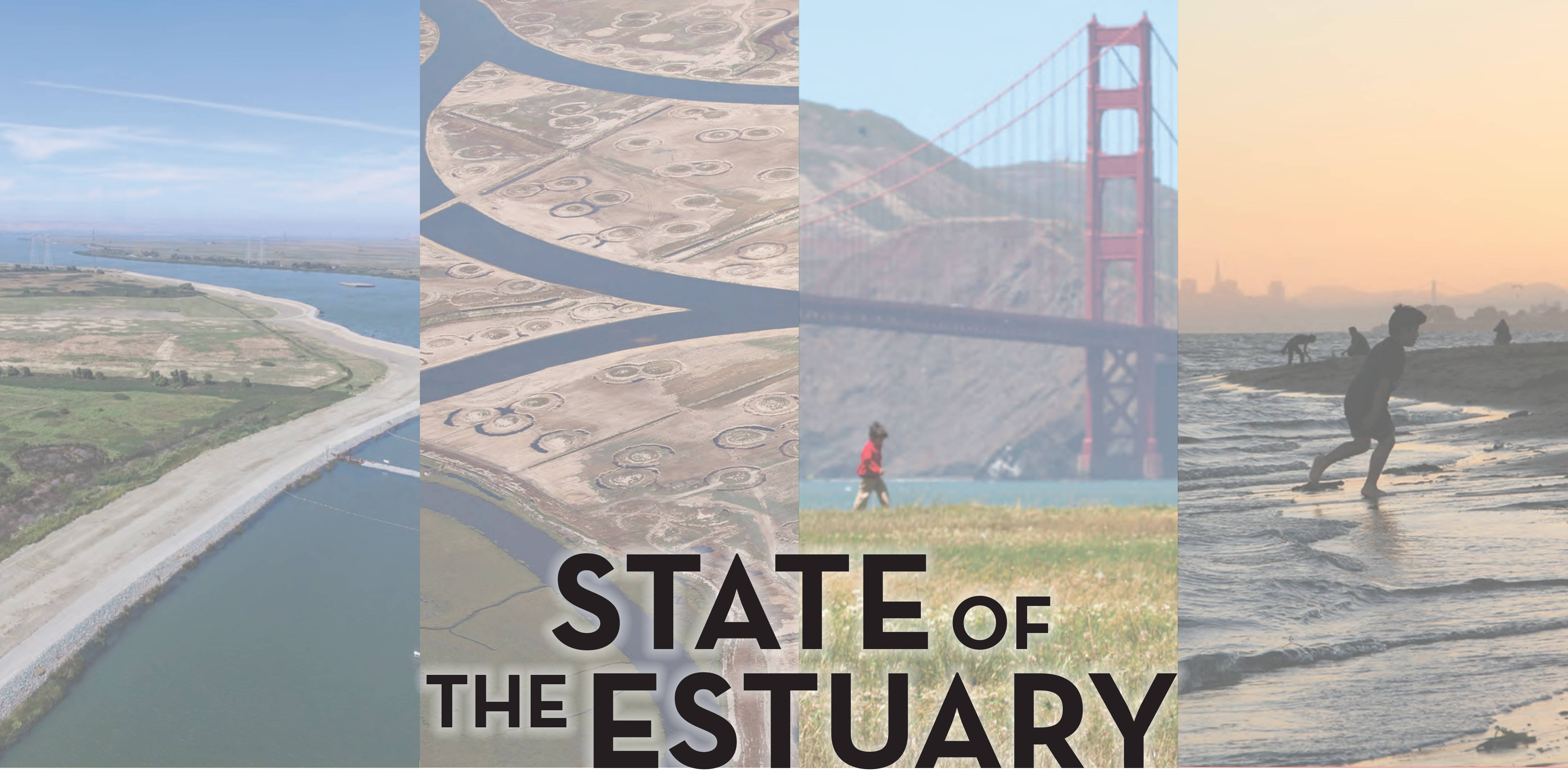

STATE OF THE ESTUARY 2015

STATUS AND TRENDS UPDATES ON 33 INDICATORS OF ECOSYSTEM HEALTH

A REPORT FROM
THE SAN FRANCISCO ESTUARY PARTNERSHIP

SAN FRANCISCO BAY & SACRAMENTO-SAN JOAQUIN RIVER DELTA
THE ESTUARY

The San Francisco Estuary Partnership was established more than 25 years ago by the State of California and the U.S. Environmental Protection Agency to prepare and implement a plan to better protect and restore the Estuary. Today, the Partnership manages over $100 million in regional restoration and water quality projects. The Estuary Partnership's local sponsor is the Association of Bay Area Governments. The Partnership is one of 28 National Estuary Programs across the country. More information about the Partnership, our staff, partners, programs, and projects can be found at: www.sfestuary.org

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San Francisco Estuary Partnership

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THE ESTUARY

THE ESTUARY, NORTHERN CALIFORNIA

CONTENTS

EXECUTIVE SUMMARY

J. LETITIA GRENIER
LEAD SCIENTIST

Photo: Shira Bezalel

The *State of the Estuary Report* is the most comprehensive health report ever completed for the San Francisco Bay-Delta Estuary. It uses the best available science and most recent data contributed by over 30 scientists to assess the status of various parts of the ecosystem. The purpose is to identify problems with estuarine health, so that conservation and restoration efforts can focus on solutions. This 2015 report expands on the scope of its predecessor in 2011, including Delta indicators for the first time, various new indicators for San Francisco Bay, and new sections linking the Estuary to the Gulf of the Farallones. The results show that the Upper Estuary (Suisun Bay and the Delta) is in critical condition. San Francisco Bay is in better health but jeopardized by climate change. Immediate action, significant investment, and bold changes to status quo management will be needed if we choose to recover and maintain a healthy estuary.

HOW HEALTHY IS THE ESTUARY?

The Upper Estuary (Suisun Bay and the Delta) is in fair to poor condition and getting worse, while the Lower Estuary (San Francisco Bay) is healthier. The status of half of the Delta indicators (most of which include Suisun Bay) is fair and the other half is poor. These indicators suggest that many Delta ecosystem components are either deteriorating over time, or have mixed trends across subregions. In contrast, the status of most Bay indicators is fair, with trends either improving or mixed across subregions.

WHY ARE THE DELTA AND SUISUN BAY IN CRITICAL CONDITION? WHY IS SAN FRANCISCO BAY IN BETTER CONDITION?

The Delta and Suisun Bay ecosystems are in poor health because human activities have had more profound impacts on the Upper Estuary than on San Francisco Bay. Also, restoration efforts are further along in the Bay, and the results show. Throughout the Estuary, the same three intertwined aspects of ecosystem degradation, described below, stand out as critical areas to address through management action.

First, we have severely altered the physical processes that create and maintain habitats. Freshwater inflows and beneficial floods now exert such a small fraction of their former influence that they no longer build and maintain the physical structure of habitats in the Estuary, nor support critical ecological functions. Indeed, diversions for human use have so reduced inflows that the Bay is in a state of chronic, artificial drought. This great loss means that low salinity habitat occurs over too small a space, too short a time, and too far upstream to support dependent food webs and wildlife. In the Lower Estuary, similar changes to the hydrology of Bay watersheds and the diking of tidal areas have deprived estuarine wetlands of the sediment they need to build up their elevation in relation to sea-level rise, something the Estuary's unfettered physical processes once accomplished. In the absence of more sediment, many Bay marshes will likely be lost to the advancing Bay in the decades to come.

Second, this impairment of critical physical processes is intertwined with habitat loss, degradation and fragmentation, which are generally more severe in the Upper Estuary. Tidal marsh now covers just 2% of its former extent in the Delta and most of the remaining patches are too small to support thriving populations of marsh-dependent wildlife. By contrast, the amount of current marsh and newly restored tidal areas in San Francisco Bay and Suisun Bay recently reached 50,000 acres – a landmark threshold halfway to the regional goal set just 16 years ago. In other habitats, low-salinity open waters in the Upper Estuary and woody riparian areas in the Delta have steeply declined. Eelgrass is in poor condition in the Bay but making a comeback due to restoration efforts.

Third, these losses of physical processes and habitats have reverberated through biological systems, contributing to unproductive food webs, small and declining native wildlife populations, and the dominance of invasive species. Indicator status consistently shows problems with burgeoning invasions (aquatic vegetation, invertebrates, and fish) and anemic food webs in the Upper Estuary. Food webs seem to be in somewhat better condition in the lower Estuary. The health of native fish communities strongly declines going upstream, with Bay fish in good condition and Upper Estuary fish in poor to very poor condition. Birds and mammals are generally in fair condition across the Estuary, although declines in the endangered Ridgway's rail in the South Bay and diving ducks in North and Central Bays are cause for concern.

Photo: Bird's Eye View

CAN WE MAKE THE ESTUARY HEALTHY?

Improvements in the status of several parts of the ecosystem show that we are very successful at restoring ecosystem health when we choose to make that investment. Water quality has improved over the last few decades due to substantial investment in sewage treatment, along with better management and regulation. Some legacy contaminants remain a problem, so managers are concentrating on reducing inputs from urban runoff. Focused collaboration along with significant funding have resulted in large gains in tidal marsh restoration over the last two decades, and improvements in marsh-dependent wildlife populations are now detectable as restored marshes mature. Investments in water conservation and recycling are reducing demand for potable water from sensitive ecosystems even while our population is increasing.

WHAT WILL IT TAKE TO ACHIEVE A HEALTHY BAY AND DELTA?

The mixed results of this assessment in different areas of the Estuary indicate that we are not doing enough to restore and maintain ecosystem health. A bolder approach will be needed to recover from past and ongoing impacts, especially since future impacts from climate change further jeopardize the ecosystem.

The Upper Estuary will require significant investment in restoring critical physical processes (notably freshwater inflows and floods) and habitats, as well as managing non-native species and preventing new arrivals. Protecting the Estuary will also require much greater efficiencies in human use of the system's fresh water, as well as changes in upstream water management and policy, to make the conserved water available to nourish the Estuary.

The Bay's wetlands are also at risk unless we take a new watershed-based, regional approach to managing sediment and fresh water as essential resources. We must also make room for tidal wetlands to migrate landward. Wildlife conservation efforts should aim to ensure successful reproduction and habitat connectivity over time as climate change alters landscapes. These management actions must all occur in the context of change in the ocean as well, requiring stronger planning for rising seas and more marine conditions in the Bay.

In short, the physical and biological processes that operate at the foundations of estuarine health are deeply damaged and must be fixed if we are to retain the Estuary's native plants and animals, wetlands (and their shoreline protection services), recreational opportunities, and clean water. This assessment of ecosystem health agrees with other regional science reports calling for stronger commitments to a healthier estuary.

This State of the Estuary Report, in conjunction with the more detailed report on Bay water quality in *The Pulse*, will be followed by a vision for how to restore the Bay's wetlands (the *Baylands Goals Science Update*, Oct 2015) and a new management plan for a more resilient estuary (CCMP, early 2016).

SUMMARY OF ESTUARY HEALTH 2015

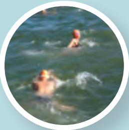
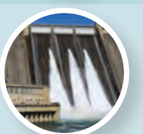
This table offers a brief, simplified summary of the 80 pages of information that follow in this report. The report, in turn, is based on painstaking work to assess the status and trends of the 33 indicators of estuary health listed below by teams engaging more than 100 scientists. Their in-depth analysis and methods are presented in the online technical appendix associated with this report. In a system as diverse as San Francisco Bay and the Sacramento-San Joaquin River Delta, status and trends findings resulting from any one indicator or another can be difficult to summarize in one ranking or trend. In ad- dition, data from a wide variety of monitoring, sampling, and research programs are summarized here — many of which divide up the Estuary into different zones. In particular, Suisun Bay, which links upper and lower estuary, is sometimes included in information provided about the Bay, and sometimes in that provided about the Delta. Suisun Bay is also sometimes included in descriptions of the North Bay, while in others San Pablo Bay and the North Bay are synonymous (check the technical appendix for clarifications on individual indicators). As part of the San Francisco Estuary Partnership's commitment to communicating the best available science to the community, so they can be well-informed in efforts to sustain the Estuary, we provide this summary and invite you to learn more about how it came to be by exploring the rest of the report.

ESTUARY HEALTH 2015

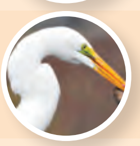
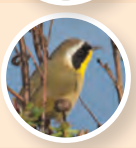
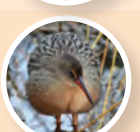
LEGEND

STATUS: GOOD FAIR POOR

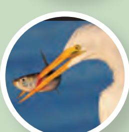
TREND: IMPROVING NO CHANGE DETERIORATING MIXED

WATER		BAY STATUS	BAY TREND	DELTA STATUS	DELTA TREND	AT-A-GLANCE
	SAFE FOR SWIMMING	GOOD	NO CHANGE			Conditions are excellent at most Estuary beaches most of the time. Conditions have been poor at 7% of beaches in summer, and 27% of beaches in wet weather at times during recent years.
	SAFE FOR AQUATIC LIFE	ESTUARY-WIDE FAIR	ESTUARY-WIDE IMPROVING			Estuary water quality is much better than 40 years ago, but the rate of improvement has slowed. Mercury, invasive species, pesticides, and trash are still problems. Improvement has been achieved for PBDEs and copper. Many potentially harmful chemicals have yet to be assessed.
	FISH SAFE TO EAT	ESTUARY-WIDE FAIR	ESTUARY-WIDE NO CHANGE			Limited consumption of most popular Estuary fish species is advised due to contamination from two legacy pollutants (mercury and PCBs). Routine monitoring in place since 1994 has shown no declines in these contaminants.
	FRESHWATER INFLOW	ESTUARY-WIDE POOR	ESTUARY-WIDE MIXED			The amounts and variability of freshwater inflow to the Estuary have been substantially reduced, resulting in degradation of habitat conditions and ecological function in the Estuary.
HABITAT						
	OPEN WATER HABITAT	POOR	MIXED	POOR	DETERIORATING	In Suisun Bay, good quaiity, low salinity habitat occurs too infrequently, and for too short a time, to support flow-dependent organisms and the estuarine food web. In Delta channel habitats, net downstream flow is too low to support native fish species.
	EELGRASS	POOR	IMPROVING			The extent of eelgrass beds in the Estuary has increased, but is highly variable year to-year. The current total acreage is significantly less than the estimated maximum potential extent.
	TIDAL MARSH	FAIR	IMPROVING	POOR	NO CHANGE	Delta marshes have been lost and fragmented to a much greater degree than Bay marshes, despite covering a greater area historically. Restoration efforts have made a significant impact on Bay habitats, but are only just getting underway in the Delta.

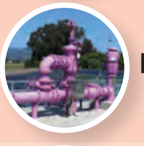
SUMMARY, CONTINUED

WILDLIFE	BAY STATUS	BAY TREND	DELTA STATUS	DELTA TREND	AT-A-GLANCE
 BENTHIC INVERTEBRATES			FAIR	↑→↓	The benthic community at the foundation of the food web still includes many native species, but there are now many non-native species present as well. In some places, most individual benthic organisms are non-native.
 FISH	GOOD	↑→↓	POOR	↓	The fish community differs across the Estuary with increasingly poor conditions toward the upper Estuary. Native fish abundance in the brackish and fresh upper Estuary has declined markedly during the past three decades and is in poor condition.
 HARBOR SEALS	FAIR	→			Harbor seal numbers in the Bay are relatively stable, but have not increased in tandem with coastal populations.
 WINTER WATERFOWL	FAIR	↑→↓			Wintering dabbling duck populations are strongly increasing across all parts of San Francisco Bay. Wintering diving duck populations are strongly decreasing in Central and North Bays but remain stable in the South Bay.
 BREEDING WATERFOWL			FAIR	↓	Populations of dabbling ducks that breed in the Estuary are mostly decreasing across Suisun Marsh and the Delta. Less common dabblers (non-Mallards) are increasing in the Delta.
 SHOREBIRDS	FAIR	↑→↓			The Estuary's population of large shorebirds is declining, especially in the South Bay. In the Central and North Bay, populations of medium and small shorebirds are stable or increasing, while in the South Bay they are on the decline.
 HERONS & EGRETS	FAIR	↑→↓			Heron and egret nest density is increasing over the long term. Nest success, in terms of fledged chicks, is relatively stable. Subregions reveal more complex patterns.
 TIDAL MARSH BIRDS	FAIR	↑			Tidal marsh bird densities are increasing for two of three species. As restored marshes mature, they are supporting more resident marsh birds.
 RIDGWAY'S RAIL	POOR	↑→↓			In the North Bay, endangered Ridgway's rail populations have rebounded since a 2007-2009 decline. South Bay populations have stabilized at low levels after a similar decline, but not rebounded.

LEGEND	STATUS	TREND:	IMPROVING	NO CHANGE	DETERIORATING	MIXED
	GOOD FAIR POOR					

PROCESSES	BAY STATUS	BAY TREND	DELTA STATUS	DELTA TREND	AT-A-GLANCE
 MIGRATION SPACE	ESTUARY - WIDE: POOR			NO DATA	Most land around the Estuary available for estuarine habitats to migrate landward, and accommodate higher sea levels, has been developed. Very little of the undeveloped portion is protected.
 BENEFICIAL FLOODS	POOR	MIXED	POOR	MIXED	Flood flow events are now too infrequent, too small and too short in the Estuary to support important ecological processes. Dams, levees and water diversions have cut high volume inflows and beneficial inundation of the Yolo Bypass floodplain.
 ZOOPLANKTON AS FOOD			FAIR	MIXED	The abundance of zooplankton has decreased in Suisun Bay and the Delta since the 1980s invasion by the clam *Potamocorbula amurensis*, resulting in reduced food availability for fish. In recent years zooplankton populations have been stable.
 FISH AS FOOD			FAIR	DETERIORATING	The abundance of fish varies across the Upper Estuary. In the historically productive marsh and open water zones, small forage fish are declining, but in the Delta beach zone, they are increasing.
 CORMORANT CHICKS RAISED	GOOD	NO CHANGE			The breeding success of Brandt's cormorants in recent years indicates that they are finding enough food in the open waters of the Estuary to feed their young, following a severe decline in success from 2009-2012.
 HERON & EGRET CHICKS RAISED	FAIR	MIXED			Heron and egret brood size is relatively stable across the Bay.

SUMMARY, CONTINUED

PEOPLE	BAY STATUS	BAY TREND	DELTA STATUS	DELTA TREND	AT-A-GLANCE
 **URBAN WATER USE**	FAIR	↑			In the Bay Area, urban water conservation efforts have lowered water use while population has increased. Short-term water use reductions in response to the drought have exceeded State-mandated targets but they may be short-lived.
 **RECYCLED WATER USE**	FAIR	↑			The Bay Area currently offsets 5% of its urban water demand with recycled water, but lags behind other urban centers in the state.
 **TRAIL ACCESS**	FAIR	↑			In recent years, public access to Bay and Delta trail systems has steadily increased.

A HISTORY OF EVALUATION & ACTION

This Report is the latest in a series of evaluations of bay and estuarine health going back decades. In one of the first global assessments of human impacts, Nichols et al published *"Modifications of an Estuary"* in *Science* (1986). In the early 1990s, the Partnership hired local scientists to write six "status and trends" reports about the Estuary. These reports assembled the best available science on the pressing environmental concerns of the day — pollution, dredging, endangered fish and wildlife, land use, and wetlands. Summarizing this information, the Partnership published the first full State of the Estuary report in 1992 and began the tradition of asking hundreds of decision-makers, scientists, activists and citizens to share such findings at a State of the Estuary Conference every two years.

Photo: Rick Lewis

During this same period, new institutions such as the San Francisco Estuary Institute and the Delta Science Program (then the CalFed Bay Delta Program) were created to improve tracking and assessment of human impacts on the Estuary. By 1996, Environmental Defense and The Bay Institute began development of a set of scientific, ecological indicators to evaluate the Estuary's health, work that led to The Bay Institute's 2003 *Ecological Scorecard*. In 2011 and now 2015, the Estuary Partnership used these indicators as the basis of our State of the (Bay) Estuary reports. From the start, these health assessments were used to create the actions in the Partnership's *Comprehensive Conservation and Management Plan* (CCMP, 1993, 2007 and 2016).

Like all ecosystems, the Estuary is not static. The system is responding to global climate change, shifts in ocean and estuarine food webs, and right now, a severe drought. Humans continue to create change as well through the many uses and demands we apply to our waters and their supporting watersheds. Humans have also been working to heal the Estuary — in part through habitat restoration projects and the creation of laws that better protect our native species and the lands and waters on which they depend.

As this report goes to press, deep in the state's fifth year of extended drought and one of the hottest years on record, we see signs that a number of species and systems may be reaching their limit. Delta smelt, an endangered estuarine fish, may have gone functionally extinct since the 2011 *State of the Bay Report* was published. Wetlands we have worked to restore are likely to face future flooding from rising seas. Sierra snowpack — the foundation of the state's vast water supply system — will less and less reach the depths necessary to sustain our cities, farms, and industries, given current demands.

As we enter a new era of greater extremes and struggle to respond with effective actions, we will need to chronicle what we are losing and what we are gaining from our management efforts. My hope is that the *State of the Estuary Reports* will continue to provide part of the foundation for this critically important work.

Judy Kelly
San Francisco Estuary Partnership

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Pervasive Pesticides, Jay Davis, Thomas Jabusch, San Francisco Estuary Institute; Kelly Moran, TDC Environmental; Stephanie Fong, State and Federal Contractors Water Agency

A Drinkable Delta, Lynda Smith, Metropolitan Water District of Southern California

Freshwater Inflows, Christina Swanson, Natural Resources Defense Council

The Ecosystem's Share, Greg Reis, Jonathan Rosenfield, Peter Vorster, The Bay Institute and SFEP Staff

HABITAT

Open Water Habitat, Christina Swanson, Natural Resources Defense Council.

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Oyster Beds, Caitlin Sweeney, San Francisco Estuary Partnership; Korie Schaeffer, NOAA Fisheries West Coast Region; Natalie Cosentino-Manning, NOAA Fisheries Restoration Center; Marilyn Latta, State Coastal Conservancy

Tidal Marsh Extent and Patch Size, Samuel Safran, San Francisco Estuary Institute

Woody Riparian Habitat, Samuel Safran, San Francisco Estuary Institute

Managed Ponds, SFEP Staff

WILDLIFE

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Harbor Seal, Denise Greig, California Academy of Sciences; Sarah Allen, Ocean and Coastal Resources Program, National Park Service

Wintering Waterfowl, Nadav Nur, Point Blue Conservation Science; Orien Richmond, United States Fish & Wildlife Service; Susan De La Cruz, United States Geological Survey.

Breeding Waterfowl, Hildie Spautz and Dan Skalos, California Department of Fish and Wildlife

Three Delta Birds of Concern: Black Rail, Tricolored Blackbird, Sandhill Crane

Black Rail, Hildie Spautz, California Department of Fish and Wildlife

Tricolored Blackbird, Hildie Spautz and Neil Clipperton, California Department of Fish and Wildlife, Bob Meese, University of California, Davis

Sandhill Crane, Hildie Spautz, Julie Garcia, California Department of Fish and Wildlife; Gary Ivey, International Crane Foundation

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Shorebirds, Matt Reiter, Nadav Nur, Point Blue Conservation Science

Herons and Egrets, John Kelly, Audubon Canyon Ranch, Nadav Nur, Point Blue Conservation Science

Tidal Marsh Birds, Nadav Nur and Julian Wood, Point Blue Conservation Science

PROCESSES

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Sediment on the Move, Letitia Grenier, San Francisco Estuary Institute, SFEP Staff, Greg Reis, Jonathan Rosenfield, Peter Vorster, The Bay Institute

Beneficial Floods, Christina Swanson, Natural Resources Defense Council

Blooms, David Senn, San Francisco Estuary Institute

Invasions, Shruti Khanna, Joaquim Bellvert, Kristen Shapiro, and Susan L. Ustin, Center for Spatial Technologies and Remote Sensing, University of California, Davis

Zooplankton as Food, April Hennessy, California Department of Fish and Wildlife

Fish as Food, Alison Weber-Stover and Jonathan Rosenfield, The Bay Institute

Heron and Egret Young Reared, John Kelly, Audubon Canyon Ranch, Nadav Nur, Point Blue Conservation Science

Cormorant Young Reared, Nadav Nur, Point Blue Conservation Science

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Recycling Water, Peter Vorster, The Bay Institute

Next Generation Education, Darcie Luce, San Francisco Estuary Partnership

Trails, Darcie Luce, San Francisco Estuary Partnership

Volunteering for Watershed Health, Darcie Luce, San Francisco Estuary Partnership

SUPPORTING MATERIALS

This report is based on the more in-depth analysis and work of the individuals and science teams listed above. Their original papers and summaries can be found in the online technical appendix at http://sfestuary.org/about-the-estuary/soter/

WATER

- SAFE FOR SWIMMING
- SAFE FOR AQUATIC LIFE
- PERVASIVE PESTICIDES
- FISH SAFE FOR EATING
- DRINKABLE DELTA
- FRESHWATER FLOWS
- ECOSYSTEM WATER

OVERVIEW

Photo: Mark Rauzon

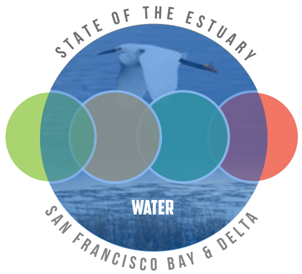
Water touches every aspect of the Estuary's health. The amounts and variability of freshwater inflows from rivers and streams – defining characteristics of an estuary – create habitat for fish and wildlife, trigger migration and reproduction, and fuel the productivity and ecological processes that make estuaries such rich and vibrant ecosystems. However, human alterations to the watershed and within the Estuary itself, such as dams, water diversions, levees, dredging and channelization, have changed freshwater inflow amounts and patterns. These changes, in turn, have affected estuarine habitat, wildlife and ecological functions. Therefore, freshwater inflow conditions are useful indicators of estuarine health.

