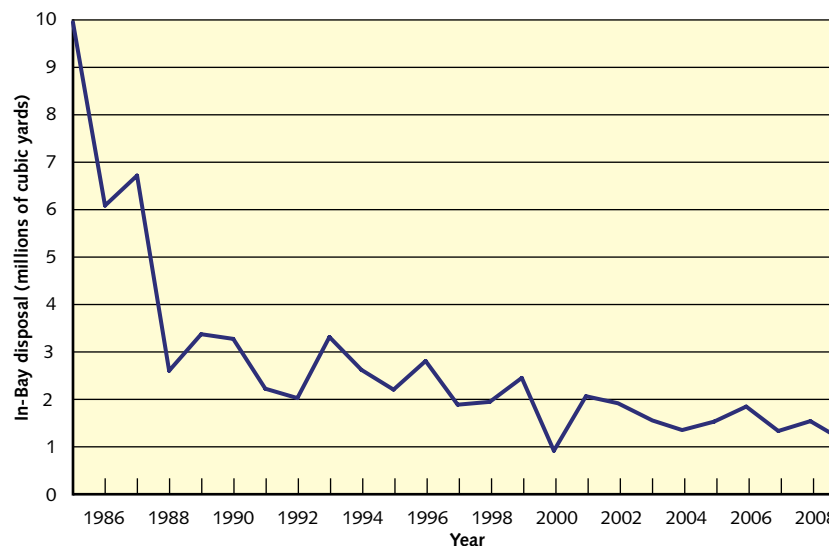
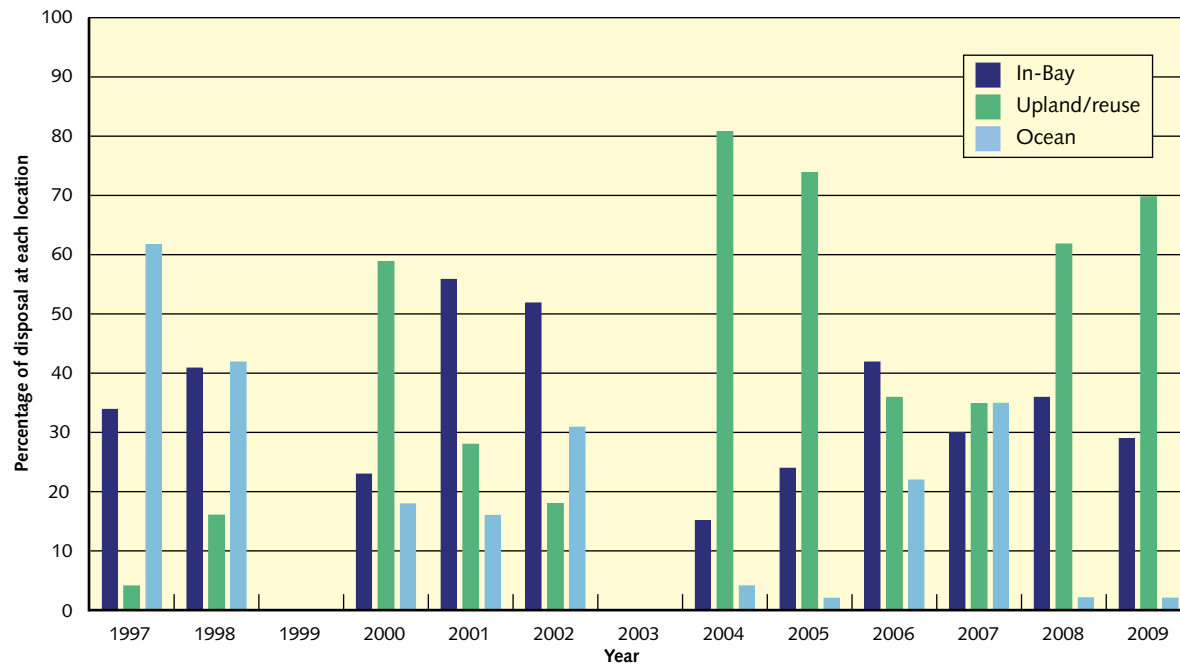


Figure 33. Distribution of Dredged Material by Disposal Location 1997–2009. * Data from: BCDC Road Map (1998 and 1999) DMMO annual reports (2000–2002, 2004, 2008); USACE database (tables from 2006–2009)



*Data not available for 1999 and 2003

SUMMARY

Through the collaborative stewardship efforts of several resource agencies and a broad range of stakeholders, the amount of in-Bay disposal of dredged material has been greatly reduced, improving water quality and subtidal habitat in the Bay. At the same time, the emphasis on beneficial reuse has created and enhanced over 3,000 acres of wetland and other aquatic habitats. Continued collaboration and cooperation of these groups should not only allow the long-term goals of the existing LTMS Management Plan to be met, but also provide a basis for adapting that plan to help protect and improve the health of the Estuary in the future.