Water quality is also an important indicator of the state of the Estuary. Organisms that spend their lives immersed in water or feeding from the aquatic food web are strongly affected by conditions in the water, including temperature. They are also affected by levels of oxygen, contaminants, and nutrients in the water. Clean water is also essential for human use of the Estuary — as a source of drinking water and food, or as a place to enjoy swimming, windsurfing, and other forms of water recreation.

Water is central to the Estuary and directly influences ecological outcomes. Given that people manage or influence so many aspects of freshwater inflow and water quality, water may be our most powerful tool for restoring health to the Estuary.

TAKE HOMES

- Conditions at 22 of 28 Bay beaches in summer were excellent ("safe") for water recreation most of the time in 2012 and 2013. Two San Mateo County beaches, Aquatic Park and Lakeshore Park, consistently have poor conditions in both wet and dry weather.
- The Estuary is in fair condition in terms of providing clean habitat that supports abundant, diverse communities of the animal and plant species that live in or depend upon the Bay, including algae, zooplankton, macroinvertebrates, fish, aquatic birds, and marine mammals.
- Pollutants posing the greatest threats to the development and survival of aquatic life in the Estuary include mercury, invasive species, pesticides, and trash.
- In the Bay, concentrations of mercury in some embryos and chicks of certain fish-eating birds like Forster's terns are high enough to kill them. High mercury levels also threaten the endangered Ridgway's rail.
- Pesticides are of particular concern in urban creeks and sometimes the water bodies into which they flow, such as the Delta, where recent studies have implicated pyrethroids as the cause of toxicity to invertebrate test organisms.
- Salmon and trout caught in the Estuary are safe to eat, with levels of all measured contaminants below thresholds of concern.
- Striped bass, black bass, white croaker, shiner surfperch, and other species should be eaten less frequently, in accordance with state consumption advice, due to high levels of PCBs and mercury.
- Pregnant women and children consuming Estuary-caught fish are especially at risk, and should carefully follow state consumption advice.
- The amounts and variability of freshwater inflows to the Estuary have been reduced to levels too low to support critical ecological processes or protect estuarine fish.
- Most of the ten indicators used in the composite Freshwater Inflow Index showed "poor" or "very poor" conditions.
- Human alterations to inflows have created chronic drought conditions in the Estuary that, particularly in the upstream region, impair ecological function, degrade habitat and productivity, and contribute to increasingly serious fish population declines.
- In the Delta, source water diverted for drinking water purposes continues to be safe to drink following treatment, and monitoring and regulatory programs are important for addressing ongoing water quality challenges.



SUPPORTING MATERIALS

This chapter summarizes data and materials written by the authors listed on page 12 and provided in full in the technical appendix for the State of the Estuary 2015 report. Go to: http://sfestuary.org/about-the-estuary/soter/

Water chapter pelican & fish photo: Rick Lewis

SWIMMING

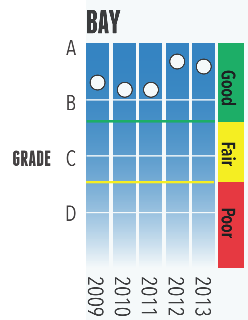
CONTEXT The Estuary's numerous shoreline parks and beaches invite residents and visitors to have more direct contact with the Bay than ever before. Bay beaches logged over 7.5 million visits over the course of a recent year, as people went to the shore to swim, play, wade, surf, and fish. The Estuary's bays and rivers are also popular for kayaking, wind-surfing, kite-boarding, and other water recreation. Clean Water Act protections have made the Bay much cleaner than in decades past, and at most monitored locations it is safe for swimming and water sports throughout the year. In some locations, however, getting into the water can expose people to potentially infectious bacteria, viruses, and protozoa. While the health risks are generally neither chronic nor severe, swimming-related illnesses (including diarrhea, colds, fevers, sore throats, and skin, ear, respiratory, eye, and wound infections) occur frequently enough to warrant monitoring of fecal bacteria levels at Bay beaches, and associated public warning protocols when standards are exceeded. Delta beaches are not routinely monitored.

Photo: Susanne Friedrich

INDICATOR The safe for swimming and water recreation indicator derives from California standards concerning the level of fecal indicator bacteria (FIB) in the water. Tests for FIB commonly measure total coliform levels, as well as levels of fecal coliforms from specific bacterial groups like *Escherichia coli* and *Enterococcus*. California's FIB standards apply from April through October at high-use beaches that are adjacent to a storm drain that flows in the summer.

STATUS & TRENDS This indicator summarizes safe-for-water-recreation grades (based on FIB standards) given to popular Bay beaches by Heal the Bay, a Santa Monica-based non-profit that translates monitoring data into Beach Report Cards. Heal the Bay reports on over 400 California bathing beaches. Overall, the latest beach report card covering the summer of 2013 indicated that conditions were excellent at 22 of 28 of Bay beaches in the summer, and at a slightly lower percentage of beaches (14 of 22) in wet weather. Two beaches were in poor condition in summer, while 6 of 22 beaches were in poor condition in wet weather. The Bay-wide average grade has been fairly constant over the past five years. Enjoyment of Estuary beaches contributes greatly to the economy and quality of life for residents and tourists. Recreation at polluted beaches, however, can be costly. A Southern California study, for example, concluded that the public health cost of gastrointestinal illnesses suffered by people coming into contact with polluted ocean waters was between $21 million and $51 million each year.

SAFE FOR SWIMMING



BAY

..STATUS..
Good

....TREND....
No change

.....BENCHMARK.....
State standards for public health risk

THREATS & CHALLENGES Contact with Estuary waters will continue to grow as the population grows and the popularity of water recreation increases. Concern is also rising about the potential for exposure to toxins from harmful algal blooms. Reports of swimmer's itch, an allergic rash common among East Coast beachgoers, are on the rise in the Bay Area. The itch comes from a parasite on an invasive snail. Likewise, extreme weather and flooding associated with climate change could exacerbate fecal contamination from sewer overflows and stormwater runoff.

AQUATIC LIFE

CONTEXT Pollutants in water and sediment pose a threat to the health and survival of species at all levels of the Estuary's food web. In an effort to protect them, water quality laws and regulations require that the Estuary be clean enough to support abundant, diverse native communities of plants and animals. However, human activities continue to add contaminants to the ecosystem via municipal and industrial discharges, agricultural and urban runoff, and other pathways. Species both at the bottom of the food chain, as well as the fish and birds that eat them, can suffer from toxic or reproductive effects. Birds that dive for fish, or forage in the mud for food, face significant risks from mercury exposure, for example. The region's water quality monitoring programs perform diverse measurements to evaluate whether pollutants are causing adverse impacts on the health and survival of species that live in the Estuary.

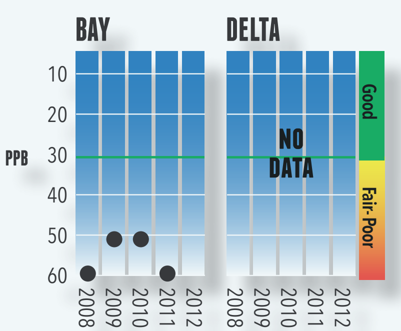
INDICATOR The "safe for aquatic life" water quality indicator measures mercury concentrations in the food web, the toxicity of Estuary waters in laboratory tests, and concentrations of chemical pollutants in water. Benchmarks for these measures have been established by the San Francisco Bay and Central Valley Regional Water Quality Control Boards.

Fish-eating birds like these terns are most at risk from mercury in their food. Photo: Verne Nelson

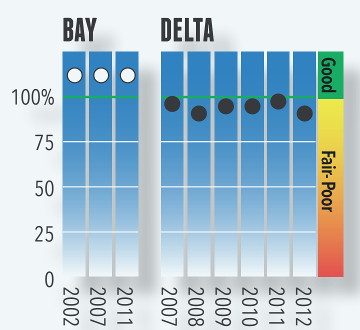
STATUS & TRENDS Over a hundred pollutants are routinely monitored and found at concentrations that meet water quality goals, and are considered to pose very low risk to aquatic life in the Estuary. Overall, water quality is fair with regard to protection of aquatic life. Several pollutants are still problems, however, including mercury, invasive species, pesticides, and trash. Pollutant concentrations in Estuary water are sometimes high enough to affect the development and survival of aquatic invertebrates. Mercury concentrations in the Estuary food web have not changed perceptibly over the past 40 years, and are expected to decline very slowly in the next 30 years. Important improvements in Estuary water quality have occurred in the last four years. A major success story for the Bay continued to unfold, as declining trends in polybrominated diphenyl ethers (PBDEs) in wildlife and sediment were documented following an industry phase-out and state ban. With increased attention to impacts from invasives and trash, more rapid improvement can be expected on this water quality front.

DETAILS

MERCURY
PARTS PER BILLION IN SMALL FISH



WATER TOXICITY
PERCENT OF SAMPLES THAT WERE NON-TOXIC TO INVERTEBRATES

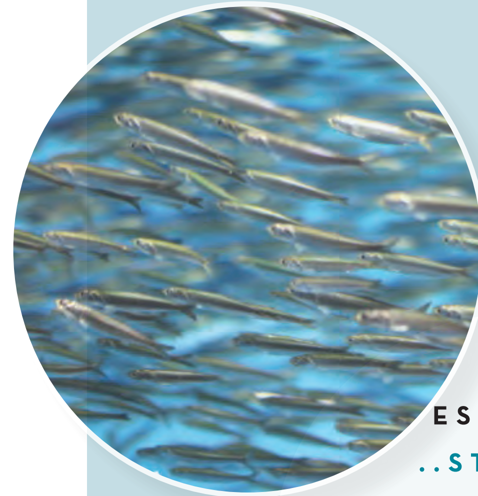


THREATS & CHALLENGES

Pollutants continue to threaten the health and survival of aquatic life in the Estuary. Scientists have found enough mercury in the embryos and chicks of some fish-eating birds to cause mortality, and mercury also threatens the endangered Ridgway's rail. They've also linked pyrethroids, a class of pesticides, to toxicity in tests of Delta invertebrates (see p.19). Meanwhile, exotic clams, snails and other imports from foreign ports, as well as invasive wetland and riparian plants, continue to displace native species, disrupt communities and food chains, and alter habitat throughout the Estuary. Despite local bans on plastics, trash still accumulates on shores and along creeks, washing and blowing into the Bay and ocean. Plastic poses a particular long-term threat because it is so persistent. Fishing lines and six pack-holders can entangle wildlife; degraded plastic particles and beads can slowly poison or choke the creatures that eat them.

Humans, meanwhile, continue to invent new and replacement chemicals, adding as yet unknown impacts on the health of aquatic life to those already coming from the insecticides, herbicides, fungicides, rodenticides, antibiotics, beta blockers, stimulants, pain relievers, lipid reducers, antidepressants, anxiety reducers, hypertension relievers, insect repellents, stain repellents, detergents, flame retardants, lubricants, polymers, plasticizers and nanomaterials, along with their byproducts, that find their way into the Estuary. Scientists suspect that exposure to this dilute soup of Estuary additives could have cumulative or synergistic effects on aquatic species. They are also concerned about the effect of chemical exposure on top of other stressors. Quantifying the net effect of these pressures remains a challenge.

SAFE FOR AQUATIC LIFE

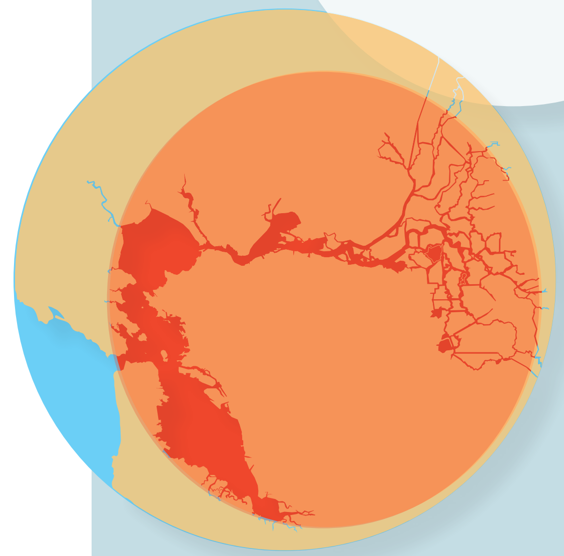


ESTUARY

..STATUS..
Fair

....TREND....
Improving

.....BENCHMARK.....
Non-toxic to aquatic life



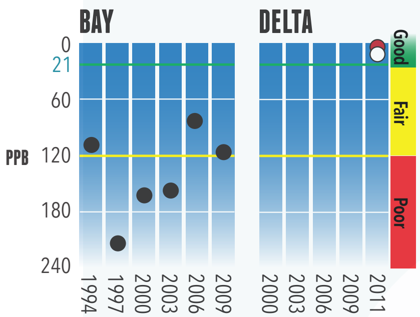
FISHING

CONTEXT Many people enjoy fishing in the waters of San Francisco Bay and Delta rivers, and some eat the striped bass, trout, croaker and other fish they catch. Fish are nutritious, containing both protein and omega-3 fatty acids that can reduce the risk of heart disease and improve brain development in unborn babies and children. Pollutants in Estuary fish, however, can reach concentrations that pose health risks outweighing the benefits. High consumption rates among subsistence fishers and some cultural groups make fish contamination an environmental justice issue estuarywide.

Photo: Max Eissler

FISH SAFE FOR EATING

PCBs



LEGEND
- Sacramento Sucker
- Shiner Surfperch
- Carp

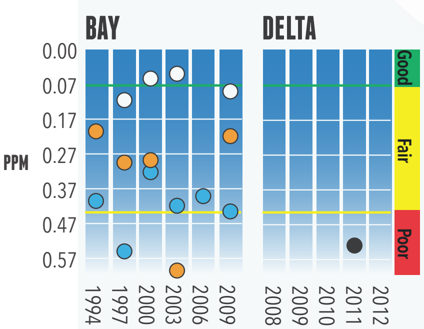
ESTUARY

..STATUS..
Fair

....TREND....
No change

.....BENCHMARK.....
State health hazard guidelines

MERCURY



LEGEND
- Jacksmelt
- Striped Bass
- Halibut
- Black Bass

INDICATOR This indicator evaluates concentrations of pollutants of concern in the tissue of fish species popular for consumption by anglers. Pollutant concentrations in fish are compared to goals established by the California Office of Environmental Health Hazard Assessment (OEHHA) to protect public health. Comparisons presented here are general indications of levels of concern. Consumers can reduce their exposure to pollutants by following consumption advice developed specifically for the Bay and Delta by OEHHA.

STATUS & TRENDS Estuary water quality is fair with regard to the fish being safe to eat. Some species, such as salmon and trout, are safe for consumption, and many pollutants are below thresholds for concern across all species, including arsenic, cadmium, chlorpyrifos, diazinon, dieldrin, DDTs, PAHs, PBDEs, and selenium. However, limited consumption of many popular Estuary fish species is advised by OEHHA due primarily to contamination from two legacy pollutants: mercury and PCBs. Neither of these pollutants has shown signs of decline over the past 20 years. (The mercury traces back to historic gold and mercury mining and the PCBs, now banned, to old equipment, building materials, and other sources).

THREATS & CHALLENGES

Mercury and PCB concentrations in some Estuary fish species can present a health risk to fish consumers, especially children and fetuses, which can be exposed via their mother's diet. Mercury can negatively affect how the brain develops in unborn babies and children, including potential decreases in learning ability, language skills, attention, and memory. It is especially important for women who are pregnant or breastfeeding to follow OEHHA's consumption guidelines. Men, women and children alike are at risk from PCBs that, as they accumulate over time, can cause cancer and developmental problems.

PERVASIVE PESTICIDES

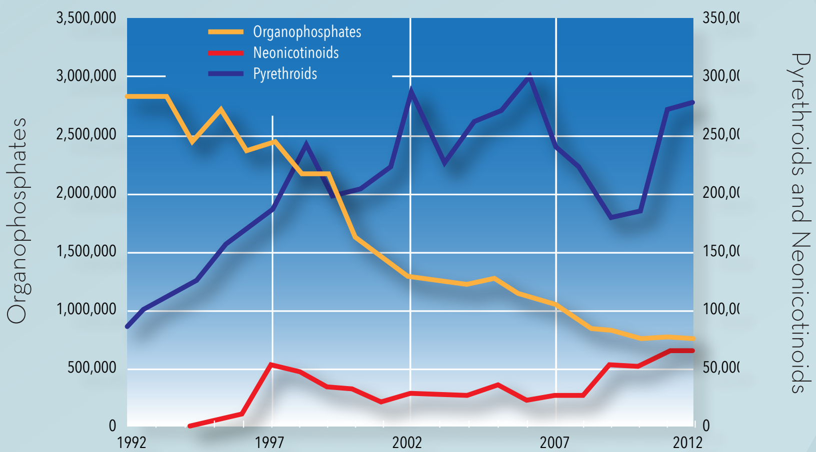
Jack Kelly Clark, ANR, UC

Pesticides are expected to be a long-time influence on the health of the San Francisco Bay-Delta Estuary. Pesticide-caused toxicity is well-documented in the Estuary and in waterways across California. These chemicals are designed to kill unwanted indoor and outdoor organisms, so it's not surprising that pesticides are among the highest-risk chemical compounds to aquatic life.

Farmers, property managers, consumers, gardeners, and boaters all use pesticides to control pests — from ants and termites to microbes and fungi. However, the majority of pesticide applications that directly affect the watershed are made by professionals hired to keep bugs out of buildings. Pesticides are a family of chemicals that include over 1,000 insecticides, herbicides, fungicides, rodenticides, and antimicrobials. These chemicals enter the Estuary primarily from urban and agricultural runoff and treatment plant discharges. And while California is the nation's leading agricultural state, more than half of California's total pesticide use happens in urban areas. By 2013, California's pesticide sales exceeded 288 million kilograms.

INSECTICIDES APPLIED IN THE SAN FRANCISCO ESTUARY WATERSHED

REPORTED POUNDS PER YEAR



Regulation of organophosphate insecticides has caused a shift toward pyrethroids and neonicotinoids. Courtesy of Jim Orlando, U.S. Geological Survey

In the 1990s, scientists linked the commonly-used organophosphate insecticides diazinon and chlorpyrifos to toxicity in the Estuary and its tributaries. State and federal regulators took several actions to address organophosphate pollution, including an agreement between the U.S. Environmental Protection Agency (USEPA) and manufacturers to phase out urban uses, regulations from the state and USEPA on agricultural use, and TMDLs for Bay Area urban creeks and the Central Valley (including the Delta). By the early 2000s — due to the phase-out of most allowable urban uses of the organophosphates — pyrethroids had become the primary class of insecticides available in the urban marketplace and were the largest source of aquatic toxicity in California urban watersheds. California adopted regulations in 2012 designed to reduce pyrethroid use. However, increasing use of other pesticides such as fipronil and the neonicotinoids pose new threats.

Pesticides are of particular concern in urban creeks and sometimes the water bodies into which they flow, such as the Delta, where recent studies have implicated pyrethroids as the cause of toxicity to invertebrate test organisms. Scientists think pesticide contamination could also be playing a role in the marked decline among key estuarine fish species, known as the "Pelagic Organism Decline". While pesticides are unlikely to be a major cause of the "POD", a review concluded they could not be eliminated as a possible contributor. Other Delta fish species not included in the POD may also be at risk – for example, pesticides could be affecting the reproduction and behavior of salmon and silversides.

It's difficult to quantify the effects of complex mixtures of pesticides and other chemicals on aquatic life in the Estuary while also considering the other stressors they already face. For many pesticides in use, we don't know the levels that adversely affect species of concern. Where such thresholds are known, they are often extremely low and below levels that can readily be measured.

Recently, there has been progress in reducing the threat of pesticides to water quality in the Estuary. In 2012, the California Department of Pesticide Regulation enacted landmark regulations restricting the ways professional applicators can apply pyrethroid insecticides around buildings, and placed special restrictions on use of bifenthrin, one of the most problematic pyrethroids. The USEPA has begun reviews of pyrethroids and fipronil. In the entire Central Valley, including the Delta, the Central Valley Regional Water Board is developing regulatory controls for pyrethroids.

As older pesticides are withdrawn, new pesticides — or new uses for existing pesticides — are registered; target pests develop resistance; and new pests become a problem. This cycle presents a continuing challenge for water quality managers and scientists who must work to adapt to a constantly changing chemical environment.

A DRINKABLE DELTA

Few things concern people more than the purity of their drinking water. And few things concern drinking water management agencies more than pollutants in their source water or problematic interactions between chemicals used in treatment and certain constituents in the water. What's in the water drawn from the Delta and the Sacramento River and San Joaquin River watersheds has an impact on what two thirds of Californians drink and offers another potential measure of the state of the Estuary.

Emergency barrier erected on False River in 2015 to prevent salinity intrusion into Delta source water.
Photo: Bird's Eye View

In the Delta, source water diverted for drinking water purposes continues to be safe to drink following treatment. However, many sources of pollution threaten the quality of water from the Estuary watershed. Drinking water agencies that rely on Delta supply have made major investments in treatment to comply with federal and state drinking water standards. But a number of water quality challenges remain, most related to managing the following constituents in the source water: naturally-occurring organic carbon from plant and other living materials, bromide and salinity from seawater, pathogens (such as *Cryptosporidium* and *Giardia*) from animal and human waste, and nutrients from various urban and agricultural activities.

Photo: DWR

One challenge stems from the interaction of some of these constituents with disinfectants. Organic carbon and bromide can react with water treatment disinfectants to form carcinogenic by-products. Another challenge is to manage salinity in water supplies. Salinity affects the aesthetic qualities of drinking water and creates water management challenges for blending, groundwater recharge, and water recycling. Nutrients are another major challenge, contributing to algal blooms that can cause taste and odor problems, produce toxins, and clog filters at water supply facilities.

Detected levels of these constituents in source water vary with hydrology and seasonal rainfall. In wet weather, organic carbon loads increase in stormwater. During dry weather, when less fresh water naturally flows downstream, salinity and bromide increases with higher seawater intrusion into the Delta.

Important tools for safe drinking water supply and to manage treatment operations include regulations and monitoring programs. Since 1983, DWR's Municipal Water Quality Investigations Program has monitored the suitability of Delta water for the production of drinking water. Monitoring includes sampling at 12 stations and analysis of organic carbon, bromide, dissolved solids, and nutrients. The program also operates four real-time monitoring stations in the Delta.

Other federal, state and Central Valley efforts have resulted in policies and initiatives that look at problems with both disinfection by-products and microbial pathogens. These efforts encourage monitoring to help determine if more advanced treatment is needed to protect public health. In recent monitoring, most Central Valley drinking water agencies were found to not require additional treatment.

In 2013, Central Valley water regulators established a non-numeric water quality objective for *Cryptosporidium* and *Giardia* and monitoring provisions to quantify pathogen sources, track their fate and transport, and characterize organism viability. More recently, several monitoring programs have banded together to better characterize background conditions in Delta source water.

With fresh water becoming scarcer as a result of drought, source waters taken from the Delta could get saltier and more contaminated. Fewer storms, smaller flows, drawn-down reservoirs, and shrinking supply of high quality snowmelt could all seasonally reduce the quality of California's drinking water. Water quality monitoring and regulatory programs in Northern California are sure to play an increasingly important role in providing clean water benefiting both people and the environment.

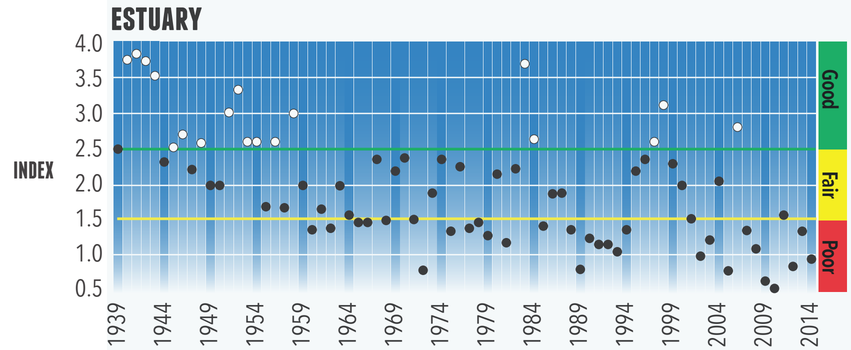
FLOWS

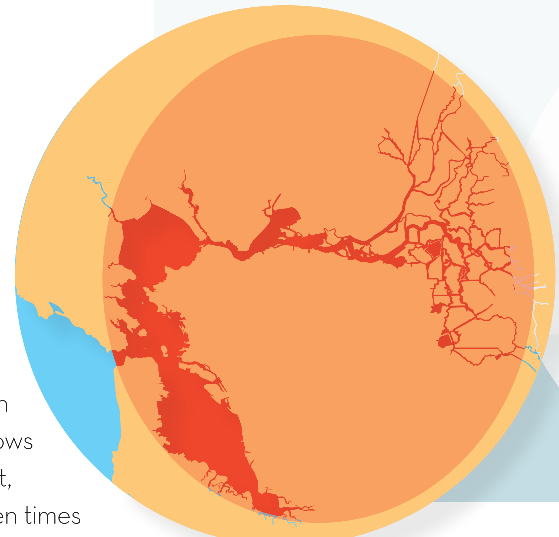
CONTEXT The amounts, timing and patterns of freshwater flow into the San Francisco Estuary from its tributary rivers and streams are critical drivers for the Estuary's ecological health. Freshwater inflows control the quality and quantity of estuarine habitat, drive key ecological processes, and significantly affect the abundance and survival of estuarine biota, from tiny planktonic plants and animals to shrimp and fish. The mixing of inflowing fresh water and saltwater from the ocean creates low salinity, or "brackish," water habitat for estuary-dependent species. Seasonal and inter-annual changes in inflow amounts trigger biological responses like reproduction and migration, and high flows transport nutrients, sediments and organisms to and through the Bay, promote mixing and circulation, and flush contaminants out to sea.

Folsom Dam spillway. Photo: Bureau of Reclamation

The San Francisco Estuary receives 90% of its freshwater inflow from the Sacramento-San Joaquin watershed, whose rivers and streams drain nearly one third of the state. Freshwater flows from this watershed are affected by both natural and man-made factors. California's Mediterranean climate and unpredictable cycles of wet and dry years produces large year-to-year and seasonal variations in rain and snow precipitation and runoff; freshwater inflows to the Estuary during a wet, flood year can be nearly ten times greater than inflows during a drought year. Flows are also affected by humans. Dams capture and store runoff from the mountains for release into the rivers flowing to the Estuary at different times of the year and even in different years. Water diversions on rivers and in the Delta, the upstream region of the San Francisco Estuary, remove water for local agricultural or urban use or export to other regions in California, reducing the amount of water that flows to the Estuary. And increasingly, climate change and resultant warmer temperatures and shifts in precipitation from snow to rain have altered the amounts, timing and duration of seasonal flows in the Estuary's tributary rivers.

FRESHWATER INFLOW





ESTUARY

..STATUS..
Poor

....TREND....
Variable but declining

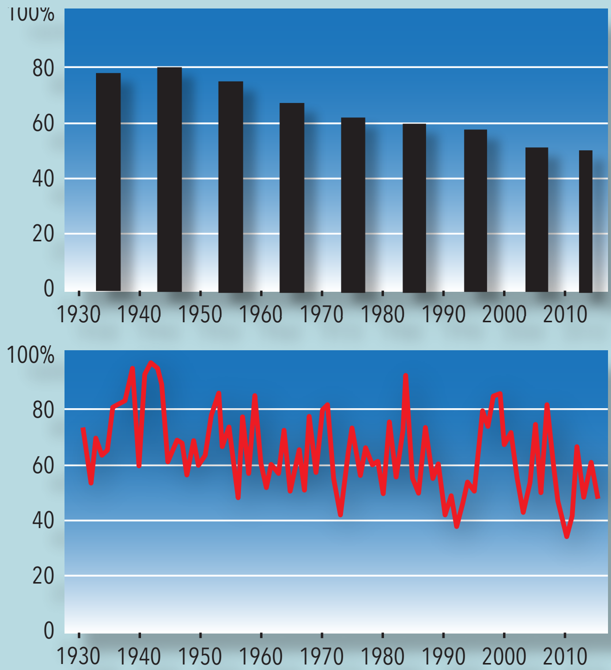
.....BENCHMARK.....
Flows needed to protect ecological integrity

INDICATOR The Freshwater Inflow Index uses ten indicators to measure and evaluate the amounts, timing, and variability of freshwater inflow from the Sacramento-San Joaquin watershed into the Delta and the Bay, and

DETAILS

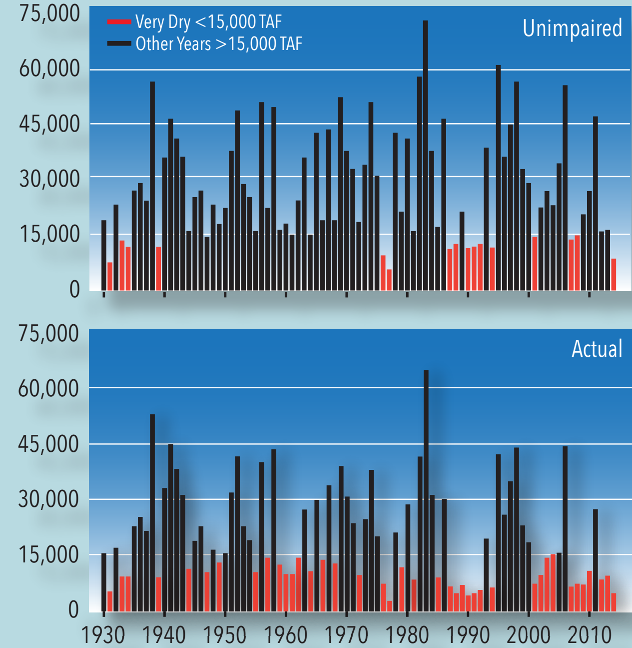
ANNUAL BAY INFLOW
PERCENT OF UNIMPAIRED

Freshwater inflows to the Bay, shown as decadal averages (top graph) and for each year (bottom graph), have declined, cut by more than half in many recent years.



ANNUAL FLOWS 1930-2014
THOUSANDS OF ACRE FEET

These man-made reductions in freshwater inflows have created chronic drought conditions in the Estuary. In most years, the amount of fresh water that now flows into the Bay is less than would have in the driest 20% of years under unimpaired conditions, if there were no dams or water diversions (shown as red bars).



INDICATOR	LONG-TERM TREND 1930-2014	TREND SINCE 1990	CURRENT CONDITION (AVERAGE FOR LAST 10 YEARS)
Annual Delta Inflow	Stable	Stable	Fair - Inflow reduced by 26%
Spring Delta Inflow	Decline	Deteriorating	Poor - Inflow reduced by 47%
San Joaquin River Inflow	Decline	Stable	Very poor - Inflow reduced by 58%
Annual Bay Inflow	Decline	Deteriorating	Very poor - Inflow reduced by 50%
Spring Bay Inflow	Decline	Deteriorating	Very poor - Inflow reduced by 56%
Delta Diversions	Decline	Deteriorating	Poor - 36% of inflow diverted
Inter-annual Variation in Inflow	Decline	Variable	Good - Reduced by 10%
Seasonal Variation in Inflow	Decline	Deteriorating	Poor - Reduced by 50%
Peak Flow	Decline	Stable	Fair - Reduced by 45 days/year
Dry Year Frequency	Decline	Deteriorating	Poor - Flow reductions triple dry year frequency
Freshwater Inflow Index (summary of 10 indicators)	**Decline**	**Variable**	**Poor**

After fighting their way upstream to spawn, adult salmon complete their life cycle. Adequate flows for upstream migration of adults and downstream migration of juveniles are critical to their health. Photo: Robert Marshak

combines them into a single metric (see table). Most of the indicators are calculated as comparisons between actual freshwater flow conditions and flow conditions that would have occurred if there were no dams or water diversions in the watershed, referred to as "unimpaired" flow conditions. By incorporating unimpaired inflow into the measurement, the indicators are "normalized" to account for the large, natural year-to-year variations in precipitation and runoff in the Estuary's watershed. Because the indicators are measures of the alterations in flow conditions rather than absolute flow levels, they are not direct measurements of the aquatic habitat conditions or ecological processes driven by freshwater inflows (see Open Water Habitat and Flood Events indicators).

The interpretation of the indicator results is based on one or more of four complementary benchmarks: scientific literature on environmental flow requirements for riverine and estuarine ecosystems necessary to maintain ecological integrity; State Water Resources Control Board flow criteria for the protection of public trust resources in the San Francisco Estuary; historical, pre-dam inflow conditions; and current state regulatory standards for freshwater inflows and Delta diversion levels.

STATUS & TRENDS Freshwater inflows to the San Francisco Estuary have been highly altered. Both the amounts and variability of inflows have been reduced, with the result of creating persistent, man-made, low inflow "drought" conditions in the Estuary. Large scale alteration of freshwater inflow to the Estuary began in the 1950s and 1960s, when most the large dams and water diversion facilities were developed, but flow conditions have deteriorated further in the last decade. Freshwater inflow conditions in 2014 were "very poor" for 6 of the 10 indicators, "fair" for 3 indicators and "good" for only one indicator (see table). As measured by the Freshwater Inflow Index, which combines the results of all 10 indicators into a single metric, freshwater inflow conditions for the San Francisco Bay Estuary have been "poor" for most of the past 15 years.

THREATS & CHALLENGES

In recent years, freshwater flows into the San Francisco Estuary have been cut by half annually, and by 60% during the ecologically important spring season. Inter-annual and seasonal variability in inflows have been reduced. These man-made alterations in inflows have created chronic drought conditions in the Estuary that, particularly in the Estuary's upstream region, impair ecological function, degrade habitat and productivity, and are a key contributor to increasingly serious fish population declines.

Confluence of Sacramento and San Joaquin Rivers near Rio Vista, where remaining flows enter the Estuary. Photo: Bird's Eye View

COUNTING THE ECOSYSTEM'S SHARE

With the recent drought, Californians are beginning to ask how much of the state's water is allocated to different uses and what kind of benefits are generated by those uses. The lingo and science of this accounting varies depending on who is doing it, and for what purpose. In the process of counting what has been "diverted for" or "applied to" various uses, ranging from irrigation to drinking water, the amount of water left to support environmental and other public benefits is often a source of debate.

In recent years, "water for the environment" has become a catchall term for any water used to protect recreational and commercial fisheries, endangered species, overall ecosystem health, or even water quality. Although some components of California's total "environmental water use" are difficult to quantify, data from multiple sources show that the bulk of these flows are physically separated from the state's water delivery system. For example, much of the water counted as "environmental water" flows in Wild and Scenic Rivers on the state's northern coast, far away from any diversion that might capture that water and deliver it to people elsewhere in the state. In other words, it is physically impossible to repurpose this share of the state's "environmental water".

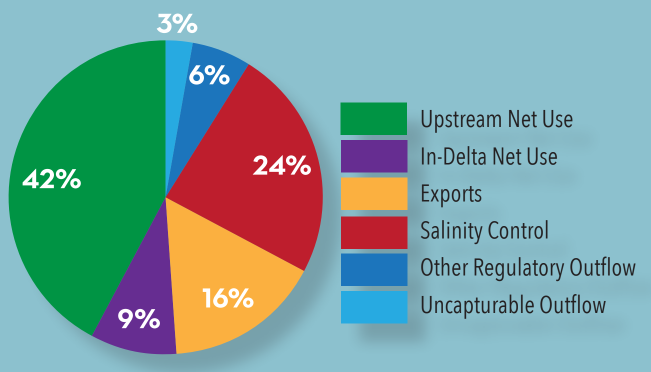
Focusing only on the Estuary and its Central Valley watershed, this report describes how much fresh water has been used specifically to help endangered fish, estuarine food webs, wildlife, and ecosystem health. For the most part, these uses of water in the Central Valley occur upstream of the diversions from which farms and cities get their water. The only component of environmental water in the Central Valley that is truly not usable by humans is water that flows out of the Delta and into the Estuary. Of the portion of Delta outflow (estuary inflow) that could otherwise be consumed by human activities, only a tiny fraction is dedicated to endangered fish.

The State Water Resources Control Board has reconstructed the various functions of Delta outflow during several recent years. In 2014 (a dry year), the total volume of water available in the Estuary's watershed from runoff, imports, and reservoir releases equaled about 12.9 million acre-feet. Of this total, 24% was used to maintain sufficient flow out of the Delta to prevent intrusion of salty water from affecting the quality of water delivered to agricultural and urban water users. Only 6% of the total was used for regulations that protect water quality for in-Delta agricultural uses and environmental safeguards.

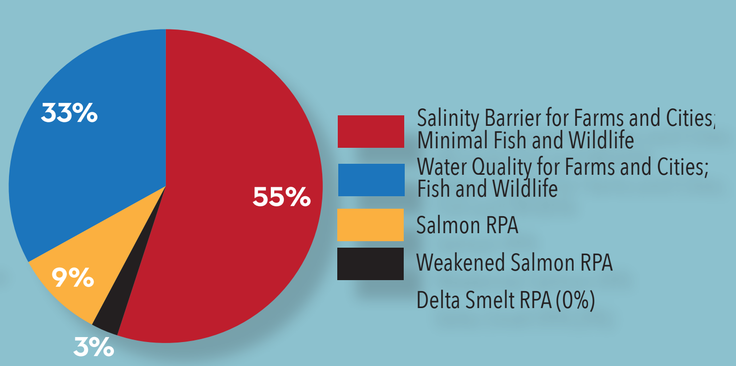
In a complimentary analysis of the effect of environmental protections on state and federal water exports from the Delta, The Bay Institute attempted to measure the number of days when those exports were governed by a particular regulation. Tracking the effect of specific regulations on the volume of water flowing out of the Delta is very complicated. Multiple regulations are involved, including the various elements of the SWRCB's Decision 1641 and the different provisions of the Biological Opinions that protect delta smelt, salmonids, and other anadromous fish under the Endangered Species Act.

During 2014, the SWRCB reduced freshwater flow standards that were designed to protect protect fisheries and wildlife; some endangered species protections were reduced as well. As a result, in this year most of the water that flowed out of the Delta was necessary simply to prevent salinity from encroaching too close to human water diversions. Endangered Species Act regulations that protect Delta smelt were never triggered in 2014 (and have not been triggered in 2015 either). The analysis suggests that, especially during the recent drought, the volume of water used for the protection of fish and wildlife, in general, has been a very small fraction of the "environmental flows" in the Delta and Central Valley water budgets.

2014 CENTRAL VALLEY OUTFLOWS



2014 DELTA EXPORTS LIMITED BY (% OF WATER DAYS)



Left: *State Water Resources Control Board accounting of how the total volume of water throughout the Central Valley was used in 2014 (calculation current as of 9/2/15).* ***Right***: *Calculation by The Bay Institute of percent of days in 2014 when exports were limited by certain restrictions or regulations (RPAs are fish protections contained in biological opinions produced under the Endangered Species Act).*

HABITAT

OPEN WATER
PONDS
OYSTER BEDS
EELGRASS
TIDAL MARSH
WOODY RIPARIAN

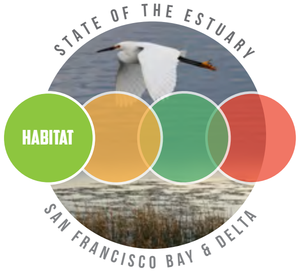
OVERVIEW

Photo: Rick Lewis

Wetlands, eelgrass beds, riparian forests, and other estuarine habitats are critical components of ecosystem health, not just in their extent, but also in terms of configuration across the landscape and quality of resources within the habitat. In a region so heavily impacted by urban and agricultural development, sustaining diverse wildlife involves conserving remaining habitats and restoring new ones. Factors such as habitat connectivity determine whether wildlife are able to move when necessary to find things like better living conditions, a breeding territory, or a safe place to wait out a king tide. Factors such as habitat quality also influence whether wildlife can find enough hiding places, nest sites, or food to feed their young. The indicators in this report focus on some of the Estuary's most important habitats, including those that harbor endangered species and provide a multitude of ecosystem services. The indicators evaluate habitat extent, quality and connectivity. These aspects of habitat translate into ecological outcomes like the health of wildlife populations and the food web, which are addressed in later chapters. Also raised in this later discussion is the critical importance of restoring the processes that create and sustain habitats over time.

TAKE HOMES

- The quality and quantity of low salinity, open water habitat in the upper Estuary has declined, and conditions are now poor in most years.
- In the Delta, reverse flow conditions, in which pumping pulls fish and other organisms toward water export facilities, have become more frequent and severe.
- In San Francisco Bay, the acreage covered by eelgrass peaked in 2011 at 4,000 acres, but by 2014 had declined to 2,790 acres. Scientists note, however, that eelgrass beds are a dynamic, variable habitat.
- Native oyster beds currently cover less than one percent of the Estuary's subtidal and intertidal shorelines.
- In the South Bay, new managed pond habitats in former salt ponds near Alviso are now a productive nursery for grass shrimp, leopard sharks, threespine stickleback, Pacific staghorn sculpin, and other young native fish, as well as for overwintering longfin smelt, a listed species.
- In San Francisco Bay, the regional extent of tidal marsh has grown by thousands of acres in recent years. Just prior to completion of the *Baylands Ecosystem Habitat Goals* in 1999, the Bay had about 40,000 acres; by 2009 there were about 45,000 acres; and 6,300 acres have been added since then.
- In January 2015, with the breach at the North Bay's Cullinan Ranch, the region reached a major milestone as Cullinan and other restored areas evolve and mature, the regional extent of Bay tidal marsh is expected to surpass the halfway point of the 100,000-acre target set in the 1999 *Baylands Ecosystem Habitat Goals Report*.
- In the Delta, the regional extent of tidal marshes has grown by 260 acres since 2009. Tidal marsh restoration efforts in the Delta are just beginning.
- Across the Estuary, tidal marsh patch size has decreased since the early 1800s. This change is much more pronounced in the Delta than in the Bay. Large patches are associated with healthier populations of marsh-dependent species.
- Historically in the Bay and the Delta, more than 95% of the tidal marsh area was part of a large patch (greater than 500 acres in size). Today, the proportion is only slightly lower in the Bay (85%), but dramatically lower in the Delta (30%).
- In the Delta, woody riparian habitat has been reduced by 64% over the past two centuries. Many of the remaining patches of this habitat are narrow, small, highly fragmented, and mostly found on artificial levees.



SUPPORTING MATERIALS

This chapter summarizes data and materials written by the authors listed on page 12 and provided in full in the technical appendix for the State of the Estuary 2015 report. Go to: http://sfestuary.org/about-the-estuary/soter/

Habitat chapter cover photo of tidepools: Rick Lewis

OPEN WATER

CONTEXT

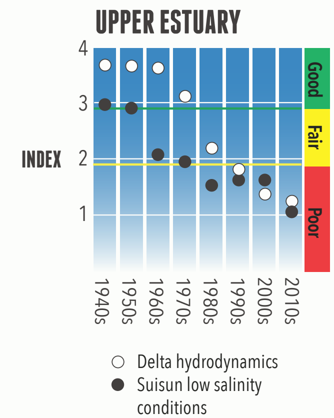
On the surface, the open blue-green waters of the Estuary help define the region's beauty. Under the surface, they provide the least accessible of the Estuary's habitats to humans but one that sustains many fish, invertebrates and other wildlife. All of the Estuary's Endangered Species Act-listed fish species – Delta smelt, longfin smelt, Chinook salmon, steelhead and sturgeon – live in or pass through this open water habitat during their life cycles. Harbor seals, bat rays, and marine species like sole, herring and sardines also use the Bay's open waters. The condition of the Estuary's open water habitat is directly linked to the health of aquatic wildlife and their ecosystem.

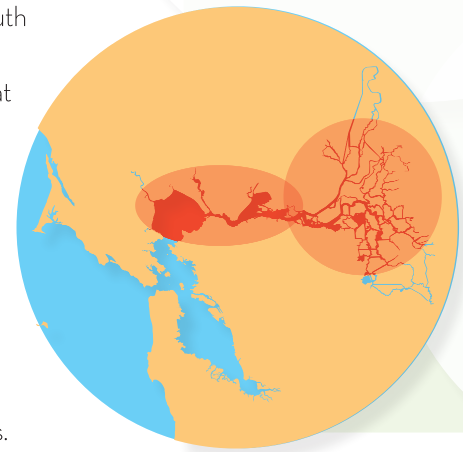
Open waters near the Rio Vista Bridge on the Sacramento River, 100 kilometers from the Golden Gate where low salinity habitat is not as beneficial to the ecosystem as it would be if pushed further downstream by higher flows. Photo: Bird's Eye View.

In the Estuary's shallow bays – Suisun Bay, San Pablo Bay and South Bay – open water habitat conditions are largely defined by salinity, which varies longitudinally along the Estuary's axis from upstream to downstream and seasonally with freshwater inflows from the Estuary's tributary rivers and streams. Open water salinities can range from near freshwater conditions in Suisun Bay to as salty as the nearby Pacific Ocean in the South Bay. In this Estuary, low salinity, open water habitat in Suisun Bay produced by high freshwater inflows during the late winter and spring is a particularly important habitat feature, driving productivity and increasing the abundance of many native fish and invertebrate species. Open water habitat in the Delta, the Estuary's most upstream reach, occurs in narrower channels and has even lower salinities, indeed it is almost always fresh.

Anglers in Delta open waters. Photo: Bird's Eye View

OPEN WATER HABITAT





UPPER ESTUARY

..STATUS..
Poor

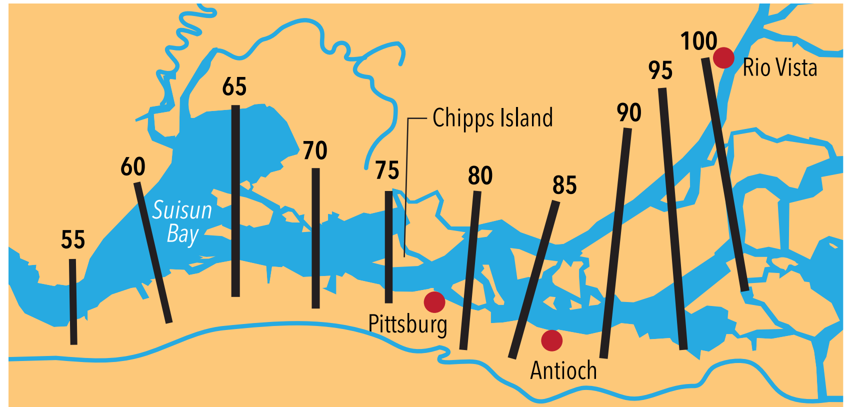
....TREND....
Deteriorating

....BENCHMARK.....
Habitat conditions that protect species survival

With large inputs of freshwater from Sacramento-San Joaquin watershed rivers and proximity to massive water diversion facilities, Delta open water habitat conditions are more affected by water movement patterns within channels than downstream bays. Low freshwater inflows and high water diversion rates can reverse flows in Delta channels and draw fish and other small organisms upstream to the Delta water pumps, where they can be killed at the pumps or eaten by non-native, predatory fish common in this area.

INDICATORS

Two indicators are used to evaluate the frequency, magnitude, and duration of the occurrence of specific open water habitat conditions in the upstream regions of the Estuary. The first indicator measures hydrodynamics and the occurrence of "reverse flow" conditions in the Delta. The second indicator measures the occurrence of low salinity conditions in Suisun Bay during the ecologically important late winter and spring period. Benchmarks for the two indicators are based on the relationships between Delta channel hydrodynamics and the entrainment of fish at the state and federal water export facilities (for the Delta open water habitat indicator) and the relationships between low salinity habitat and estuarine species survival and population abundance (for the low salinity, open water habitat indicator) and set at levels that corresponded to moderately good open water habitat conditions. Additional information on unimpaired freshwater inflow conditions and current regulatory standards for seasonal flows and exports was also considered to evaluate the indicator results.



The abundance and survival of many estuary-dependent fish and invertebrates relates to the extent of low salinity open water habitat usually found in Suisun Bay. Regulators created the first "habitat" based standard around this low salinity zone, commonly referred to as the X2 standard. X2 is the location in kilometers of the 2 parts per thousand isohaline from the Golden Gate, with 65 kilometers equated with moderately good conditions for the ecosystem. Source: The Bay Institute.