What's Next?

Results from this assessment reveal a complex picture of Bay health. Some indicators show that aspects of Bay health are stable or improving slowly while others show declining trends. Clearly, work remains to “achieve and maintain an ecologically diverse and productive natural estuarine system” as envisioned in 1993 in the Comprehensive Conservation and Management Plan for the San Francisco Bay Estuary (CCMP). The members of the San Francisco Estuary Partnership remain committed to this goal as we continue to implement the actions called for in the CCMP. We also see opportunities to measure and evaluate that health more effectively, and to strengthen the integration of current monitoring and reporting efforts, both within the Bay proper and the Delta.

Continued work on improving Bay health

That significant additional actions will be needed to restore the Bay's health is not a surprise. It took many decades for the health of the Bay to reach its present compromised state, and



STRAY

RISE IMPACTS RAILS AND MICE MOST

While it has long been predicted that coastal areas and estuaries will be among the first to feel the effects of climate change and sea level rise, new USGS models show that sea level rise in the Bay could impact salt marshes sooner than thought—and that the endangered species that they are managed for—the California clapper rail, the black rail, and salt marsh harvest mouse—could suffer the most. The USGS study used RTK (Real Time Kinematic) GPS elevation data, plant community characteristics, and habitat information to develop sea level rise impact models for the San Pablo Bay National Wildlife Refuge. In contrast to most other models and maps, which are based on mean tides, USGS looked at what will happen during high tides. “If you’re talking about animals, you need to talk about tidal cycles,” says USGS’s Karen Thorne. “Animals don’t live in means—it’s the extremes that matter.” Thorne says the maps and models based on mean tides predict that the refuges around the Bay will be inundated in around 100 years. But the USGS model indicates a much shorter time frame: “Instead of being completely flooded by 1 meter of sea level rise, we’re looking at a half meter where you’ll have all of the refuge under water during high tides” says Thorne. “It’s much more imminent than 2100.”

Thorne says sea level rise will likely fragment habitat and make endangered species more vulnerable to predators, especially during the highest tides of the year. Right now those extreme events only happen a couple times a year, says Thorne, but as sea level rises, extreme events will happen more often. Thorne says USGS researchers have expanded their study to include 11 more marsh sites around San Francisco Bay, and found that some salt marsh patches are at much higher risk than others: a report was completed in July, 2011.* Thorne hopes her study will help resource managers save the rails and mice. “In San Francisco Bay resource managers really care; they’re very concerned and surprised. They want to know what to do but they don’t necessarily have the right information available to them.” Thorne says that because the San Pablo Bay refuge is near so much open space, an obvious solution in that area is to acquire and/or preserve adjacent land on which the Bay can expand. The bottom line, she says, is that “if you’re worried about endangered species, you need to take high tides into account.”

A slightly different version of this article first appeared in ESTUARY NEWS, April 2011.

**Takekawa, J.Y., K. Thorne, K. Buffington. Program Summary Report: Sea-level rise modeling across the California salt marsh gradient for resource managers. Unpublished Report, USGS San Francisco Bay Estuary Field Station, Western Ecological Research Center. July 2011.*



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the most tractable problems were attended to first (e.g., polluted discharges from specific facilities). While a number of significant improvements have been made to Bay health during the past few decades, we are making slower progress on some of our most challenging problems, such as reducing pollution from urban and nonurban runoff. Funding for major public works projects has been increasingly difficult to secure, and so improvements to public infrastructure that might alleviate some of the most challenging problems have not always been feasible. Nonetheless, work is underway to green streets and cities, to use and reuse water more efficiently, and to continue to address pollution in our waterways.

As the community of agencies and organizations work around the region on major restoration efforts, we recognize that the pace of restoration can be slow and that it takes time for restored landscapes to reach their full potential as habitat. And while restoration funding and technical challenges will need to be addressed, the citizens of our region highly value the Bay, and we expect that the Bay Area will continue to be a national leader in habitat restoration.

Significant hurdles continue to stand in the way of reaching the CCMP goal of “increasing the amount of fresh water that flows into the Bay in most years.” No clear path to achieving increased flows has yet emerged although efforts are now underway, both political and technical, to resolve aspects of this long-standing problem. The results of this analysis are consistent with previous evaluations and once again remind us that limited flows are having negative effects on the health of the Bay.

The San Francisco Estuary Partnership continues to implement the actions set out in the Comprehensive Conservation and Management Plan. The results of this report will assist efforts to focus on the most significant of those actions, help us make the best use of our resources, and provide a way to highlight the results of these efforts.

New and more refined health goals and indicators

While continued focus on long-term problems is vital, additional threats to the Bay's health continue to arise. The future condition of the Bay will be influenced by phenomena about which we are still learning—including climate change, the ecological impacts of species yet to be introduced to the Estuary, the impact of an aging pollution control infrastructure, and the influence of oceanic cycles such as the Pacific Decadal Oscillation or PDO.²⁶

The Bay is also entering a new phase of sediment cycling and supply. After many decades of sediment building up on the Bay bottom from gold mining and other activities, the Bay is now showing signs of erosion. This could hamper wetlands restoration goals because accumulation of sediment is essential to building new wetlands and keeping existing wetlands from being drowned as sea level rises. Less sediment in the water allows for more light penetration, which could lead to algal blooms that impact Bay water quality and recreational opportunities.

Given these challenges and uncertainties, an ongoing assessment of how well we're doing the

job is essential. We need thoughtful goals and benchmarks to help us map progress. We need indicators to help us track long-term physical changes so that we can continue to take the right steps to improve health and adapt to inevitable changes. We must clearly communicate to the public and to decision makers the condition of the Bay and present an accurate accounting of progress. This report delivers an essential snapshot of our understanding of the health of the ecosystem that can be used by scientists and resource managers in the future as they consider new information.

Future *State of the Bay* reports will be improved by refining existing indicators, developing new ones, and setting goals that can be used to evaluate those indicators (Table 7). For example, natural habitats—like wetlands, especially tidal marshes—that remove carbon dioxide from the atmosphere should be valued highly as the need to mitigate impacts from climate changes becomes clear to all. Understanding and tracking this ecological process will require new research to measure the movement of greenhouse gases into and out of different Bay habitats.

Table 7: Possible refinements for future *State of the Bay* reports.

INDICATOR REFINEMENT	RATIONALE
Carbon sequestration	Understand and measure Bay habitats as sources/sinks of greenhouse gases
Resilience to climate change	Understand if the Bay is becoming more or less capable of withstanding the expected stressors due to climate change
Sediment supply	Understand if there is enough sediment entering and circulating in the Bay to maintain and restore baylands
Nutrient cycling	Understand if processes that cycle nutrients through the Bay are being overwhelmed by human inputs
Aquatic resource restoration	Understand the extent and trends for restoration of eelgrass, oysters, and streams; add subtidal habitats goals and indicators
Watershed health	Improve and expand the use of current and new methods; go beyond the demonstration stage to assess regional watershed health; add upland habitat goals
Improved stewardship indicators	Improve existing stewardship indicators and develop additional measurements that highlight evolving public actions
Goals for existing indicators	Establish numeric goals for indicators such as the Fish Index or the Freshwater Flow Index to substitute for reference conditions that have not been subject to public debate

FISCAL AND REGULATORY CONSTRAINTS TO THE PACE OF HABITAT RESTORATION

Is the restoration of the Bay's habitats proceeding as fast as it should? If not, what constraints are slowing the process?

Funding, says San Francisco Bay Joint Venture coordinator Beth Huning, sets the pace of restoration. State bonds were a reliable source before the recent freeze. Federal stimulus funds channeled through NOAA helped deliver the South Bay Salt Pond and Napa Plant Site projects more quickly than initially projected.

Huning says a recent analysis for the San Francisco Foundation indicates that bond money will run out in about three years, with no new bonds in place. Congressional member requests for funding have ended with the elimination of the earmark system, leaving the budgeting process to federal agencies. As revenues decline, it will take more energy and strategy to match from multiple sources what was previously secured through direct appropriation or bond funding. That will make it difficult to maintain the recent pace of restoration.

Coastal ecologist Peter Baye, a long-time observer, sees current models of planning, budgeting, and implementing large restoration projects as products of the economic climate of the late 1990s and early 2000s, adapting slowly to recent economic decline. The resulting lag time could pose a challenge for large projects with long planning and implementation horizons, like Montezuma Wetlands.