STATUS & TRENDS

Analysis shows that the frequency, magnitude and duration of the occurrence of good quality open water habitat have declined significantly in both the Delta and the Estuary's northern and upstream bays. Conditions are now poor in most years. Hydrodynamic conditions in the Delta deteriorated from consistently good prior to 1970 to poor or very poor conditions in most recent years. Springtime low salinity habitat conditions are more variable but, since the 1990s, they have been poor or very poor in most years. In sum, open water habitat conditions, as measured by these indicators in these regions of the Estuary, are not sufficient to support healthy and abundant populations of the native fish and invertebrate species that depend on these habitats.

Salinity control gates to Suisun Marsh, which keep this duck hunting landscape near Suisun Bay more hospitable to the plant species certain species of waterfowl favor. Photo: Birds Eye View

THREATS & CHALLENGES

The declines in habitat condition measured by the two indicators are largely the result of human water management activities, now exacerbated by the prolonged drought. Regulatory standards for freshwater inflows to the Estuary and for Delta water export rates aimed at protecting the quality of open water habitat have not, according to this evaluation, prevented the continuing decline in habitat conditions.

EELGRASS

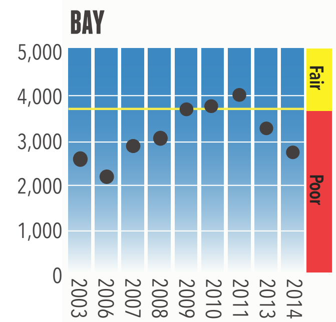
CONTEXT Eelgrass is an underwater flowering plant that grows in the subtidal and intertidal zone of the lower Estuary in San Francisco Bay. In the estuarine ecosystem, these beds of submerged aquatic vegetation provide shelter and food to pipefish, staghorn sculpin, three-spined stickleback and other small fishes, as well as long blades of sea grass upon which Pacific herring can lay their eggs. Diving and dabbling birds find a diverse buffet in eelgrass beds. Eelgrass also slows currents and traps sediment in the Estuary, reducing turbidity and buffering the shoreline. Although current eelgrass coverage of the Bay floor is limited, ecosystem planners hope these rich underwater meadows might one day be much more extensive.

Photo: Stephanie Kiriakopolos

INDICATOR The indicator for subtidal habitat health in San Francisco Bay is acreage of eelgrass beds. The benchmarks derive from the 2010 San Francisco Bay Subtidal Habitat Goals Report. The report set phased restoration goals for native eelgrass in the Bay. Scientists used a habitat suitability model to determine that under current conditions about 9% of the Bay floor could sustain eelgrass. Only 1% was covered at the time of report publication. The report set goals of increasing coverage by 25 acres within five years, 100 acres within 10 years, and up to 8,000 acres within 50 years (about 4% of the Bay).

STATUS & TRENDS Inventories of eelgrass bed coverage in San Francisco Bay have been undertaken since 2003, and monitoring shows an overall trend of expansion. By 2011, acreage had increased from a 2009 baseline of 3,700 acres to nearly 4,000 acres – meeting the ten- year goal of 100 more acres in less than five years. By 2014, however, the latest monitoring data was showing a decline to 2,790 acres, well below the 2009 baseline. Scientists note, however, that eelgrass beds are a dynamic habitat and can experience tremendous variability year-to-year as a result of unique events or changes in environmental conditions. For instance, substantial declines in eelgrass detected in October 2006 principally resulted from winter 2005-2006 storms and subsequent flooding, which loaded the North Bay with smothering sediment and depressed salinities for months at a time.

ACRES OF EELGRASS

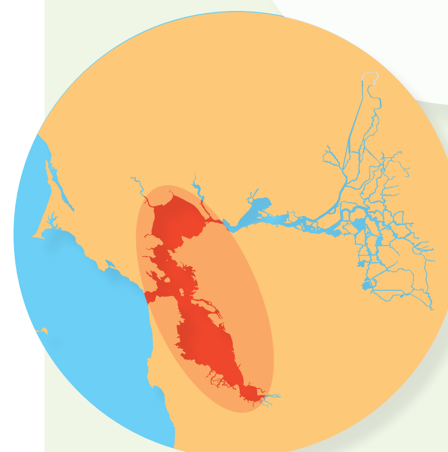


BAY

..STATUS..
Poor

....TREND....
Mostly Improving

.....BENCHMARK.....
3,800 acres by 2020
8,000 acres by 2060



OYSTER BEDS

Native Olympia oysters (*Ostrea lurida*) currently cover less than 1% of San Francisco Bay's shoreline but scientists think there's enough suitable habitat for them to cover up to 9%. As oysters build beds in the shallows, they create more diverse intertidal and subtidal habitats in the Bay, habitats that could enhance the health of the Estuary.

In San Francisco Bay, native oysters and native mussels are the only native bivalves that form beds. Inventories of native oyster bed coverage and intertidal shoreline oyster habitat have been undertaken since 2000 by various entities, and since 2012 under a comprehensive monitoring program managed by the San Francisco Bay National Estuarine Research Reserve. Results are not quite developed enough yet to be a defensible indicator of the state of the Estuary. A preliminary review, however, does suggest a trend of general expansion in oyster density and bed acreage in the Bay since 2000.

Native oyster beds are a dynamic habitat and can experience tremendous variability in coverage from year-to-year. Though small native Olympia oysters do not commonly form tall, three-dimensional reefs, as do Virginia oysters, they can add structure to hard substrates and colonize soft substrates. In this sense they can be considered an ecosystem engineer, altering their environment by increasing bottom roughness, reducing current speeds, and as a result, trapping sediments.

The 2010 *Subtidal Habitat Goals Report* set goals of increasing native oyster coverage by 100 acres within five years, 400 acres within 10 years, and up to 8,000 acres within 50 years. In 2014, an interdisciplinary academic and resource management team launched a research project that promises to support this restoration experiment. The team began by evaluating oyster population densities at 12 sites in San Francisco Bay. They also recorded information on supportive and stressful environmental factors.

Photos: Stephanie Kiriakopolis

Researchers found that oyster densities ranged from three to 961 oysters per square meter at the 12 sites. They also estimated a total population of native oysters in the shallows (MLLW) at all sites combined of 160,000 oysters.

Of the 12 sites evaluated, top-scoring sites for restoration were Berkeley Marina (Shorebird Park area), Strawberry (Brickyard Cove), the San Rafael shoreline, and Point Pinole Regional Shoreline. All of the high-ranked restoration sites also ranked high as conservation sites. Several additional sites ranked high only for conservation of existing oysters: Richmond (Point Orient), Loch Lomond Marina, Sausalito (Dunphy Park), and Coyote Point Recreation Area.

Native oyster beds are subject to many threats, especially burial when sedimentation rates are high and stress when air temperatures are hot and the tide low, leaving them exposed. Competition for space may be more important in the South Bay, where hard substrate is limited, and in the subtidal zone, where non-native competing organisms are abundant. However, 40% of intertidal substrate surveyed was bare of organisms. Diseases and parasites do not present a major threat, although this could change if population density increases and changes in water temperatures occur due to climate change. Heat stress in warm intertidal areas may reduce oyster survival. Drought years where salt water intrudes farther upstream, however, appear to favor oysters. The full ramifications of stressors on native oyster distribution and future abundance are not yet known, but remain a concern with respect to achieving restoration goals and a healthier estuary.

During the recent drought years, eelgrass has expanded towards the Delta and even slightly into Suisun Bay. Some of the largest, most stable beds have concurrently suffered some significant declines, however. In some cases, these declines may be related to lower water levels, prolonged exposure to sun during low tides, and resulting conditions that cause eelgrass to dry out within intertidal areas. In other cases, declines at the shallow margins of these beds could stem from being immersed in warm water for too long. There may also be loss from disease, although no direct evidence of expansive bed damage has yet been noted in San Francisco Bay. Additional monitoring will help determine if the recent decline suggests the end, or even reversal, of the eelgrass expansion trend.

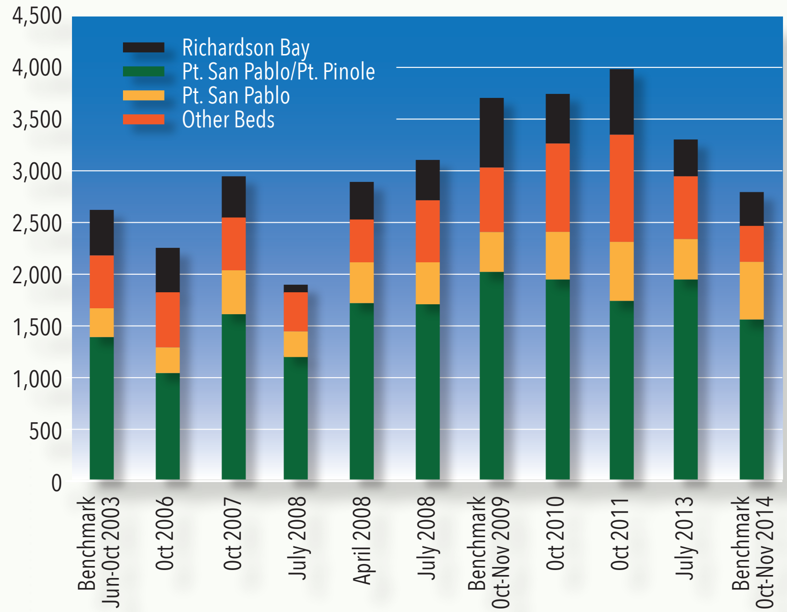
Herring eggs on eelgrass. Photo: Jude Stalker

THREATS & CHALLENGES Eelgrass beds are sensitive to factors such as light penetration, disturbance and disease. If the water is too turbid and cloudy, light cannot penetrate deep enough for the eelgrass to grow. The Bay's turbidity derives from both large-scale factors such as sediment delivered by tributary rivers and streams, as well as from localized dredging and shipping activities. Eelgrass beds can also be disturbed by wave action, and by dredging or construction in Bay margins. In recent years, scientists have noted a new threat in a variety of California bays and estuaries, including San Francisco Bay, called wasting disease. In the central California estuary of Morro Bay, the system hit hardest to date, eelgrass extent has shrunk by 97% since 2007 and efforts are now underway to foster recovery. Obviously, the disease could be a factor of major concern with respect to achieving restoration goals in San Francisco Bay.

Eelgrass researcher.
Photo: Stephaine Kiriakopolis

DETAILS

EELGRASS EXTENT AND DISTRIBUTION IN ACRES



TIDAL MARSH

CONTEXT The push to restore tidal marshes from a few remnant patches to a substantial natural feature of the region's shorelines has, since the first project over 100 acres broke ground in the 1970s, been a benchmark project in any assessment of the state of the Estuary. As the total area of tidal marsh in the Estuary increases, so does the abundance and diversity of the plants and animals that live in, and frequent, marshes. When larger marshes are fragmented into smaller ones, their value as wildlife habitat tends to decrease. Larger marshes are more likely than smaller marshes to support a mosaic of high and low marsh habitats, and marsh pans, as well as to buffer native wildlife from nonnative predators, and have well developed tidal channel networks. In addition, the bigger their size, the more ecosystem services marshes provide in terms of absorbing floods, improving water quality, and enhancing recreation.

Freshwater tule marsh in the Delta and tundra swans. Photo: Rick Lewis

Tidal marshes provide a wide array of ecosystem services. They provide habitat and support food webs for wildlife, stabilize shorelines and protect them from storm damage, store floodwaters and maintain water quality, preserve biodiversity, store carbon, and offer profound opportunity for scientific study, education, recreation, and aesthetic appreciation.

Sears Point marsh restoration site in the North Bay, including new higher elevation areas (circles) as refugia from high tides and rising seas. Photo: Bird's Eye View

The Bay's tidal marshes (salty and brackish) are not the same as the Delta's tidal marshes (fresh) – they have different physical characteristics, support different plants and wildlife species, and suffer different stresses. Increasing the total extent of tidal marshes across the whole Estuary – from the South Bay to the North Delta – will ensure that marsh habitat exists along the full length of important ecological gradients (such as tidal influence, salinity ranges, and vegetation), providing a range of options for marsh species. Restoration in both regions could go a long way to improving the health of the Estuary.

INDICATORS This report examines two indicators of tidal marsh health: total extent and patch size. The first indicator measures the combined area of all tidal marshes in the Estuary and is derived from detailed habitat and vegetation maps. The second indicator assesses the size of individual patches of tidal marsh habitat. For both indicators, analysis evaluated Bay and Delta information separately.

Benchmarks used for tidal marsh extent are different for the Bay and Delta. For the Bay, scientists used 100,000 acres. This goal, which was established and described in the 1999 *Baylands Ecosystem Habitat Goals Report*, reflects a consensus on the habitat needs of tidal marsh species and the changes needed to improve the Bay's ecological functioning and biodiversity. Since no similar quantitative goals exist for the Delta, this assessment instead presents three reference values: 180,000 acres (half the historical extent); 78,000 acres (current marsh area plus diked lands at intertidal elevations); and 17,000 acres (California Eco Restore goal).

For the patch size indicator, the benchmark derives from the proportion of tidal marsh area belonging to a patch greater than ~500 acres in size, a value that seems to support maximum densities of certain marsh birds.

STATUS & TRENDS Analysis suggests that the regional extent of tidal marsh in the Bay has recently grown by thousands of acres. In 2009, the Bay had about 45,000 acres, or 45% of the 100,000-acre goal. Since 2009, an additional 6,300 acres have been opened to the tides. Much of this restored habitat is expected to transition into tidal marsh in the future and, if counted in full, would bring the regional extent of tidal marsh to 51% of the goal (see table).

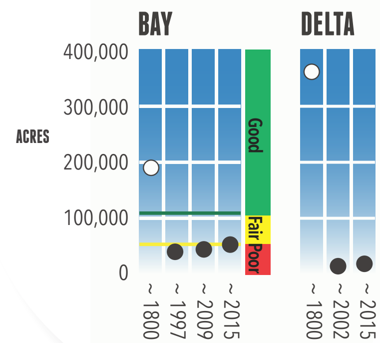
By contrast, the regional extent of tidal marsh in the Delta has only grown by 260 acres since 2002. The Delta had about 8,000 acres in 2002. This area is 4% of the 180,000 acre reference value; 10% of the 78,000 acre reference value; and 47% of the 17,000 acre reference value.

In terms of general trends, the area of tidal marsh in the Bay continues to increase towards the regional goal of 100,000 acres. A major milestone passed in January 2015, when backhoes breached the levees at Cullinan Ranch in the North Bay. With this breach, the area of existing tidal marshes plus restored intertidal wetlands moved past the regionwide goal's halfway mark of 50,000 acres. Over the next 20-30 years, an additional 24,000 acres of tidal marsh will likely be added to the Bay as part of already funded or permitted projects.

Tidal marsh restoration efforts in the Delta lag behind those underway the Bay. Part of this can be explained by the extensive subsidence of the Delta's peat islands — while these extensive areas once supported tidal marsh, many now sit 10-25 feet below sea-level at an elevation that is much too low for vegetation to grow. This still leaves about 70,000 acres, mostly diked lands on the Delta periphery, as suitable in elevation for restoration according to landscape analyses. This acreage does not, however, account for what percentage of the area will actually be available for restoration given other priority land uses. Looking forward, restoration and mitigation projects expected to break ground within the next two years would, if successful, add approximately 4,650 acres of tidal marsh to the current Delta total.

Analysis of trends in the second indicator suggests that the proportion of tidal marsh habitat in big patches (greater than ~ 500 acres) has decreased since 1800. This trend is much more pronounced in the Delta than in the Bay. In the Bay, the current proportion of total tidal marsh

TIDAL MARSH EXTENT



BAY

..STATUS..
Fair

....TREND....
Improving

.....BENCHMARK.....
100,000 acres

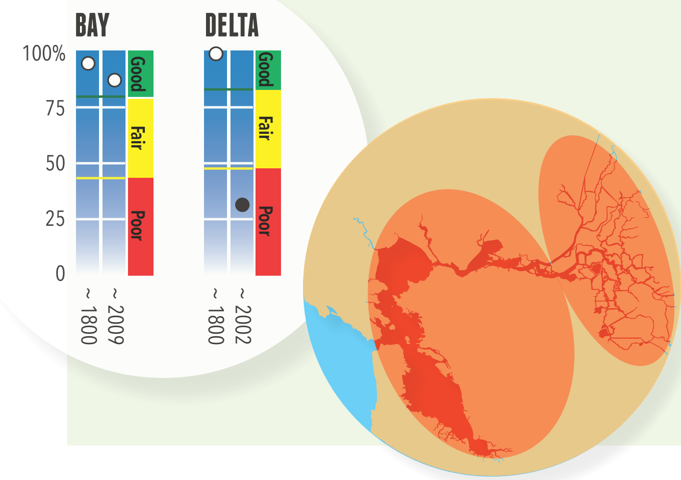
DELTA

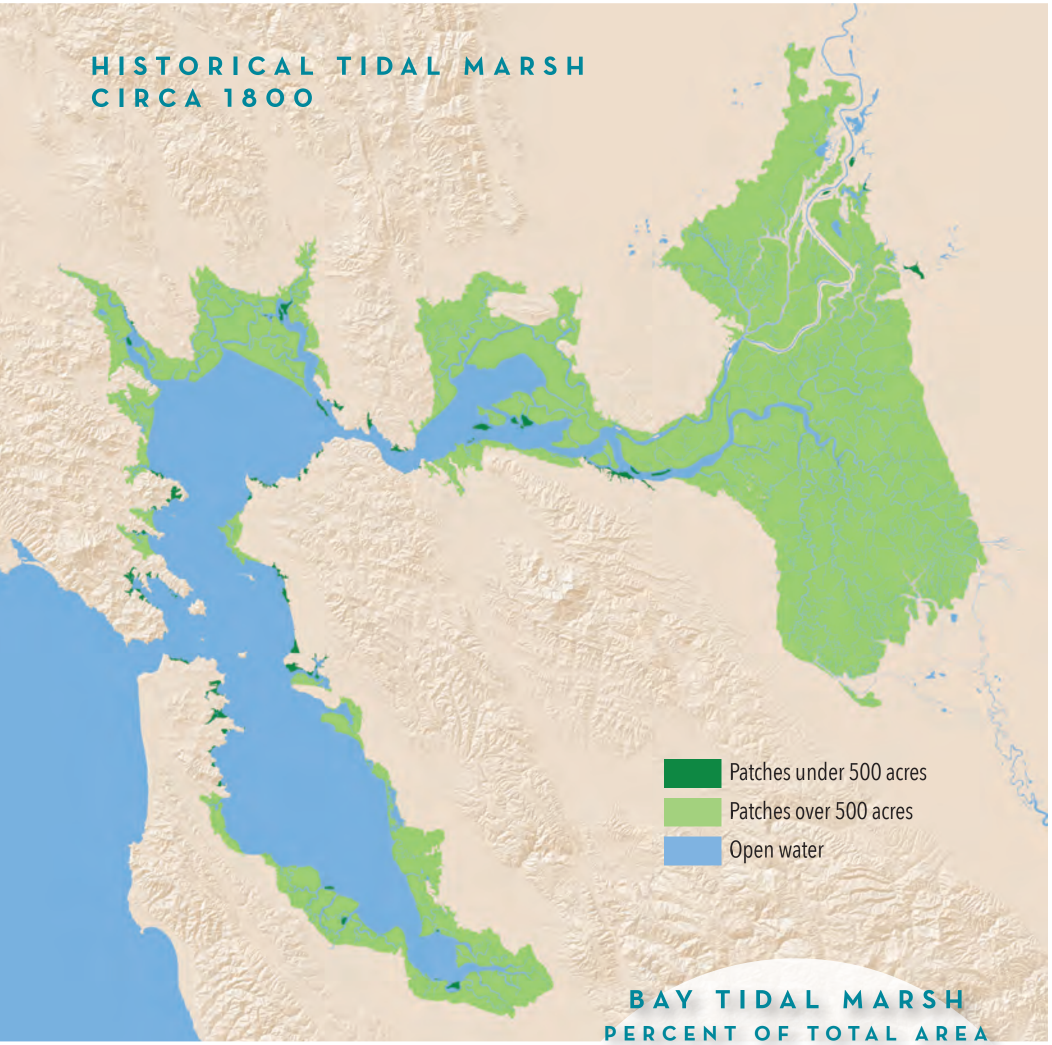
..STATUS..
Poor

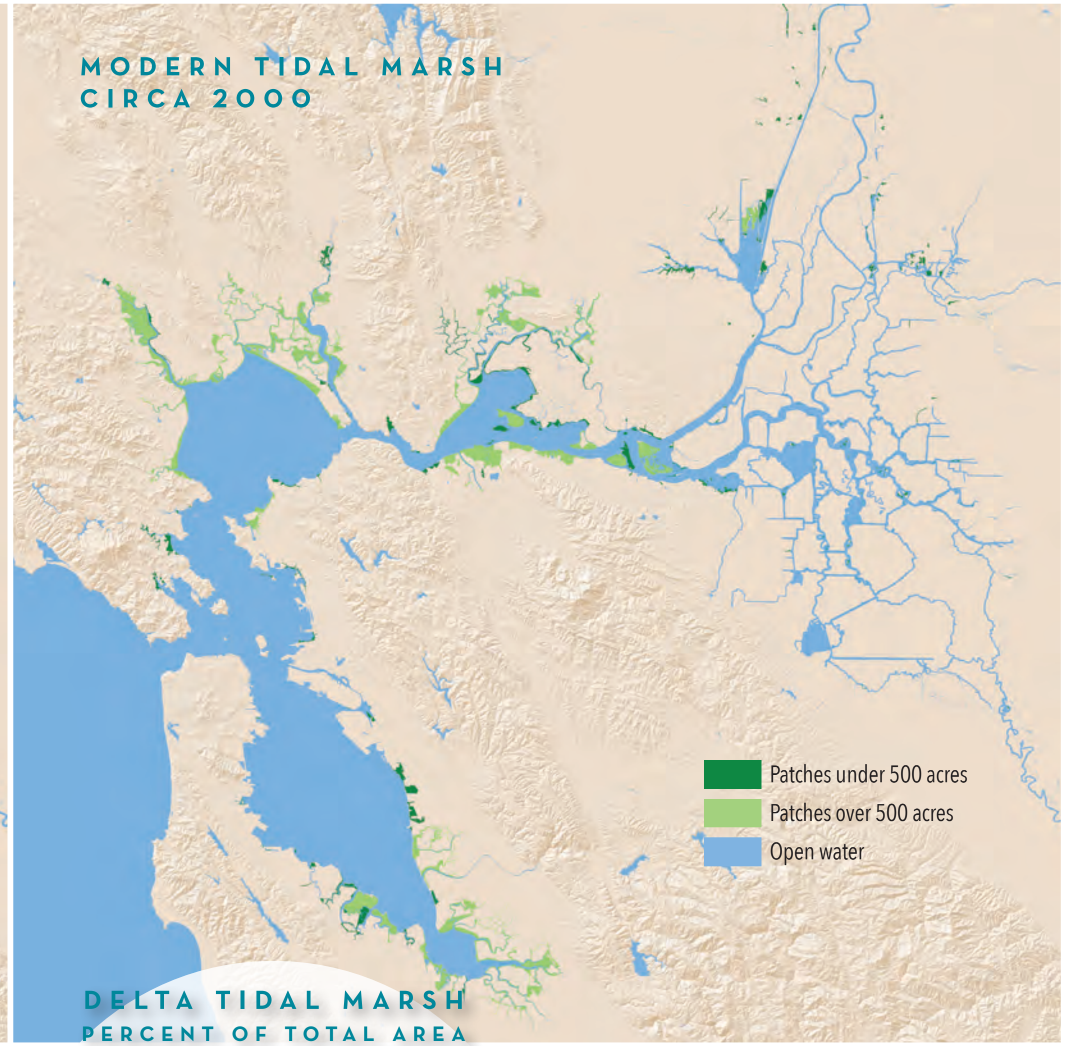
....TREND....
No change

.....BENCHMARK...
None available

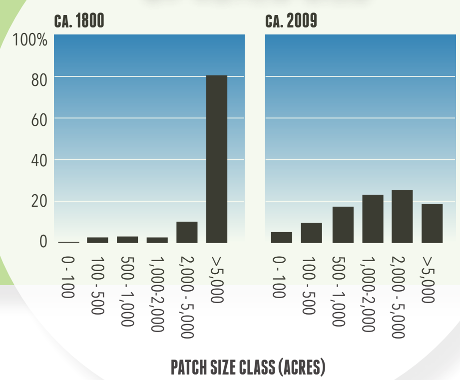
TIDAL MARSH IN BIG PATCHES > 500 ACRES



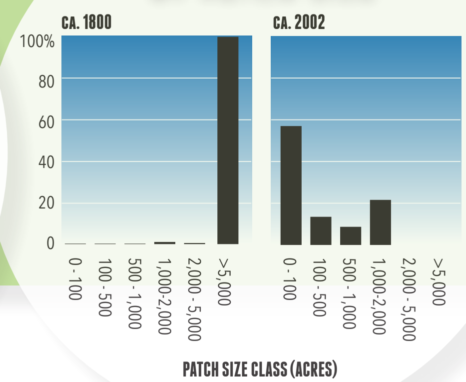




BAY TIDAL MARSH
PERCENT OF TOTAL AREA
BY PATCH SIZE



DELTA TIDAL MARSH
PERCENT OF TOTAL AREA
BY PATCH SIZE



The historical and modern extent of tidal marsh in the Estuary. Although the extent of tidal marsh has decreased in both the Bay and Delta, the decrease in area is much more pronounced in the Delta. In addition to the loss of total marsh area, the size of individual marsh patches has also decreased, with a greater proportion of the total marsh area now situated in smaller patches (see charts).

area belonging to patches greater than 500 acres in size is 88% of the historical proportion (a sign of high ecosystem value). In the Delta, it now stands at only 30% of the historical proportion (a sign of low ecosystem value).