Baye is also concerned that the feasibility of restoration may decline as sea level rise accelerates. He foresees a shift to projects with minimal flood-control costs relative to the size and importance of wetlands recovered, or selection of targets based on adjacent land use that is insensitive to flooding. Another adaptation might be providing habitat in more cost-efficient ways, such as reconnecting hydrology in existing muted marshes where limited tidal exchange occurs through culverts or small channels. However, Baye says some Fish and Game-led projects may already be as lean as possible under current regulatory and monitoring requirements.

Along with funding, the regulatory process can extend the timetable for restoration. Permitting can be time-consuming as project managers address endangered species and multiple jurisdictions. As Huning sees it, after the current group of restoration projects is delivered, it will be harder to deliver a second round of projects, due to declining funding.



MICHAEL BUKAY

Integration with other monitoring and reporting efforts within the Bay and Delta

The San Francisco Estuary Partnership plans to periodically produce *State of the Bay* reports and will refine and improve the methods and content of the report over time. Achieving these improvements will require the support and input of all the organizations that participate in the Partnership, and it will also require that the monitoring programs that generate the key datasets remain in place. Among these are the San Francisco Bay Program of the Department of Fish and Game and the Regional Monitoring Program for Water Quality managed by the San Francisco Estuary Institute (SFEI). Continuing these programs involves maintaining both the scientific expertise and the institutional support necessary to conduct the monitoring, analyze and report on the data, and maintain data archives so they may be used by future investigators.

Other evaluation reports, like SFEI's annual *Pulse of the Bay* and *Pulse of the Delta*, and The Bay Institute's *Ecological Scorecard* contribute significantly to Bay health assessment. We hope to strengthen the collaboration among these assessment programs as we work together toward an expanded "voice" for the health of the Bay.

Notes

1. Value derived from \$34 billion value of containerized goods at Port of Oakland (this is 99 percent of the Bay Area total). This is certainly a conservative estimate of the value of maritime commerce.
2. San Francisco Bay Restoration Authority Poll conducted by FM3 Associates, August 2010.
3. Fonseca, A. and P. Prange. May 2008. *The History of the San Jose/Santa Clara Water Pollution Control Plant: Celebrating over 50 Years of Service*. City of San José, Environmental Services.
4. CCMP. 1993. Frontpiece.
5. Estuary Partnership *State of the Estuary* report, 1993, p. 233.
6. These programs include the Regional Monitoring Program, the California Department of Fish and Game San Francisco Bay Study, and ongoing monitoring of San Francisco Bay water quality by the U.S. Geological Survey. See [technical appendix](#) for description of indicator screening process.
7. This step also identified indicators that would be valuable to analyze, but for which we presently do not have available data (see What's Next? (last section of report)).
8. The method by which indices are derived from their component indicators is described in the [Technical Appendix](#).
9. The California Office of Environmental Health Hazard Assessment (OEHHA) is the agency responsible for establishing safe eating guidelines for wild fish caught from California water bodies, including San Francisco Bay. OEHHA has developed thresholds called advisory tissue levels (ATLs) that are one component of their complex process of data evaluation and interpretation in the development of safe eating guidelines. Other factors are also considered in this process, such as omega-3 fatty acid concentrations in a given species in a water body, and risk communication needs. The San Francisco Bay Regional Water Quality Control Board has also used the exposure of people to pollutants in sport fish as a driver for establishing regulations regarding pollutant discharges to the Bay. More information on how numeric guidelines from these agencies were used is available in the [Technical Appendix](#). Safe eating guidelines for San Francisco Bay, issued by OEHHA in 2011, represent the definitive guidance for the public on the safety of consuming Bay fish.
 10. http://www.swrcb.ca.gov/rwqcb2/water_issues/programs/stormwater/mrp.shtml
 11. For more information on the indicators and the Freshwater Inflow Index, see [Technical Appendix](#).
 12. SWRCB (2010) Development of Flow Criteria for the Sacramento–San Joaquin Delta Ecosystem. State Water Resources Control Board report prepared pursuant to the Sacramento–San Joaquin Delta Reform Act of 2009, August 3, 2010. While the State Board report was used as the basis for the Freshwater Inflow indicator, it is important to note the limitations of the State Water Board approach to the setting of these criteria as expressed in the Executive Summary of the SWRCB report where it states [in part] “When setting flow objectives with regulatory effect, the State Water Board reviews and considers all the effects of the flow objectives through a broad inquiry into all public trust and public interest concerns. For example, the State Water Board would consider other public trust resources potentially affected by Delta outflow requirements and impose measures for the protection of those resources, such as requiring sufficient water for cold water pool in reservoirs to maintain temperatures in Delta tributaries. The State Water Board would also consider a broad range of public interest matters, including economics, power resources (such as habitat for terrestrial species). The limited process adopted for this proceeding does not include this comprehensive review.” Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/final_rpt.shtml.
 13. X2 is measured as the location of the 2 parts per thousand salinity in kilometers upstream from the Golden Gate. When inflows are high, brackish water habitat shifts downstream and X2 is low, for example 55 kilometers. When inflows are low, brackish water habitat shift upstream and X2 is high, for example 75 kilometers.
 14. Another basis for setting a goal is the federal anti-degradation policy provided in Section 303(d) of the 1972 federal Clean Water Act, which says in part that activities by people should not degrade the existing uses of waters of the United States, which includes tidal flats. This suggests that the amount of tidal flat existing in 1972 is the minimum acceptable amount. Of these two possible goals, the one for 1993 seems most appropriate because there is an accurate map of tidal flats for that time period, which is the same map used to set the acreage goal for tidal marsh. For the purposes of this

report, the amount of tidal flat that existed in 1993 is selected as the tidal flat acreage goal.

15. For the purposes of this report, an individual tidal marsh is defined as an area of the intertidal zone that supports at least 5 percent cover of vegetation and, during low tide, is completely separated from other areas of the same kind by uplands or open water at least 100 meters wide. This definition of a tidal marsh reflects what is known about the maximum widths of uplands and open water that resident marsh wildlife readily cross. It is also consistent with the discreet intertidal areas referred to by name as marshes, such as Whale Tail Marsh, Triangle Marsh, Arrowhead Marsh, and Petaluma Marsh. The maps of tidal marshes used to set the overall acreage goal for tidal marshes are based on this definition.
16. The 1993 California Wetlands Conservation Policy could be the basis for a goal. However, the marshes were already fragmented by 1993, and therefore might not represent the marsh sizes needed in the future.
17. The goals for larger marshes might be emphasized because of their assumed greater importance for wildlife protection. Given the range of marsh sizes in each size class, and the unknown marsh size requirements for many of the resident species of marsh wildlife, a 25 percent departure from the goals for small and medium size marshes might be acceptable.
18. Although the importance of Bay tidal flats as habitat is broadly recognized, the data and information about Bay tidal flat conditions are not adequate to establish benchmarks for assessing their condition. Hence, the discussion focuses just on tidal marsh.
19. The benchmark should reflect the precision of the attribute scores, which is about 10 points. Given that the mean score for Bay marshes is 53 (± 10), and that the mean score for North Coast marshes is 84 (± 10), the present condition of the Bay marshes is about 65 percent of their condition goal (\pm about 20 percent).
20. Catchment, catchment area, catchment basin, drainage basin, and drainage area are watershed synonyms.
21. It should be emphasized that this approach is only for the purposes of this report.
22. During the 1980s and most of the 1990s, the Pacific Decadal Oscillation (PDO) was in a “warm” phase, with relatively lower productivity in local coastal waters. In the late 1990s, the PDO shifted to a “cool phase,” improving conditions for many species like Dungeness crab that reproduce and feed in these ocean habitats.
23. Longfin smelt (CA threatened), Delta smelt (US threatened, CA endangered, Chinook salmon—winter run (CA and US endangered) Chinook salmon—spring run (CA and US threatened), Green sturgeon (US threatened), Central Valley steelhead (US threatened).
24. Counts were natural log-transformed for comparison with the reference period, 1989 to 1993. For dabbling ducks, benchmark values (expressed as mean log counts) varied from 1.04 (in Suisun Bay) to 6.65 (in South San Francisco Bay); for diving ducks, benchmark values varied from 4.74 (in Suisun Bay) to 6.93 (in the North Bay).
25. This indicator does not include the very small but growing effort by residents and businesses to recycle greywater on-site to meet irrigation and plumbing needs.
26. The PDO is a long-lived El Niño-like pattern of Pacific climate variability.

*“It is important for the region’s
economy to have a clean, healthy
and vibrant San Francisco Bay.”*

Statement supported by 92% of Bay Area voters in a 2010 poll