Scientists expect the decrease in the proportion of tidal marsh area belonging to patches greater than ~500 acres to have had a negative impact on resident tidal marsh birds like the endangered Ridgway's rail. This rail species only achieves its maximum population density in bigger patches. In general, fragmented wetlands support smaller wildlife populations. The fact that the proportion of bigger patches in the Bay is almost 90% of the historical proportion is reassuring, however. This reflects the increasing size of individual tidal marsh restoration projects in the Bay over time, and highlights the need to restore and connect larger tidal marsh patches in the Delta.

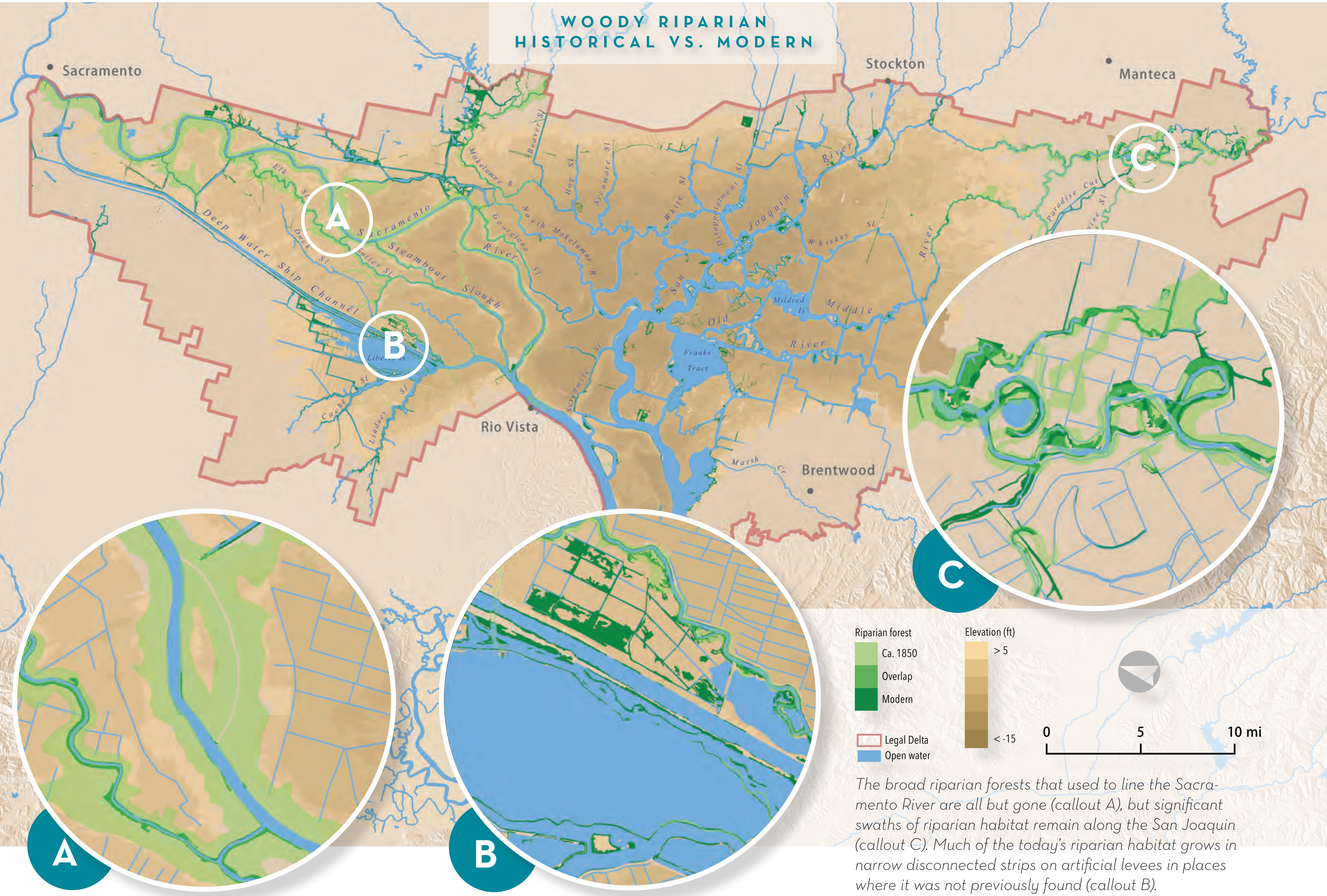
THREATS & CHALLENGES

Restoration progress in the Delta is still a challenge to evaluate due to the lack of clear regional habitat goals though various planning efforts now underway could close that gap. In the meantime, the health, extent, and patch size of both existing and proposed tidal wetlands in the Bay and Delta is sure to be impacted by sea level rise caused by global warming. Although the Estuary's tidal marshes have generally kept pace with sea level rise over the last several thousand years, by trapping sediment and bulking up with vegetation, they may not be able to continue to do so through the end of this century.

Modeled scenarios of high sea-level rise rates and low sediment supply, the most likely trajectory, project that Bay tidal marshes will be unable build up fast enough to avoid flooding and that their total regional extent will decrease. Scenarios incorporating relatively low sea-level rise rates and high sediment supply project an increase in the total regional extent, however.

Although similar projections have not been developed for the Delta, its tidal freshwater marshes (which produce more organic matter than saltier marshes) are expected to be less sensitive to reduced sediment availability than the Bay's tidal marshes. Planners now need to give more careful thought to elevation and sediment supply in choosing sites for restoration, and in designing the most resilient systems possible for the Estuary's tidal marshes.

RECENT RESTORATION SITES	YEAR OPENED TO TIDAL ACTION	PLANNED AREA OF TIDAL WETLAND RESTORATION (ACRES)
BAY (TIDAL WETLAND RESTORATION SINCE 2009)		
Napa Plant Site: Central Unit	2009	175
Alviso: Pond A6	2010	330
Napa Plant Site: South Unit	2010	1,080
Eden Landing: Ponds E8A/E9/E8X	2011	630
Alviso: Ponds A8/A7/A5	2012	1,400
Alviso: Pond A17	2012	130
Bair Island: Middle Bair	2012	646
Hamilton Marsh	2014	380
Bruener Marsh	2014	26
Cullinan Ranch	2015	1,549
TOTAL (BAY)		**6,346**
DELTA (TIDAL WETLAND RESTORATION SINCE 2002)		
Twitchell Island Setback Levee	2005	1
Sherman Island Setback Levee	2005	7
Liberty Island Conservation Bank and Preserve	2010	31
Cosumnes Floodplain Mitigation Bank	2011	73
Calhoun Cut	2014	147
TOTAL (DELTA)		**259**



The broad riparian forests that used to line the Sacramento River are all but gone (callout A), but significant swaths of riparian habitat remain along the San Joaquin (callout C). Much of the today's riparian habitat grows in narrow disconnected strips on artificial levees in places where it was not previously found (callout B).

WOODY RIPARIAN

Immense oaks, elegant sycamores, feathery willows, and a variety of other trees and shrubs once formed a continuous band of woody riparian habitat along the banks of the Delta's major rivers and streams. Today, such habitats are highly fragmented due to diking, draining, farming, and development activities. Today their regional extent within the legal boundary of the Delta is just 36% of their historical extent in the early 1800s.

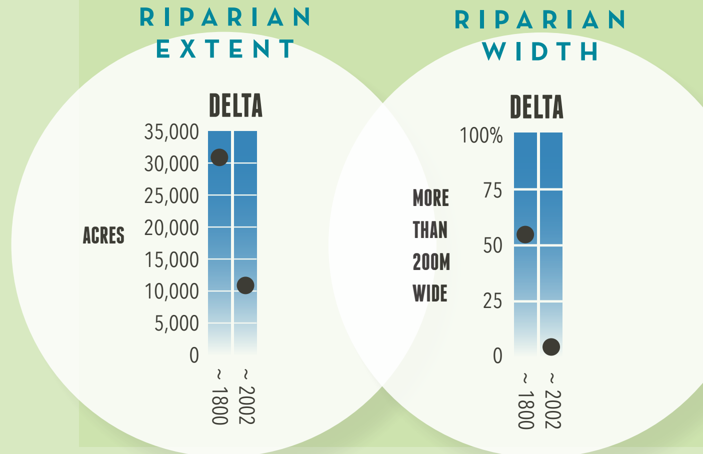
Sacramento River.
Photo: Bird's Eye View

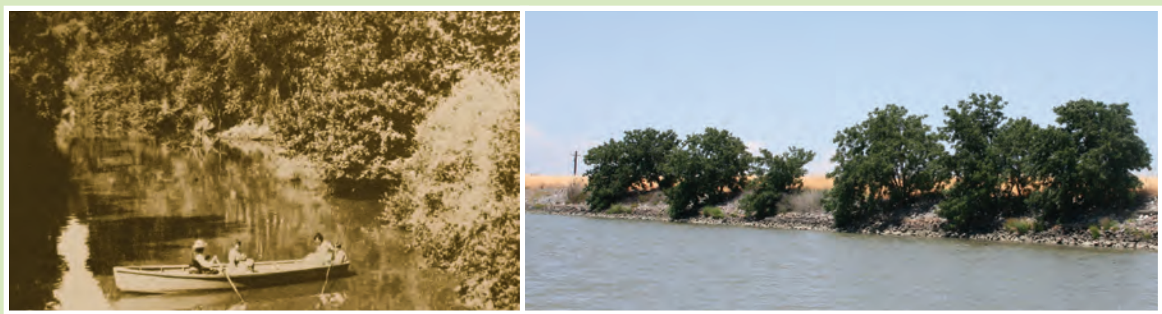
As transitional areas between terrestrial and aquatic or wetland ecosystems, woody riparian zones are habitat connections important to the state of the Estuary. Despite comprising only a small proportion of the Delta's total riparian extent, the woody parts of the riparian zone offer a wide range of ecological functions. Their complex array of trees, shrubs, and understory plants, for instance, provides a suite of food resources and sites for resident and migratory birds (like Swainson's hawks and least Bell's vireos) to forage, nest, and roost. Riparian habitats can also serve as movement corridors for far-ranging mammals (like coyotes and now-extirpated grizzly bears), as well as smaller mammals (like ringtails). These shady forests also cool adjacent pools for salmon and drop habitat-building organic mater into the water. Delta riparian habitats support a number of species that are only found in the riparian forests of the Central Valley; these include the riparian brush rabbit, riparian woodrat, and valley elderberry longhorn beetle.

Yellow billed cuckoo. Photo: Mark Dettling, Point Blue

Woody riparian habitats have been highly altered in the Delta. The 36% of historical habitat remaining occurs in small, scattered patches, mostly found on artificial levees, an arrangement that breaks down the connections between habitat types. In addition, the overall width of existing woody riparian habitats has notably decreased: while more than 50% of the historical habitat (measured by length) was wide enough to be considered "suitable" for the endangered western yellow billed cuckoo (at 200 meters), today only 5-8% of existing habitat currently meets this width threshold. Width is important because the number and level of ecological functions provided by riparian habitats generally increase as the habitat becomes broader.

These measurements of woody riparian habitat in the Delta have not been developed into quantitative indicators for three major reasons. First, there are no existing benchmarks. Second, the methods used to calculate the length of riparian habitats of various widths are labor intensive and not yet sensitive enough to meaningfully measure the small incremental changes expected in the near future. And third, scientists have yet to agree on the best single statistic to evaluate the width of riparian habitat over time. Although this report focuses on the percent of habitat greater than 200 meters wide based on information concerning the needs of cuckoos, a better statistic would more conclusively reflect the relationship between riparian habitat width and the diversity and abundance of native riparian wildlife.





Historic and current riparian habitat in the Delta. Photos courtesy Erin Beller, SFEI (right); Shipley Walters and the Yolo County Historical Society (left)

WATERSHEDS

Providing a good indication of the health of the local watersheds that drain into the San Francisco Estuary is a goal of the State of the Estuary advisory team but one not realized in the 2015 report. Investigators attempted a top-down analysis focused on the Bay and Delta watersheds using statewide data sets. In doing so, they found there was not enough information available from local watersheds in comparable formats to provide a defensible indicator of the state of watershed health. In future, monitoring designed at the regional scale would be needed to have enough data to assess watershed health.

Dimond Canyon, Oakland. Photo: Andrew Aldrich

MANAGED PONDS

Just a few years after their levees were breached and the Bay's tides flowed in, 2,000 acres of former South Bay salt ponds ("the Alviso Ponds") have become a productive nursery for young fish, grass shrimp (mysid shrimp), and other aquatic organisms, including species like the Pacific staghorn sculpin, three-spine stickleback, Northern anchovy, English sole, yellowfin goby, Pacific herring, and arrow goby—and lots of leopard sharks, according to monitoring results from the U.C. Davis Fisheries Research Team. The restored ponds are also providing overwintering and potential spawning habitat for the state-listed longfin smelt. Longfin smelt were one of the most abundant species in the winter months and at times during the study, were more abundant than in the Delta areas where they spawn.

Supporting the food web of this fish nursery are large numbers of grass shrimp, a key prey item for growing fish that has declined elsewhere in the Estuary. Analysis shows that mysid shrimp abundance is much greater in the Alviso Ponds than Suisun Marsh. It also shows very high primary productivity, with lots of algae for the mysid to feed on. It seems the Alviso Ponds are turning into a veritable food factory at the heart of the 15,100-acre South Bay Salt Pond Restoration Project.

Scientist at work in South Bay salt ponds adjacent to Aliviso Slough. Photo: Maureen Downing-Kunz

Researchers also compared the new tidally restored ponds to existing, natural sloughs (adjacent channels that carry water in and out with the tides). After conducting monthly and bi-monthly fish surveys for the past four years, the team concluded that the newly restored ponds are supporting a predominance of native species, and that the same species that are found in the sloughs are also using the new habitat. Although the total number of species fluctuated, there was no difference in species richness between the newly restored ponds and the sloughs.

In a Bay where the lion's share of restoration opportunities involve restoring former salt production ponds in incremental stages so as not to disturb bird species already dependent on the ponds, the data on fish in the Alviso complex is good news for Bay habitats indeed.

WILDLIFE

BOTTOM DWELLERS

FISH

HARBOR SEALS

WINTERING WATERFOWL

BREEDING WATERFOWL

SHOREBIRDS

HERONS & EGRETS

TIDAL MARSH BIRDS

RIDGWAY'S RAIL

OVERVIEW

Wildlife species are some of the most critical endpoints used to assess ecosystem health. This chapter examines indicators of the health of wildlife at all levels of the estuarine ecosystem, from bottom-dwelling invertebrates in the oozes to fish, waterfowl, shorebirds and seals. As indicators, wildlife can be challenging to interpret, because the health of wildlife populations depends on myriad, often interacting, factors. For many of the wildlife populations in the Estuary, key factors are freshwater inflows; water quality; habitat extent, configuration and quality; impacts from non-native species; and food availability. Monitoring across the Estuary has become more complete over time, allowing scientists to now see how wildlife respond to changes in habitat quality and the food web, among other factors. These outcomes, measured in the lives of wild plants and animals, show how our management choices, both unintended and intended, ultimately affect the other forms of life with which we share the Estuary. Creating a healthier ecosystem for wildlife will also support a healthier environment for people.

Shore crab with eggs in Sausalito. Photo: Rick Lewis

TAKE HOMES

- A large proportion of benthic invertebrate species and individuals are now non-natives at some sites in Suisun Bay and the Delta.
- Native fish populations in San Francisco Bay (South, Central and North Bays) are generally healthy, although non-native species are increasing in the Bay. However, the health of upper Estuary native fish communities in Suisun Bay and the Delta has declined markedly during the past three decades and is now in poor condition.
- Aquatic invertebrates and fish in the upper Estuary have been strongly impacted by water management operations (in the Sierra, Central Valley, and Delta) that reduce and alter the patterns of freshwater inflow, and by invasions of non-native species, among other stressors.
- While harbor seal numbers along the adjacent coast have improved since the Marine Mammal Protection Act of 1972, Estuary harbor seal numbers have not, remaining in fair condition.
- Dabbling ducks are increasing across San Francisco Bay in general, while diving ducks are declining significantly in the North Bay and Central Bay.
- Breeding waterfowl populations in the Delta and Suisun Marsh are generally in fair condition but declining, largely due to decreases in mallards, the dominant species in both areas.
- Wintering populations of small-sized shorebirds are generally stable and in fair condition in San Francisco Bay. Medium and large shorebirds are in poor condition, however, declining particularly in Central and South Bays.
- Great blue heron and great egret nest density is increasing over the long term, and nest success is fairly stable.
- After a steep decline across San Francisco Bay prior to 2010, Ridgway's rail has recovered in the North Bay but populations remain low in the South Bay.
- Tidal marsh birds, other than Ridgway's rails, are in fair condition across San Francisco Bay and densities have increased over time, possibly due to improving marsh conditions following restoration efforts.

SUPPORTING MATERIALS

This chapter summarizes data and materials written by the authors listed on page 12 and provided in full in the technical appendix for the State of the Estuary 2015 report. Go to: http://sfestuary.org/about-the-estuary/soter/

Chapter cover photo of great blue heron nest: Michael Baird

BOTTOM DWELLERS

CONTEXT The tiny creatures living at the bottom of the Estuary will never be seen by most people, yet these filter and deposit feeders can affect the entire food web. When ecosystems lose native benthic diversity, they can be less productive, less resilient in the face of stresses, and provide fewer ecological services. The benthic community is a key part of estuary food web dynamics and nutrient cycling, and a classic bio-indicator of estuary health. Benthic invertebrates are more localized indicators of estuary health than plankton or fish. They are sufficiently sensitive and have short enough life cycles that changes in benthic community patterns can indicate large recent changes in nutrient loading, toxic substances, or sedimentation patterns.

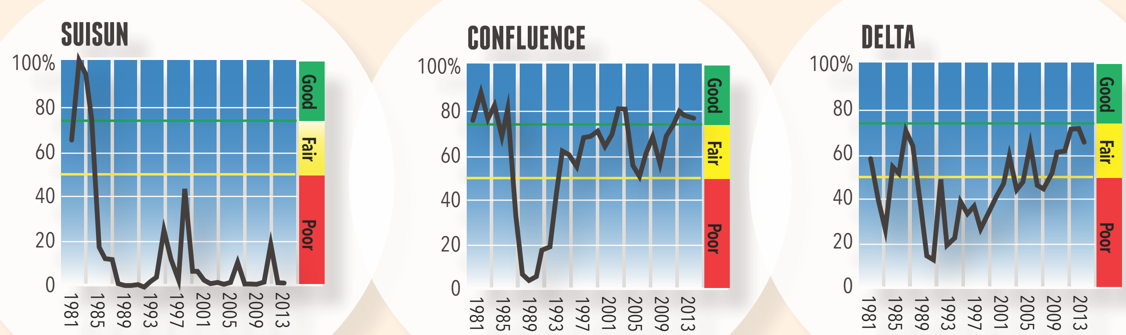
INDICATOR This indicator analyzes benthic community composition and native species diversity in the upper Estuary at three sites with long sampling records (1981-2013). Scientists analyzed the three sites independently because of the large differences in benthic communities between regions. The data analyzed for the indicators comes from benthic grab samples, which have been collected, identified to species, and counted in the same way for the whole period of the monitoring program. The benchmark is based on the historical period of 1981-86: 1981 was the earliest year-round monitoring at all sites, and the 1986-87 invasion of the Asian overbite clam (*Potamocorbula amurensis*), along with several other non-native species, marked a drastic community shift at two of the study sites. Current (2009-2013) native diversity that was equal to or higher than the historical average was counted as good. For community composition, good was set at or above 75% native. Trends for all three sites were evaluated by determining whether the current status differed significantly from the historical benchmarks.

STATUS & TRENDS The status and trends for the various benthic indicators vary and are not entirely positive. While native diversity has remained good compared with 1981-86 historical levels, a large proportion of the community's species and individuals are now non-natives at some sites. This is especially true at one site in Suisun Bay, a major site of *Potamocorbula amurensis* invasion. At this site, over the last five years, native species were 50% of the species diversity but native individuals were only 5% of the total count. The current community composition was considerably better at the confluence of the Sacramento and San Joaquin Rivers, where 74% of species and 74% of individuals were native. Community composition was also better in the Delta, where 88% of species and 67% of individuals were native.

THREATS & CHALLENGES The patterns seen among benthic invertebrate indicators are a clear indication the benthic communities of the Estuary and Delta are not in a pristine state and are unlikely to return to their original composition. The Estuary remains one of the most invaded in the world. It is not clear exactly how the current benthic community functions differently from the historical one: many of the non-native species were introduced long before regular monitoring. While it is heartening that there has been no large net loss of native diversity at the species level, management of species such as salmonids and smelt should take into account the potential changes in benthic-pelagic food web interaction.

DETAILS

COMMUNITY COMPOSITION BY INDIVIDUAL
PERCENT NATIVE INDIVIDUALS



NATIVE BENTHIC INVERTEBRATES

SUISUN BAY & DELTA

..STATUS..
Fair

....TREND....
Mixed

.....BENCHMARK.....
Diversity level 1981-1986
Community composition
% native

FISH

CONTEXT Sports fishers appreciate the Estuary for its tasty striped bass and white sturgeon, but its sparkling blue-grey waters are also habitat for more than 100 fish species, both resident and migratory, including commercially important Chinook salmon and Pacific herring. The Estuary is also home to the threatened Delta smelt. These fishes variously use the Estuary to spawn in and raise their young, and to migrate between the Pacific Ocean and the rivers of the watershed. Amounts and timing of freshwater inflows, extent of rich tidal marsh and floodplain habitats, pollution, and the prevalence of non-native species all affect the numbers and types of fish that the Estuary can support. Measures of fish abundance, diversity, species composition and distribution are useful biological gauges for environmental conditions in the Estuary. A large, diverse fish community distributed broadly throughout their habitat and dominated by native species is an indicator of a healthy Estuary.

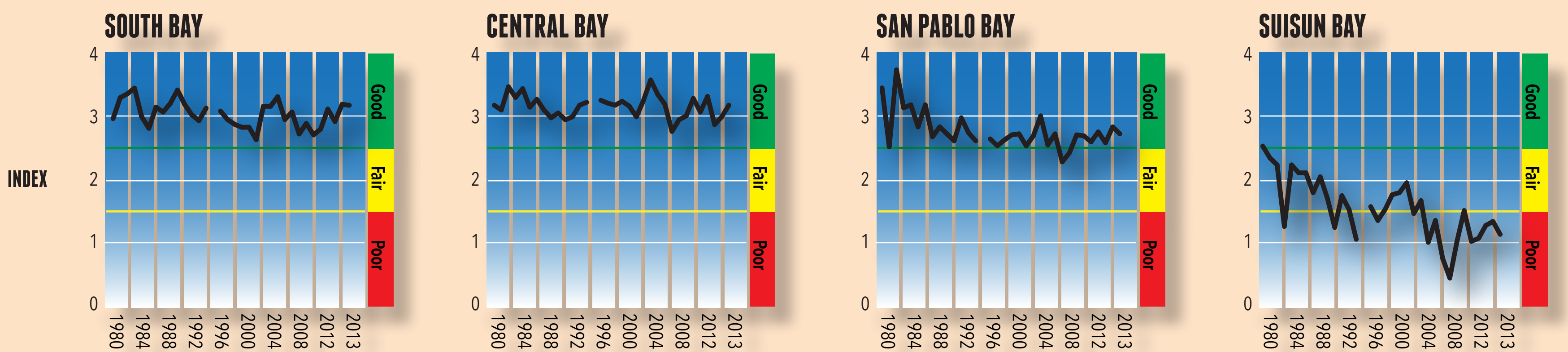
Sturgeon migrate through the Estuary all the way up to Shasta Dam near Redding. Photo courtesy SJWTP

INDICATORS The Bay Fish Index uses ten indicators to measure and evaluate the status and trends of the Estuary's fish community in four sub-regions: South, Central, North and Suisun Bays. The indicators evaluate different attributes of the fish community: abundance, diversity, species composition and distribution. Indicator results for each of these attributes were then aggregated into a regional Fish Index, a single metric for each sub-region. Except for the species composition indicators and the sensitive species abundance indicator, all indicators measure only fish species that are native to the San Francisco Estuary and local coastal waters.

To provide a geographically comprehensive view of trends among fishes in the San Francisco Estuary, a smaller set of indicators was developed to reveal conditions in Suisun Marsh, Suisun Bay, and the Sacramento-San Joaquin River Delta (collectively, the upper Estuary). The upper Estuary's aquatic habitat and fish fauna differ from those found in the open waters of the Estuary's main bays. Data for indicators in the upper Estuary comes from three long-term sampling programs and the approach mirrors that used in the Bay Fish Index. An additional indicator, portraying the fish assemblage's role in the Estuary's food web,

DETAILS

BAY FISH INDEX BASED ON TEN INDICATORS



was calculated for fishes of the upper Estuary (see Ecological Processes).

The benchmarks (or reference conditions) for the Bay Fish indicators are based on measured values from 1980-1989 (the earliest years for most of the surveys), maximum measured values for the Estuary or sub-regions, recognized interpretations of ecosystem health, and best professional judgment. The upper Estuary fish indicators mirror this approach for setting benchmarks.

STATUS & TRENDS The condition of the Bay fish community differs among the four sub-regions. Abundance, diversity, species composition, and distribution are all highest in Central and South Bays, where overall conditions (the regional Fish Index) were consistently good. The Central Bay, influenced by conditions in the ocean, is healthy and stable. Conditions in the North Bay are generally good but declining, with lower abundance levels and increasing prevalence of non-native fish species. The South Bay Fish Index is also good but declining, driven by declining abundance of pelagic (open water) fish species.

In contrast, the health of the upper Estuary has declined markedly during the past three decades and is now (and has been for more than 20 years) in poor to very poor condition. In Suisun Bay, more than half of all fish are non-native and, in some areas, native species are no longer consistently found. Suisun Marsh and the Delta are heavily dominated by non-native species and the abundance of native fish is declining in almost all areas.

UPPER ESTUARY INDICATORS	SUBREGION	STATUS	TREND
NATIVE FISH ABUNDANCE	Suisun Marsh	Poor	Decline
	Suisun Bay Pelagic	Very Poor	Decline
	Central-West Delta Pelagic	Very Poor	Decline
	Delta Beach Zone	Poor	Stable
PERCENT NATIVE FISH	Suisun Marsh	Very Poor	Stable
	Suisun Bay Pelagic	Poor	Stable
	Central-West Delta Pelagic	Very Poor	Stable
	Delta Beach Zone	Very Poor	Stable
PERCENT NATIVE SPECIES	Suisun Marsh	Very Poor	Decline
	Suisun Bay Pelagic	Fair	Stable
	Central-West Delta Pelagic	Very Poor	Decline
	Delta Beach Zone	Very Poor	Stable

FISH

UPPER ESTUARY

..STATUS..
Poor

....TREND....
Deteriorating

.....BENCHMARK.....
Historical average
1980-1989
1995-2004 (Delta Beach)

SAN FRANCISCO & SUISUN BAYS

..STATUS..
Good to Poor

....TREND....
Mixed

.....BENCHMARK.....
Historical average
1980-1989

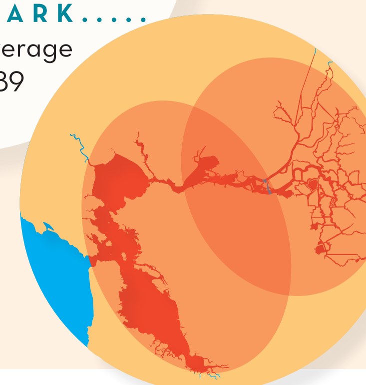
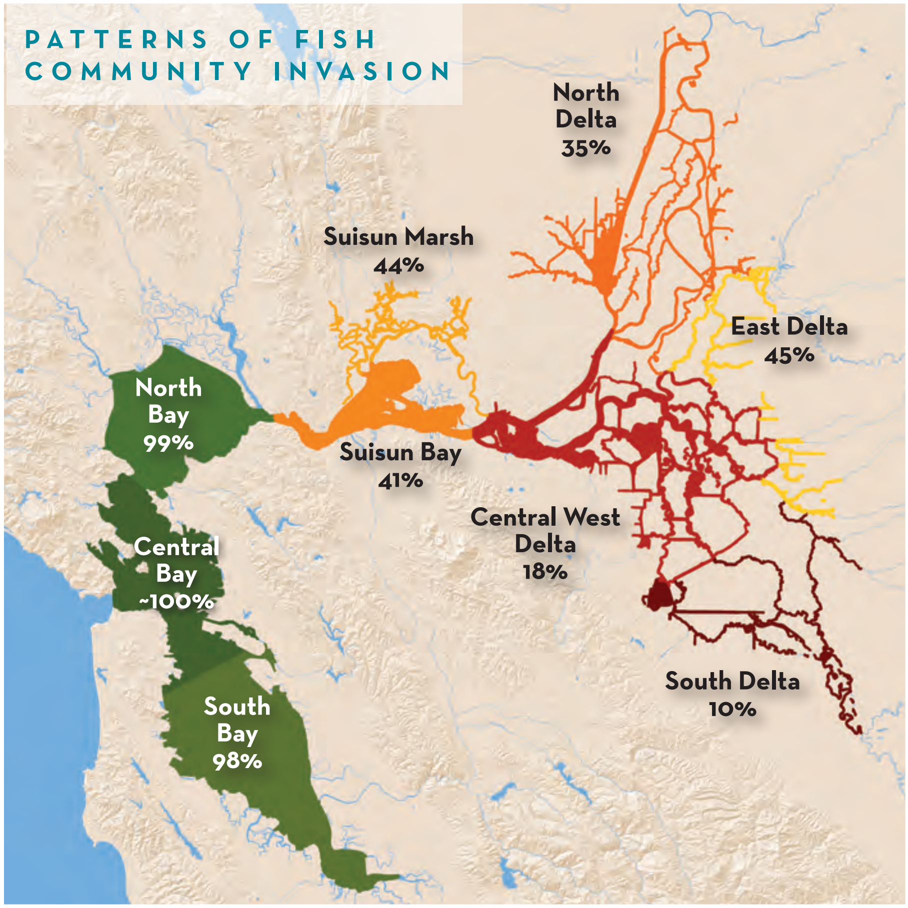
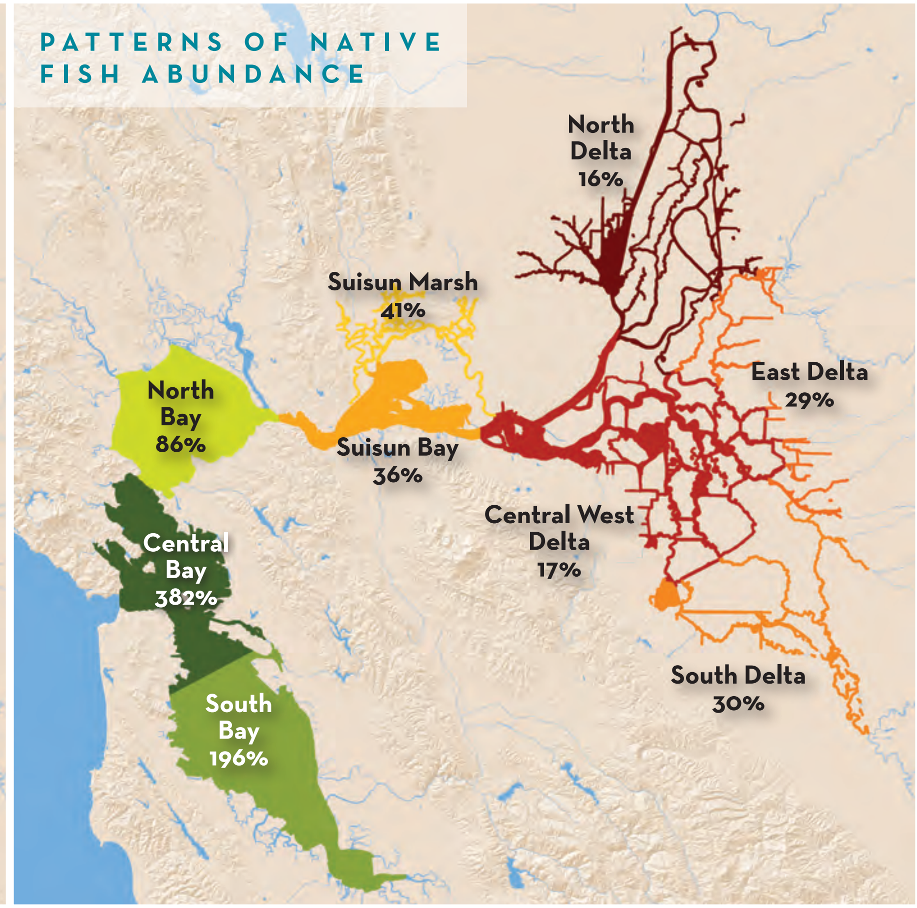


Photo: Dale Kolke, DWR

THREATS & CHALLENGES

The stark regional differences in the conditions and trends of the Estuary's fish community reflect differences in human impacts on habitats and the ecological processes that create and sustain them. While the lower Estuary, which is most influenced by ocean conditions, supports a healthy and stable





Percentage of Native Fish: *The presence of larger percentages of non-native species in the fish community is an indicator of degraded ecological conditions. In the San Francisco Estuary, nearly all the fish in the lower Estuary are natives, but the upper Estuary is dominated by non-natives. This indicator measures the percentage of native fishes in different regions of the Estuary using data from four different survey programs.*

Percentage of Past Abundance: *Healthy ecosystems support abundant fish populations. Native fish populations have increased in the South and Central Bay but declined substantially in the upper Estuary. In Suisun Bay and the Delta, recent fish abundance levels are just a third of levels measured 30 years ago. This indicator measures the abundance of native fish for the most recent five-year period compared to average abundance from 20 or 30 years ago using data from four different survey programs.*

fish community, the fish community in the upper Estuary, which is impaired by deteriorating freshwater inflows and associated ecological processes and habitats, is in dire condition. These results underscore the need to improve the upper Estuary's ecological health and, combined with results from other sections of this report, point the way. Preserving a healthy diverse fish community throughout the Estuary will require focused attention on the upper Estuary, and actions to improve freshwater inflows, re-establish key ecological processes that increase productivity, and restore open water, floodplain and tidal marsh habitats (see Freshwater Inflow p. 21, Open Water Habitat p 27, Tidal Marsh Habitat p 33, and Flood Events p. 66).

Photo: Bob Wick, BLM

HARBOR SEALS

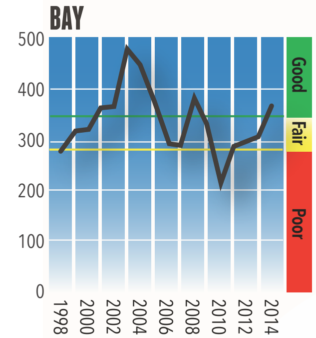
CONTEXT Bay Area residents sometimes glimpse harbor seals, with their spotted, pudgy bodies and soulful eyes, lounging on the rocks near the Richmond-San Rafael Bridge, at Alameda Point, the Richardson Bay shoreline, or Sausalito. Harbor seals sit at the top of the food web within the Estuary and along the nearshore outer coast, preying on many different fishes, octopuses, squid, and crustaceans. They rest, molt, and nurse their pups on land at traditional haul-out sites but forage at sea, often close to their haul-out sites. Harbor seals are the only year-round, resident marine mammal in the Estuary. As opportunistic predators of seasonally abundant fish and invertebrates, harbor seals respond quickly to changes in regional environmental conditions. During El Niño years when many prey species moved away from warmer than usual waters, the number of total seals surveyed at colony sites in central California declined.

INDICATOR This indicator provides an index of harbor seal abundance. Protocols for monitoring harbor seals are well established and have been implemented in the Estuary since 1998 at two prime locations for breeding harbor seals: Yerba Buena Island and Castro Rocks. Harbor seal abundance, excluding pups, was used to gauge the health of the Estuary, based on a series of timed counts of harbor seals during the breeding season. The benchmark is based on the mean — 328 seals — of the annual maximum number of seals counted at the two locations from 2000-2010.

STATUS & TRENDS There is no clear trend to the data between 1998 and 2014. Adult harbor seal numbers decreased in 2011, but pup numbers were not as depressed. Analysis suggests the status of the harbor seal population is fair: there has not been a substantial drop in numbers. While harbor seal numbers along the adjacent coast have improved since the Marine Mammal Protection Act passed in 1972, Estuary harbor seal numbers have not.

THREATS & CHALLENGES Seals are vulnerable to disturbances from boats, habitat loss, human-related pollutants (oil, mercury, pesticides, and other contaminants), and prey availability, as well as the cumulative effects of all of these threats. Seals in the Bay also respond to the ecological condition of the coastal ocean, and its biological diversity (see also The Ocean Connection p. 61). Unusual warm ocean conditions, such as the El Niño conditions of 2015, are often associated with a breakdown in food webs, with less prey such as anchovies — prey for seals — in nearshore coastal waters. But since resident seals within the Estuary forage more on resident prey species, El Niño may have less of an impact on them. The intensity and frequency of El Niño events is predicted to increase in the future in response to changes in climate, and seal monitoring could provide opportunities to react to these new types of events as they unfold.

HARBOR SEALS



BAY

STATUS
Fair

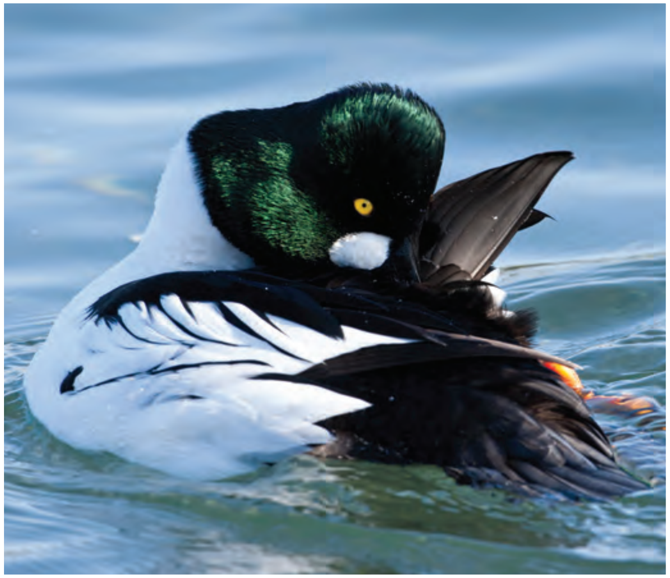
TREND
No change

BENCHMARK
Derived from historical average 2000-2010

WINTERING WATERFOWL

CONTEXT Birdwatchers gazing out over the Estuary during the winter may see large flocks of ducks dipping their bills into the water or tipping upside down and diving beneath the surface. These ducks – both year round residents and migrants – spend their winters in the Estuary, which provides some of the most important wintering habitat for waterfowl in North America. It hosts nearly half of some diving duck species that are counted in the lower Pacific Flyway during winter. The Estuary is also valuable to waterfowl during the breeding season (especially in the Suisun Bay region) and during the spring and fall migratory periods. More than 30 species of waterfowl are commonly observed in the San Francisco Bay region. Waterfowl are an important part of the Estuary ecosystem and the aquatic food web, consuming both plants and invertebrates. In addition, duck hunting is an important economic and recreational activity.

INDICATOR This wintering waterfowl indicator measures the abundance of six species of dabbling ducks and six species of diving ducks surveyed each January between 1989 and 2014 as part of the Midwinter Waterfowl Surveys. Abundance was calculated for three regions of the Estuary: North Bay, Central Bay, and South Bay. Dabbling ducks include American wigeon, gadwall, green-winged teal, mallard, Northern pintail, and Northern shoveler. Diving ducks include bufflehead, canvasback, goldeneye (Barrow's and common), ruddy duck, scoter (black, white-winged, and surf scoter), and scaup (lesser and greater scaup). The indicator analyzed changes in the abundance index for all six species simultaneously, for each group (dabblers, divers).

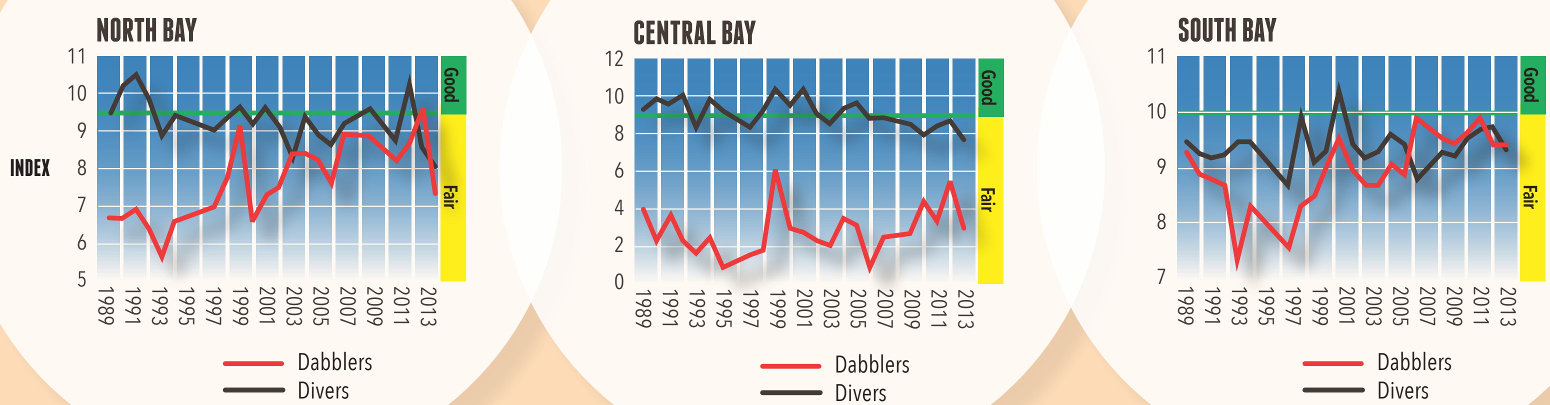


Common goldeneye. Photo: Rinus Baak, USFWS

Benchmarks derive from mean abundance between 1989 and 1993. The most recent five-year period (2010-2014) was compared to the benchmark. Abundance exceeding the benchmark is considered good.

DETAILS

INDEX OF ABUNDANCE OF SIX SPECIES



STATUS & TRENDS Overall, dabbling ducks are increasing in all three regions while diving ducks are declining significantly in the North Bay and Central Bay. South Bay diving ducks show a modest, non-significant increase compared to the benchmark.

The strong decline in diving ducks is potentially of great concern. However, a better understanding is needed of how wintering distributions of diving ducks are shifting over time in response to climate change and other factors. The difference in outlook for diving versus dabbling ducks likely reflects differences in food availability, both prey or plant species, as well as availability of foraging location (dabbling ducks can forage in shallower water). A second important factor is the status of breeding populations outside of the San Francisco Estuary since most wintering waterfowl breed elsewhere. Since Pacific Flyway populations are characterized by declining scaup and increasing dabbling ducks, such as mallards, it is not surprising that the San Estuary Midwinter Waterfowl Survey results show a similar picture.

The widely observed increase in dabbling ducks is consistent with favorable environmental conditions in the Estuary during the winter, but it may reflect changes in the wintering distribution of these species. In addition, favorable conditions on their breeding grounds, far from the Estuary, may be contributing to the increase.

THREATS & CHALLENGES The San Francisco Bay region is identified as a waterfowl habitat area of major concern in the North American Waterfowl Management Plan. The San Francisco Bay Joint Venture has made waterfowl conservation in the Bay Area a priority. Waterfowl conservation has also been a prime objective of significant restoration projects around the Bay. Tracking waterfowl population changes is important in assessing overall response to restoration, as well as to management intended to reduce or eliminate adverse impacts. Both dabblers and divers may be affected as managed ponds are converted to tidal marsh, for example. Diving ducks will likely be more impacted whereas dabbling ducks can forage in shallow water areas within marshes, if these are present. Diving duck declines may also be related to drought, range contraction due to climate effects, increased development leading to habitat loss or alteration, and long-term changes in prey resources.

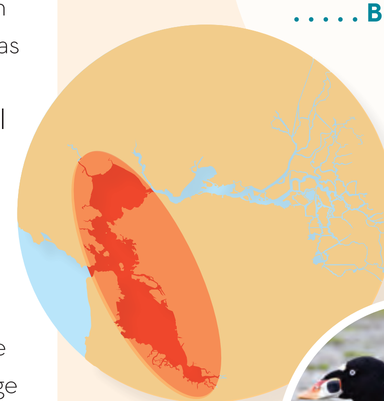
WINTERING WATERFOWL

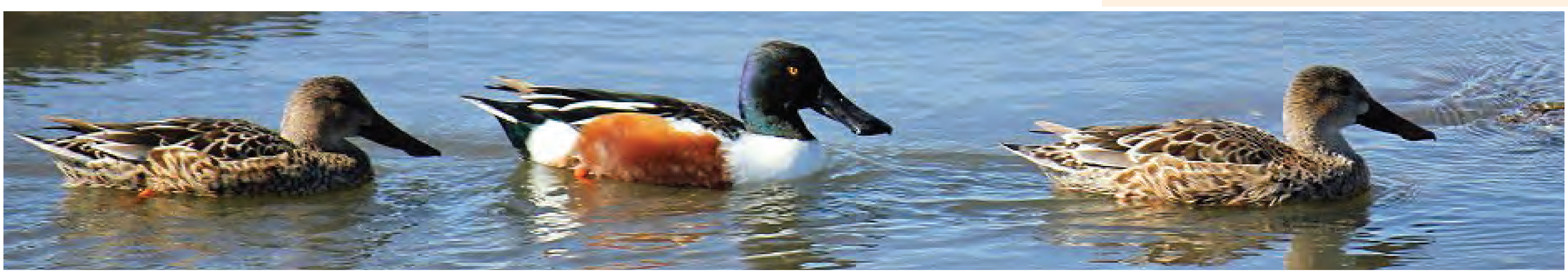
BAY

STATUS
Dabblers: Good
Divers: Fair to Poor

TREND
Dabblers: Improving
Divers: Deteriorating

BENCHMARK
Abundance
1989-1993





Northern shovelers (2 females and 1 male). Photo: USFWS Bubble: Male surf scoter. Photo: Rinus Baak, USFWS

Pintail pair in flight (and green-headed male mallard in the water). Photo: USFWS

BREEDING WATERFOWL

CONTEXT Most locals know the difference between a web-footed duck and a long-legged shorebird; many can even name the more common green-headed mallard male on sight. Few may know that the mallard is a dabbling duck, a duck that feeds on the surface with tail tipped in the air, and that dabblers are among the most abundant breeding waterfowl in the Estuary (see p. 46 for diving ducks). The abundance of five common dabblers during their breeding season offers a strong indicator of the health of the region's native wildlife.

Breeding ducks need undisturbed uplands for nesting in proximity to water. During the month while they lay and care for their eggs, they forage in adjacent waters for food. Shortly after their eggs hatch, they bring their brood to the water. Such habitats are not always pristine. In the Delta, ducks share habitats with farmers; in Suisun Marsh, their habitats are hunting clubs, some of which are also managed to support breeding waterfowl. Fall and winter hunting is a popular pastime in many of the region's more rural areas, and healthy waterfowl breeding populations are important to hunters and birdwatchers alike. Higher breeding populations in California can mean higher hunting bag limits set for the state.

In general, breeding waterfowl numbers are higher in areas with more available habitat, appropriate land use practices, and lower threats from predators like foxes and falcons. Higher rainfall years also tend to support more waterfowl than dry or drought years.

INDICATOR This breeding waterfowl indicator measures annual abundance of five of the most abundant dabbling duck species in the Estuary: mallard, gadwall, green-winged teal, northern pintail, and northern shoveler. The indicator combines data on abundance from two separate regions of the Estuary – the Delta and Suisun Marsh – between 2010 and 2014. Data was sourced from California Waterfowl Breeding Population Survey 1992-2014 and also compared to statewide trends. Benchmarks derive from mean abundance between 1992 and 2001, the first ten years of the survey. Less than 60% of benchmark was considered poor condition in this analysis.

STATUS & TRENDS The current status for the five most abundant species of breeding waterfowl in the Delta and Suisun Marsh is fair but decreasing from baseline. The trends are different for mallards relative to the remaining four species, particularly in the Delta. Mallards are the dominant waterfowl species in the Delta (~92%) and Suisun (~59%). Between 1992 and 2014, mallard abundance decreased more than 2% per year in both regions. For the remaining four waterfowl species, abundance is increasing at a rate of 7.7 percent per year in the Delta and decreasing at a rate of 2.3 percent per year in Suisun Marsh. Decreases mirror statewide trends.

In the Delta, the current population estimate of 7,400 birds for all five species over the last five years was 67% of the benchmark. In 2014, the estimated mallard population of 3,826 was the lowest in the history of the survey. In 2013, the estimated northern shoveler population of 1,170 was the highest in the history of the survey. Statewide, species that tend to nest later are doing better, such as the northern shoveler and gadwall.

In Suisun Marsh, the current population estimate of 23,000 birds for all five species over the last five years was also 67% of benchmark.

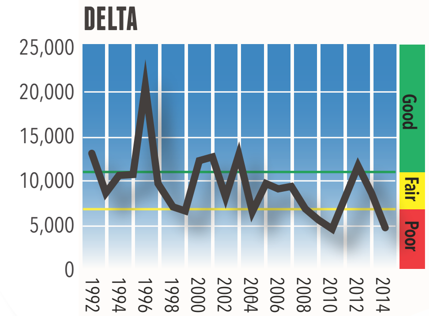
A comparison with statewide data suggests that for mallards conditions are deteriorating in the Delta and Suisun relative to elsewhere in California. For the four other species the comparison suggests conditions are improving in the Delta and deteriorating in Suisun Marsh.

THREATS & CHALLENGES

Ducks that breed in the Estuary experience a number of pressures on their nesting habitat and food supply. These include encroaching land uses and agricultural practices; low water levels in wildlife refuges local irrigation ditches, ponds, canals, and sloughs; predation, hunting, disease, invasive plant species, and contaminants in their environment. Problems outside the region can also affect local waterfowl. Reduced water availability in the Klamath Basin, where many of the Central Valley birds go to molt (i.e., shed their feathers and grow a new set, during which time they are flightless) has led to increased exposure to avian botulism, for example. As the landscape continues to change in the Delta and Suisun Marsh, the suitability of habitat available for breeding waterfowl is likely to change too. Restoration, enhancement, and wetland protection is likely to improve habitat while climate change, drought, and the conversion of row crops to orchards and vineyards may degrade it.

Mallards. Photo: T. Grey

BREEDING WATERFOWL

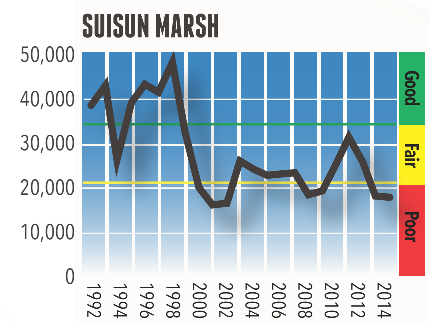


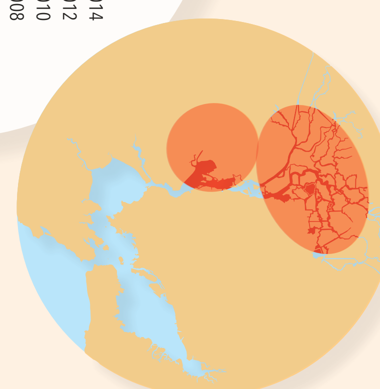
UPPER ESTUARY

..STATUS..
Fair

....TREND....
Deteriorating

.....BENCHMARK.....
Abundance 1992-2001





SHOREBIRDS

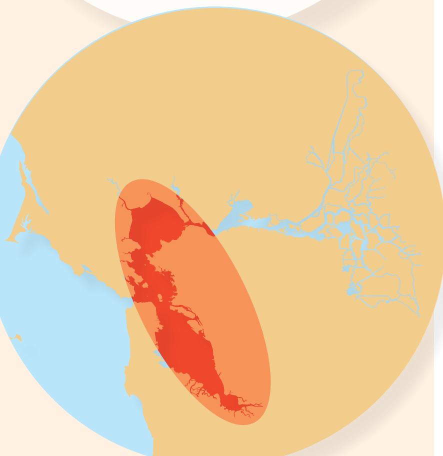
WINTERING SHOREBIRD ABUNDANCE

SAN FRANCISCO BAY

..STATUS..
Fair to Poor

....TREND....
Mixed

.....BENCHMARK.....
Derived from average abundance 2006-2008



CONTEXT In winter, the mudflats that ring the Estuary shimmer with thousands of peeps and plovers, plucking away at worms, tiny clams, and other critters in the ooze. The Estuary is a site of hemispheric importance for migratory shorebirds that overwinter here. Over one million shorebirds, including year-round residents, use the intertidal mudflats, marshes, and saline ponds of the Estuary each year (>300,000 birds in winter). Species of shorebirds using the Estuary in the non-breeding season vary greatly in body size and abundance; their migratory pathways and breeding ground locations vary as well. The variety among wintering shorebirds make them a good measure of the condition of San Francisco Bay's intertidal wetlands and saline ponds.

INDICATOR The indicator measures the abundance of shorebirds per hectare during the winter. Scientists selected nine common, wintering, migratory shorebird species, representing three groups based on body size and breeding distribution, as indicators for intertidal mudflats, salt marshes, and saline ponds in the north, central, and south regions of the Estuary. Large shorebirds included American avocet, willet, and marbled godwit. Medium-sized included black-bellied plover, and short- and long-billed dowitchers. Small included dunlin, Western sandpiper, and least sandpiper.

Marbled godwit. Photo. Rinus Baak, USFWS

Photo: Rick Lewis

The benchmark derives from the average abundance of each group in each Bay region from early winter surveys conducted 2006-2008. The indicator score is based on difference in density relative to the benchmark and the degree of certainty in density estimates. The 2006-2008 makes a good benchmark because it represents the state of shorebird populations just prior to a period of substantial change in wetlands in San Francisco Bay brought about by large-scale restoration of saline ponds to tidal marshes.

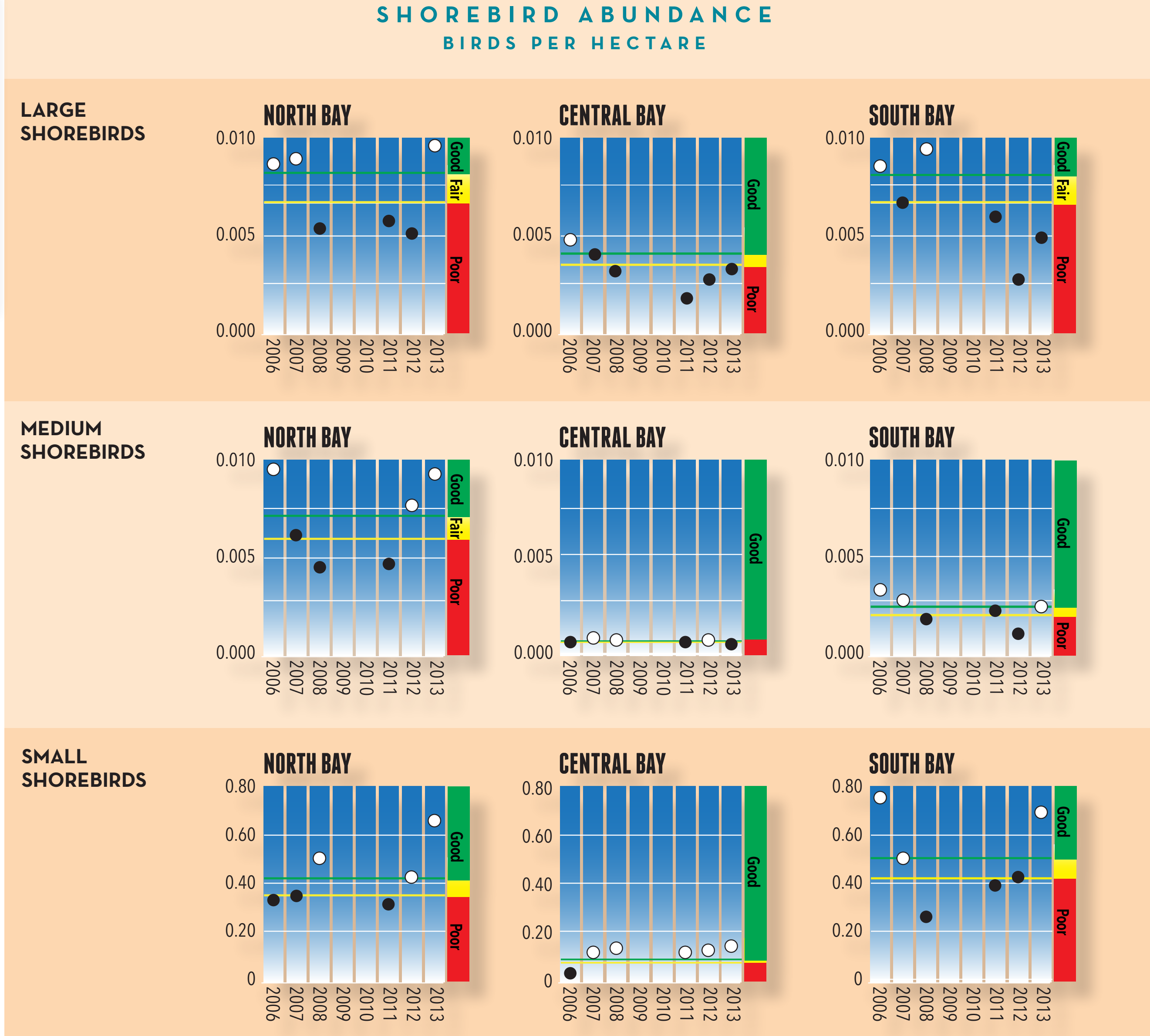
STATUS & TRENDS The status of large and medium shorebirds is poor; small shorebirds are fair. Non-breeding shorebird populations of different species and size groups are changing in different ways in abundance

American avocet. Photo: Rick Lewis

and perhaps in distribution within San Francisco Bay. Small shorebirds appear generally stable. Large and medium shorebirds were in decline across the Estuary but particularly so in the Central and South bays.

THREATS & CHALLENGES With large-scale restoration work occurring on thousands of acres of former salt ponds, shorebird habitats in San Francisco Bay have undergone significant transformations in the last decade, particularly in those areas. Whether declines in medium and large shorebirds in the South Bay are related to these changes in wetlands requires additional research. Ongoing annual monitoring of randomly selected sites and periodic Bay-wide comprehensive surveys are needed to better understand the year-to-year variation and to establish whether the changes observed represent changes in wintering abundance or shifts in bird distribution.

DETAILS



HERONS & EGRETS

CONTEXT The sight of a large, prehistoric looking bird—dark grey-blue or stark white—standing or lifting off from a marsh is magnificent and surprising. Great egrets and great blue herons are used to indicate population responses to different habitat conditions. Great egrets preferentially forage in small ponds in emergent wetlands and in areas with shallow, fluctuating water depths. In contrast, great blue herons forage along the edges of larger bodies of water and creeks and are less sensitive to water depth. Nesting abundance and success of these two, large wading birds are affected by changes in land-use, hydrology (especially water circulation and depth), geomorphology, environmental contamination, vegetation characteristics, and the availability of suitable prey. Heron and egret nest abundance is a valuable metric for assessing biotic condition in estuarine and wetland ecosystems.

Photo: Rick Lewis

INDICATOR This indicator is comprised of two indices: heron and egret nest density and nest survival. Analysis uses data from ongoing regional heron and egret studies by Audubon Canyon Ranch. Their repeated annual nest counts at all known colony sites provide extensive measurements of nest abundance and an index of regional breeding population sizes. To facilitate comparisons among regions, nest abundance is converted to nest density, based on the number of nests per 100 km² within foraging range of suitable wetland feeding areas. Results are provided for each year (1991-2014), for all known nesting colonies in the Central Bay, the North Bay, and Suisun Bay, and the combined area of all three.

Nest survival is a measure of nest success. Great egret and great blue heron nests are considered to successfully survive if at least one young survives to minimum fledging age of seven or eight weeks, respectively. The number of young fledged per successful nest is used, separately, as a food web indicator (see chapter on Processes). Nests are sampled in approximate proportion to colony size. In colonies with fewer than 15 active nests, all nests initiated before the colony reaches peak nest abundance are treated as focal nests. At larger colonies, random samples of at least 10-15 focal nests are selected. The nest survival indicator, calculated as the annual, arithmetic mean of apparent nest success, between species, is based on the proportion of focal nests that remain active through the nesting cycle, from nest initiation or early in the incubation period, at 40-50 colony sites within 10 km of the historic tidal wetland boundary.

The nest survival index is sensitive to nest predation and colony disturbance by native and introduced nest predators (especially by human commensal species such as raccoons and ravens), land development and human activity near heronries, and severe weather. Such ecological processes can vary over space and time in response to habitat changes, dynamics of predator populations, and changes in human land use, and are therefore likely to differentially affect nesting colonies of herons and egrets.

The benchmark for nest density is the average nest density observed from 1991-2000, across the Central Bay, the North Bay, and Suisun Bay. The benchmark for nest survival is the average nest survival from 1994-2000 across the same three regions.

STATUS & TRENDS

Great blue heron and great egret nest density is increasing over the long term but there have been recent short-term declines within some regions. Heron and egret nest success is fairly stable, increasing and decreasing within some regions.

In the North Bay, nesting densities of herons and egrets are stable or increasing, possibly due to improvements in wetlands and the extent or quality of suitable foraging and nesting areas or to the supply and availability of fish and suitable prey. In the North Bay, substantial increases in nesting density may be associated with wetland restoration efforts. The recent leveling off of nest densities in the North Bay, however, suggests that regional heron and egret distributions may have stabilized after the colonization of new wetland feeding areas.

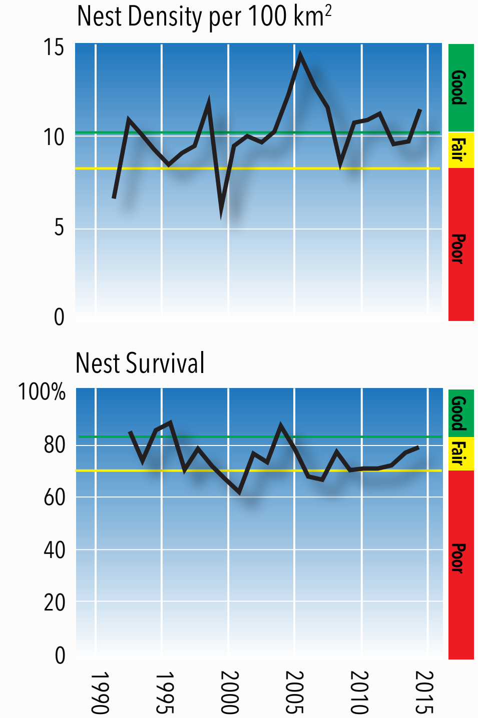
Heron and egret nest survival is stable when measured across all areas of northern San Francisco Bay. The declining trend in nest survival in the Central Bay is consistent with the parallel decline in nest density.

THREATS & CHALLENGES

A relatively steep, declining trend in nest density in Central San Francisco Bay may be of some concern. Ravens, raccoons, and other nest predators, as well as human visitors, may be disturbing egrets and herons on several islands, a situation that may need to be managed.

Great egrets nesting at Martin Griffin Preserve, Marin. Photo: Larry Goodwin

EGRET & HERON NEST DENSITY & NEST SURVIVAL



BAY

..STATUS..
Fair

....TREND....
Mixed

.....BENCHMARK.....
Average nest density 1991-2000
Average nest survival 1994-2000

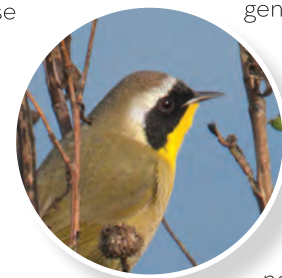
TIDAL MARSH BIRDS

CONTEXT Buzzy calls and trills ringing out from the marshes around the Estuary are often the first clue to finding the sometimes-secretive songbirds and rails that live there. Tidal marsh birds are valuable indicators of tidal marsh ecosystem condition. San Francisco Estuary tidal marsh habitat has been dramatically altered in the past two centuries. Over 80 percent of the original tidal marsh habitat in the Bay region has been lost. Many of the species that depend on tidal marsh habitat are currently listed as federally- or state-threatened or endangered, such as the California black rail, or are designated as California Species of Special Concern (tidal marsh song sparrow species and the saltmarsh common yellowthroat).

INDICATOR This indicator is an index that measures the current condition of three tidal marsh-dependent bird species, providing insight into success at recovering or maintaining these threatened populations. The indicator measures the breeding season abundance of the California black rail (*Laterallus jamaicensis coturniculus*), song sparrow (*Melodia melospiza* subspecies), and common yellowthroat (*Geothlypis trichas sinuosa*). Subspecies of all three live and breed in the Estuary. They are uniquely adapted to tidal marsh habitat and are of conservation concern. Standardized surveys of these species have been conducted in tidal marsh habitat since 1996, and from this an index of population density was constructed, combining results for the three species.

Data from the most recent four years of surveys (2011-2014) for all three species combined was compared to benchmark values. Ten marshes were surveyed regularly during 1996-2014, from about ten stations per marsh. Birds were identified and enumerated within 50 meters of an observer.

STATUS & TRENDS The three species Tidal Marsh Bird Population Index varied from 0.93 birds per hectare to 1.32 birds per hectare during the four years 2011 to 2014, with a mean value of 1.09. The Tidal Marsh Bird Index demonstrated a significant, increasing trend over the entire time period. An average annual growth rate of 2.77 percent over the course of 18 years translates into a total increase of 63 percent. Black rails and common yellowthroats increased significantly over the entire period. Song sparrows exhibited a weak, insignificant increase. The overall trend reflects an early increase (1996-2005), followed by no overall increase during the latter period (2005-2014). The best estimate of the trend in the first nine years is 5.1 percent increase per year. In the last nine years, the trend is indistinguishable from 0 percent change. The trend during the entire period of study, 1996 to 2014, is significantly positive.



The 2015 Tidal Marsh Bird Population Indicator reflects a mixed picture. While there is a general increase in density of the three-species-index since 1996, no clear increase is evident in the more recent years (2005 to 2014). Furthermore, only two out of the three species demonstrate an increase in density over the entire period, 1996 to 2014. That said, there is no evidence of a decline in density during the entire time period.

THREATS & CHALLENGES Reduced, degraded and fragmented habitat, plus the spread of invasive species, have all contributed to reductions in the population size and viability of the birds that depend on tidal marsh. Management and restoration efforts by agencies and NGOs have been directed at recovering depleted populations or ensuring their stability. At this time, habitat is sufficient to maintain populations at their current density and possibly to support an increase in density, at least for rail species and the common yellowthroat. Density is expected to increase as young, restored marshes mature and better support growing populations of tidal marsh bird species.

Photo: Rick Lewis

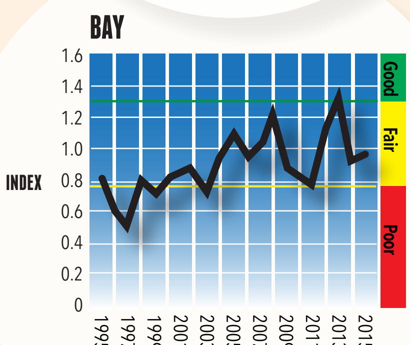
TIDAL MARSH BIRDS

BAY

STATUS
Fair

TREND
Increasing

BENCHMARK
Upper quartile population density, 1996-2008



RIDGWAY'S RAIL

CONTEXT Although often described as secretive, the endangered California Ridgway's rail, the size and color of a small chicken, is easy to spot in marshes and mudflats around the Bay. All species that rely on tidal marsh habitat are affected by habitat loss, alteration, and stressors. But this rail, formerly California clapper rail, is especially affected because they use low marsh for foraging, depend on channelized marshes, and need mid-marsh and upper marsh areas for nesting and refugia from predators. The Estuary's population of *Rallus obsoletus obsoletus* is much reduced compared to the 1970s. Fewer than 1,200 individuals may remain, making this species highly vulnerable to extirpation.

As a federally endangered subspecies, the rail has also been the focus of extensive tidal marsh restoration efforts throughout the Estuary, as well as a number of management activities. The rail is an excellent indicator of tidal marsh health.

INDICATOR This indicator measures the density of birds per hectare as determined from comprehensive, standardized breeding season surveys conducted throughout the San Francisco Estuary since 2005. Surveys have been conducted by the Invasive Spartina Project, Point Blue Conservation Science, and various regional, state, and federal agencies. This indicator uses the most recent, state-of-the-art analysis by Point Blue for surveys carried out 2005-2013. The benchmark derives from the three-year mean density during 2005-2007.

STATUS & TRENDS The density of Ridgway's rail declined in the North Bay between 2005 and 2008, but since then the trend has mostly been reversed. In the South Bay, density declined between 2006 and 2008, and apparently into 2009. Though no further decline has been seen since 2009, neither is there clear evidence of a reversal.

In the South Bay, large-scale removal of invasive Spartina (especially the *alterniflora x foliosa* hybrid) during the period 2006 to 2010 improved conditions for native plant species but also removed intact vegetation used by the rails. An increase in bay-wide rail numbers to 2005-2007 levels will require time for current habitat restoration efforts to provide mature, native tidal marsh, and for other management actions targeting rails to take effect. In the North Bay there was also a substantial decline from 2005 to 2008, though there was much less *Spartina* eradication in this region.

THREATS & CHALLENGES The biggest threats to the Ridgway's rail are loss, fragmentation and alteration of habitat, loss of transitional habitat bordering tidal marshes (refuge for rails during high tides), changes in salinity, pollutants, human disturbance, and invasive plants and predators.

The goal of the *Tidal Marsh Recovery Plan* is to increase the current population size of Ridgway's rail in the Estuary to approximately 5,500 individuals over a 50-year period. The best recent estimate (for the period 2009-2011) for this region is fewer than 1,200 individuals. To meet this ambitious goal will require an increase in tidal marsh habitat. Current management actions and activities are being directed at planting or maintaining important plant species that provide cover, refugia from predators, and locations for successful nesting. Those include gumplant (*Grindelia stricta*) and native cordgrass (*Spartina foliosa*).

RIDGWAY'S RAIL

Photo: Rick Lewis

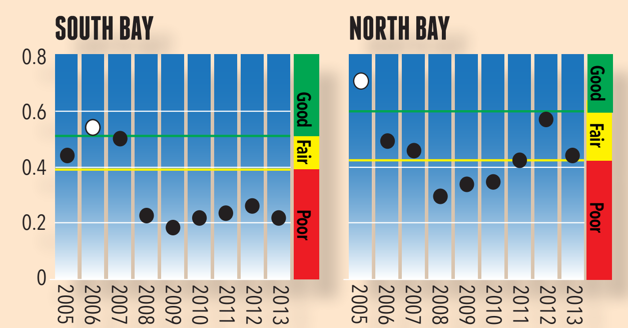
BAY

STATUS
North Bay: Fair
South Bay: Poor

TREND
Mixed

BENCHMARK
Derived from regional average 2005-2007

RIDGWAY'S RAIL POPULATION INDEX



THREE DELTA BIRDS OF CONCERN

The behavior and abundance of a tricolored blackbird, a small, secretive rail, and a crimson-crowned crane offer clues as to the health of tidal marsh and other wetlands in the Delta. There, where so much of the landscape is farmed, the status of these bird populations is also indicative of agricultural practices, which can either be friendly, disruptive, or dangerous to birds nesting or foraging in the vegetation cover provided by crops, ditch banks, peripheral wetlands, and marshes.

Photo: Sam Spaulding

THE TRICOLORED BLACKBIRD (*Agelaius tricolor*), a species found almost entirely in California, was given emergency protection as an endangered species under the California Endangered Species Act in 2014. Protection was triggered by an extremely low statewide population estimate of 145,000 birds – a 63% decline since 2008. Recent threats to the population include loss of foraging habitats in the San Joaquin Valley, catastrophic nesting failures associated with agricultural harvests, and high predator populations.

The tricolored blackbird breeds in large colonial groups, with hundreds to thousands of pairs breeding closely together in a single field. Its success in raising young is indicative of the availability of key habitat features and appropriate agricultural practices. During the breeding season, it requires nesting vegetation (primarily wetlands, grain fields, Himalayan blackberry, or weedy fields) adjacent to rich foraging areas. These areas must not only furnish the insect resources necessary to support large breeding colonies, but also provide water for drinking and bathing. The species appears to have evolved to take advantage of ephemeral resources, including insect outbreaks and recently disturbed wetlands that exhibit vigorous new growth for nesting. Since this blackbird is in the habit of nesting in groups, crop harvest or weed abatement activities in fields with large colonies can significantly reduce the annual reproductive output for the entire species.

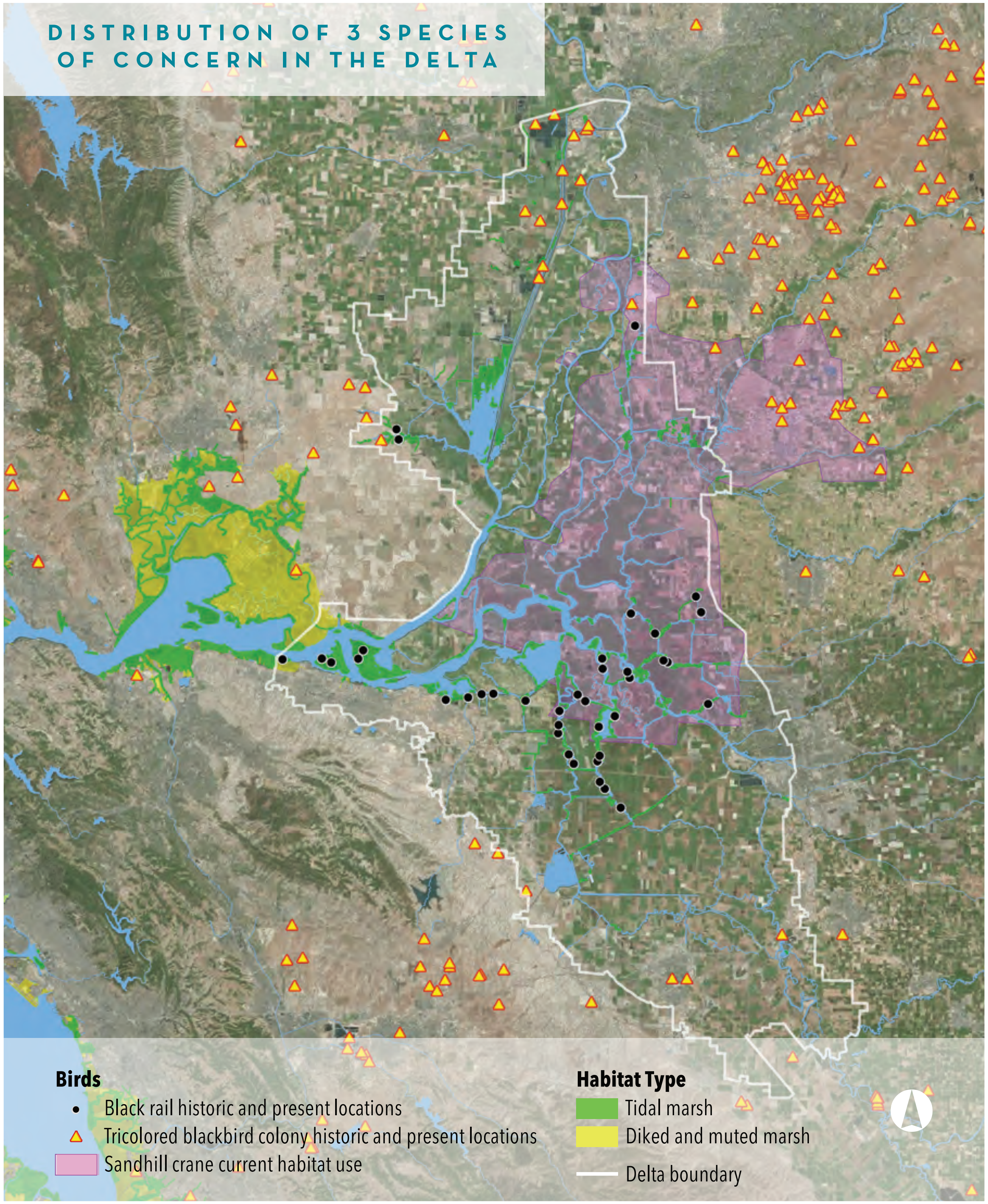
Records of tricolored blackbirds breeding in the Delta are few. Recent surveys documented a small number of larger colonies in Suisun Marsh and around the periphery of the Delta. In-Delta sites where this species has been noted include West Sacramento, the Yolo Bypass Wildlife Area, and Tracy but there were no breeding colonies found in the Delta during the 2014 Statewide Survey.

Historically, the tricolored blackbird was likely abundant in portions of the vast freshwater wetlands of the historical Delta that were adjacent to productive uplands on its periphery. Today, the species is most abundant in the Delta in winter, when it forms huge foraging flocks with other blackbird species and eats primarily grains found on agricultural fields or provisioned for livestock. The effects of blackbird control efforts to limit grain harvest losses need further study.

At the time of this report's publication, information on nesting colonies in the Delta was not adequate to develop the species as a quantitative indicator of this region of the Estuary system. As the tricolored blackbird is a covered species under several existing and proposed regional Habitat Conservation Plans, and may be a rare Delta breeder due to poor vegetation management, more monitoring may be called for. As Delta wetlands are restored and managed specifically for tricolored blackbirds, their numbers may increase. Management actions should stress the importance of young, lush, fast-growing wetland vegetation and adjacent uplands for foraging. Additional research is needed to assess the importance of the Delta to wintering birds, and to assess whether a wintering population indicator would be appropriate.

THE CALIFORNIA BLACK RAIL (*Laterallus jamaicensis coturniculus*) is a house sparrow-sized, secretive bird species found in wetlands. This species is listed as threatened under the California Endangered Species Act due to population declines caused by habitat loss. The

Photo: Nadje Najar



largest black rail population in California is in the San Francisco Estuary where it is found primarily in San Pablo and Suisun Bay tidal marshes (see p. 33). A smaller outlying sub-population has been found in the Delta, and black rails have also been seen in a few upper watershed marshes associated with seeps and irrigation ditches in the Sierra Nevada foothills.

The black rail is an indicator of the availability of good quality emergent wetlands, including tidal marsh habitat with an adjacent upland transition zone. Black rails require wet areas with shallow water (generally < 3 centimeters deep) and dense vegetation close to the ground for nesting. In tidal marshes, the species also requires adjacent higher elevation vegetated areas where they can hide from predators during high tides.

Scientists don't know much about the black rail's breeding habitat requirements in the Delta. They were likely present in the historical Delta at the upper edges of tidal marshes and in other perennial wetlands with shallow water. During recent Delta surveys, black rails have been documented using the largest available mid-channel islands with mature tidal marsh and non-tidal marshes. The most recent surveys discovered black rails along tidal channels at newly-restored Lindsey Slough on the Hastings Tract in Solano County, suggesting they can colonize new habitats quickly.

These elusive birds may be more abundant in the Delta than we currently think. A quantitative indicator could not be developed for the 2015 report due to a lack of consistent and recent data. Baseline surveys need to be conducted with the express purpose of establishing density and distribution and total population size. As habitat restoration proceeds, black rail surveys should be repeated at regular intervals to determine appropriate restoration design criteria and to establish trends. In the future, the black rail is likely to be an important indicator of successful tidal marsh habitat restoration in the Delta, as it is in San Francisco Bay.

THE SANDHILL CRANE ("crane," *Grus canadensis*) is a classic example of "charismatic megafauna," attracting a myriad of visitors to the Sacramento-San Joaquin Delta each year. The Delta supports approximately one-third of the cranes wintering in California, including both the greater sandhill crane (*G. c. tabida*), listed as Threatened under the California Endangered Species Act, and lesser sandhill crane (*G. c. canadensis*), a California Species of Special Concern.

A winter 2007-2008 survey of cranes in the Delta estimated a maximum bird count of 27,213. Historically, cranes were distributed much more widely throughout the San Francisco Estuary than they are now. They used coastal tidal marsh in the Bay, and shallowly flooded wetlands throughout the Delta and Central Valley, wherever water levels were right and vegetation was short. Most of this historical habitat has been lost, and disturbance makes much of the remaining habitat unsuitable. Cranes require shallowly flooded, undisturbed night roost sites (usually protected wetlands or flooded croplands) and in today's Delta landscape forage in adjacent agricultural fields, primarily post-harvest corn and rice. Conversion from seasonal row crops to vineyards, orchards, and residential areas has resulted in a loss of valuable foraging habitat for cranes. Concern over this loss has led to the acquisition, protection and enhancement of Delta lands specifically for use by cranes.

At the time of this 2015 report, the data currently available for sandhill crane populations in the Delta are not sufficient or accurate enough to develop a quantitative indicator. Limited winter crane surveys on Staten Island and other reserves are insufficient to evaluate crane population trends on a Delta-wide scale. Two 2014 conservation documents include recommendations to develop survey methods to estimate winter populations of both subspecies: *Conservation Priorities and Best Management Practices for Wintering Sandhill Cranes in the Central Valley of California*; and the *Coastal California Waterbird Conservation Plan*. Several local habitat conservation plans propose to restore and preserve habitat for the greater sandhill crane in the Delta, and include monitoring strategies.

Photos: Rick Lewis

PROCESSES

- OCEAN CONNECTION
- MIGRATION SPACE
- BENEFICIAL FLOODS
- SEDIMENT
- BLOOMS
- FOOD
- FEEDING CHICKS

OVERVIEW

Efforts to restore ecological processes are the new frontier in estuarine management. For decades, managers focused on habitat restoration to recover imperiled species or to reestablish ecosystem services. Restoring habitats alone, however, can no longer achieve these goals in a landscape so modified by humans, so invaded by non-native species, and so stressed by changes in climate and hydrology. Instead, the processes that allow ecosystems to function and maintain themselves over time need to be restored. These processes sustain resilient habitats and wildlife populations, and support the kind of ongoing succession and evolution that allows natural systems to adapt to change. Finding ways to accommodate ecosystem-sustaining processes in the urban, agricultural, industrial, and open landscapes surrounding the Estuary will be a challenge and time is short. This chapter examines indicators of the current health of processes that create food, accommodate habitat migration, deliver nutrients and sediment to floodplains, and nurture healthy fish and wildlife populations. It also explores factors that impede these processes, such as water management and the invasion of the Delta by non-native aquatic vegetation. Decisions regarding how to manage such challenges and restore ecological processes must be made very soon given the pace of climate change.

The Marine Mammal Center

TAKE HOMES

- The ocean's influence on the Estuary will increase with global warming and rising seas.
- Recent changes in the ocean include a blob of warm water offshore, changes in upwelling cycles reducing krill and other food supplies, and more zones of low oxygen water that can suffocate organisms.
- Tidal wetlands need to migrate landward to keep pace with rising sea levels but very little of the undeveloped space that could accommodate this transition is protected.
- The frequency, magnitude and duration of beneficial floods are too low to drive and support critical ecological processes.
- Nutrients are impacting Bay water quality more than they used to. Scientists note a 2-3 fold increase in the biomass of summer plankton blooms in the South Bay since 1999. In the Bay as a whole, they've recently detected a number of harmful algae species and toxins.
- The total area of the Delta invaded by alien aquatic weeds has increased from 9,000 acres in 2004 to more than 12,500 acres today.
- The abundance of zooplankton, critical prey at the base of the estuarine food web, has continued to decline in recent years, especially in the Delta.
- Overall fish abundance, another important trophic level in the food web, declined throughout most of the upper Estuary, except in the Delta's beach zone, where populations of non-native fish are increasing.
- Overall there is less and less food in the upper Estuary, and regional goals of recovering and reversing declines in estuarine fishes in the upper Estuary have not been met.
- Brandt's cormorants have been finding enough food, on average, to raise their young, successfully fledging enough chicks to sustain a stable population. This reflects some stability in the upper trophic levels of the estuarine food web in the context of recent, temporary declines.
- Heron and egret productivity rates have remained close to the long term average, with a stable to slightly declining trend in the average number of young produced in each successful nest. This slight decline may be worthy of some concern, but is small enough not to be significant.

SUPPORTING MATERIALS

This chapter summarizes data and materials written by the authors listed on page 12 and provided in full in the technical appendix for the State of the Estuary 2015 report. Go to: http://sfestuary.org/about-the-estuary/soter/

Chapter cover photo of Yolo Bypass: Bird's Eye View

THE OCEAN CONNECTION

The San Francisco Estuary does not end at the Golden Gate Bridge. Water flowing to and from the Gulf of the Farallones connects the Bay to the ocean in myriad ways, supplying the Bay with nutrients and plankton that support the aquatic ecosystem. The upwelling of nutrient-rich cold water over the continental shelf is a critical process that drives the productivity of coastal ocean food webs, supporting countless fish, sea birds, and marine mammals, and sustaining local commercial fisheries. Processes like these are also an important driver of estuarine conditions. While watershed processes and changes in river flow exert more influence upstream, in the Delta, the Central Bay more often mirrors marine conditions.

Changes offshore that can exert a strong influence on the state of the lower Estuary can be both large and small, and can occur over decades or hours. Ocean conditions change continuously, from the rise and fall of tides over hours to the daily and seasonal changes in upwelling winds, inter-annual changes like El Niño, and longer-term fluctuations like the Pacific Decadal Oscillation and the Northern Pacific Gyre Oscillation.

Reports of such ocean influences on San Francisco Bay in past years have focused on year-to-year changes in the delivery of nutrients, phytoplankton, and organisms through the Golden Gate and into the Bay. In the last couple years, however, two other phenomena are of note: first, unusually warm coastal waters; and second, increased upwelling of low-oxygen waters in spring and summer. Both are examples of ecological connections between the Estuary, the ocean and the atmosphere.

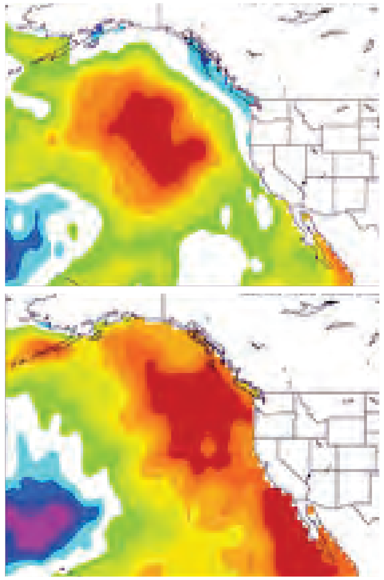
The surface water of the northern Pacific has been anomalously warm for over a year, developing in concert with California's drought. Given that cold upwelled waters supply the nutrients for plankton productivity, which supports the continental shelf ecosystem off San Francisco Bay, this warm anomaly may represent a major disruption of the food web. The "blob," as it is now commonly known, is a warm water mass up to 2°C above normal temperatures that extends to 100 meters in depth far offshore, with centers off Alaska and southern California. Scientists think the blob derives from the milder winters and reduced cooling caused by the persistent high-pressure atmospheric ridge over the northeast Pacific.

Up until the middle of 2014, wind-driven upwelling of cold water in the coastal waters of central and northern California prevented effects from the warm water "blob". Although normal cold temperatures and upwelling were observed off San Francisco Bay until June 2014, in July there was a sudden increase in temperatures and a shut down of upwelling winds. With this, the coastal currents turned northward and even warmer water and plankton were transported into the region from the south. From July to December 2014 water over the shelf was 3°C warmer than normal. The anomaly peaked at 4°C last September — exceeding even the effect of the strong 1982-83 El Niño. Warm water anomalies of 1-2°C persisted through winter, until April 2015, when coastal upwelling returned with enough strength to bring temperatures back to normal. The air got hotter too. February air temperatures at the Southeast Farallon Islands were higher in 2015 than at any time in the last 45 years.

Starved sea lion pups at rescue center in 2015. Photo: The Marine Mammal Center.

Common dolphins. Photo: NOAA

Ecological changes offshore likely associated with this anomaly include the disappearance of krill and juvenile rockfish from seabird diets. In other changes, species normally associated with sub-tropical waters moved north off central California, with common dolphins being seen off Bodega Bay and starving Guadalupe and northern fur seals off Point Reyes. During the 2014-15 winter on the Farallon Islands, seals and sea lions had difficulty reproducing and finding food, local seabirds had low colony attendance, and two tropical species of seabird showed up on the island. With the return of upwelling in April, however, Cassin's auklets and other seabird nesting species were laying eggs as they do in spring each year.



Persistence of ocean blob in 3/2014 (top) and 3/2015 (bottom): ocean surface temperature (red is warmest) Courtesy: NOAA

While anomalous conditions may have departed from the coastal zone for the 2015 upwelling season, the blob persists offshore – both north towards the Gulf of Alaska and south off Baja and southern California. Scientists think a return of anomalous conditions is likely in 2015; conditions could also be exacerbated by the El Niño developing in the equatorial Pacific.

The second notable ocean condition that may significantly affect the state of the Estuary is the appearance of low-oxygen waters over the shelf during upwelling. Whether due to increased upwelling (drawing waters from greater depth) or to low-oxygen waters from the deep ocean coming up onto the continental shelf through other forces, hypoxic events have been observed multiple times each season over the last few years. Hypoxia refers to oxygen levels below two milligrams per liter (mg/l), which represent a threat to marine life; however levels below five mg/L can be problematic.

The most noteworthy low-oxygen event in the Bay occurred in April 2011, when scientists observed a large mass of cold and salty oxygen-deficient water intruding into the South Bay. Although a similarly large ocean intrusion has not been seen during prior or subsequent monthly surveys of the San Francisco Bay by the US Geological Survey's research vessel *Polaris*, surveys have documented ocean water with dissolved oxygen below five mg/L at other times in the Central Bay.

Point Reyes, Pacific Coast: Photo: Rick Lewis

Data from 2015 confirm that hypoxic waters upwelled in the Gulf of the Farallones regularly move towards San Francisco Bay but stop at the horseshoe-shaped sandbar outside the Golden Gate. Intrusion all the way into the Bay, as occurred in 2011, requires special tide and river conditions.

To track this phenomenon, scientists are continuing to keep an eye on conditions off Bodega Bay, which are similar to those in the Gulf. Indeed dissolved oxygen levels recorded at the Bodega Marine Lab mooring every 10 minutes show that hypoxia has occurred nearshore as often as 10% of the time during recent upwelling seasons.

Ecological responses to hypoxic conditions are expected but not well documented. Bottom-dwelling organisms like invertebrates and crabs are particularly susceptible. Reports of crab mortality off Pacifica and Half Moon Bay in May 2014 were concurrent with a week of hypoxic waters recorded at 100-foot depth off Bodega Bay. While the 2014 event was not recorded by a San Francisco Bay sensor off Tiburon, scientists expect future hypoxic intrusions with impacts on benthic communities in the future.

Where these low-oxygen waters are seen over the continental shelf, they also exhibit low pH, high nitrate, and high dissolved carbon dioxide, factors of water quality interest. Intrusions of this enriched upwelled water, as occurred in April 2011, would thus import large amounts of nitrate, as well as hypoxic and acidic ocean waters, to the Bay — all parameters that are used to index local pollution.

These are just two 2011-2014 examples of the Estuary's seasonal and long-term susceptibility to atmospheric and oceanic processes. The presence of warm water off the Golden Gate may be merely interrupting "normal" upwelling processes now, impacting the aquatic food web, but could become a more common occurrence under a changing climate. The repeated observations of upwelled low-oxygen water reflect a persistent change that may be the "new normal" with the potential for widespread low-oxygen events in the Bay under certain conditions. Despite these obvious current and potential influences on the state of the Estuary, the intrusion of ocean material into the Bay is not well-monitored. Preliminary indices could be developed for oxygen, pH, nitrate, algal blooms and crab larvae, using existing mooring, survey and satellite data. Data would have to be combined with an understanding of upwelling, tidal and buoyancy processes, and biogeochemical cycling. In the meantime, however, no effective indicator of the ocean's influence on the state of the Estuary exists today.

MIGRATION SPACE

CONTEXT Scientists project a 2-5 foot rise in the level of the sea within the next century due to climate change. As the ocean moves increasingly into the Bay and Delta, and floods lower elevation shorelines, urban development continues to encroach on these same zones. While many wetlands, wildlife habitats, and parklands in these zones are protected from development, the buffer zones around them may not be, leading scientists concerned with sea level rise impacts on estuary health to evaluate "migration space" for shoreline habitats and sensitive species. Migration space is the upland area between the present-day shoreline of the Estuary and a higher, future shoreline resulting from sea level rise. In rough terms, this area offers space for lower, outer wetlands, for example, to build up sediment and biomass naturally, and "migrate" inland into higher areas. The total area of migration space has to do mainly with the slope of the land immediately adjacent to the Estuary. The space is widest across broad, gently sloping valleys and plains.

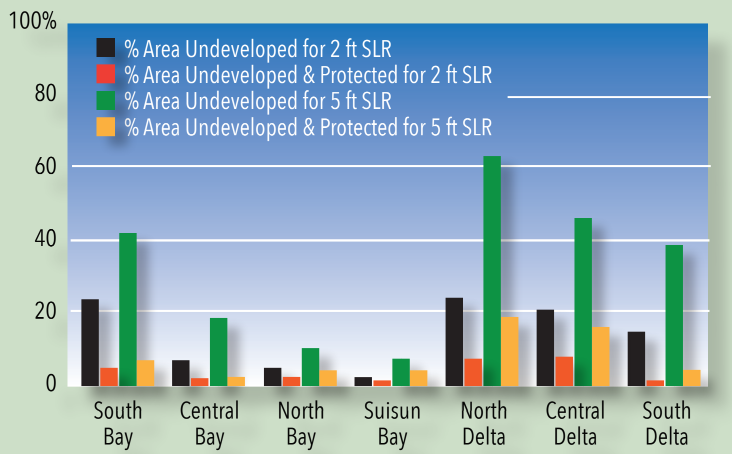
Access to this zone of natural transition from estuarine habitats to terrestrial habitats is critically important for the health of the Estuary. Shallow estuarine habitats help protect the shore against erosion and flooding due to storm surges or erosive waves generated by high winds. Without protected, undeveloped migration space, the Estuary will rise against the developed landscape, compressing the natural shore into a narrow band of vulnerable habitats with minimal cultural, economic, or ecological value.

INDICATOR This indicator evaluates two alternative migration spaces – one for a two-foot and one for a five-foot rise in sea level – in seven sub-regions of the Bay and Delta. It measures the current percentage of undeveloped space, and the percentage of that space that is protected from development. For the purposes of this evaluation, migration space excludes all existing tidal areas, as well as any reclaimed areas, such as salt ponds in South San Francisco Bay or diked farmlands in the Delta that would be flooded without their dikes or levees. However, migration space does include all areas of landfill within the historical limits of the Estuary that are above the future shorelines.

Benchmarks for migration space, as a new measure of Estuary health in the face of future sea level rise, have no reference point yet. However, for the purposes of this evaluation, scientists have set the benchmark at 50% of the total migration space in each sub-region being undeveloped, and 75% of that undeveloped space being protected.

DETAILS

MIGRATION SPACE
% OF TOTAL



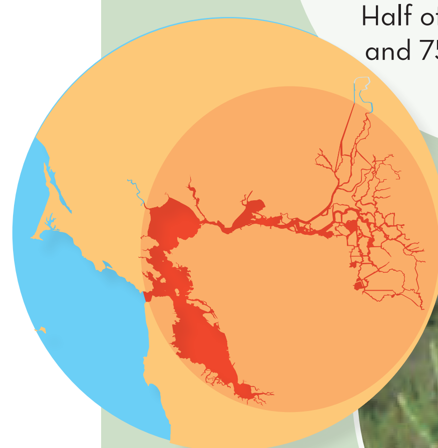
MIGRATION SPACE FROM RISING SEAS

ESTUARY

..STATUS..
Poor

....TREND....
No data

.....BENCHMARK.....
Half of space undeveloped, and 75% of that protected



STATUS & TRENDS While appreciable amounts of undeveloped migration space exist in some sub-regions, most of the space around the Estuary has been developed, and only a small percentage of the undeveloped space is protected from future development. For the Estuary as a whole, the existing transition zone is not well protected, and opportunities to restore are few. This analysis shows that much less than half the total migration space is undeveloped, and that less than half the undeveloped space is protected, so therefore the overall condition of the migration space is considered poor.

The overall patterns of development in the region suggest that much of the migration space was developed during the last century, before environmental regulation. Since then the rate of development of the migration space has likely lessened, although the quality of the remaining undeveloped space continues to be threatened by pollution, overuse, biological invasion, and ecological isolation. Furthermore, there is generally more undeveloped space for the two-foot rise in sea level than for the five-foot rise. This reflects the pattern of urban encroachment toward the shoreline. It suggests that there will be less undeveloped space in the future than there is now. For either a two-foot or five-foot rise in sea level, very little of the undeveloped space is protected.

Migration space above China Camp marsh in Marin County. Photo courtesy: SFEI

Burrowing owls often live in the stunted transition zone offered by levees. Photo: Rick Lewis

THREATS & CHALLENGES The rising sea will cause saline conditions in the Estuary to move upstream in local watersheds and toward the Delta. Areas of healthy transition zone are needed in every sub-region of the Estuary to allow the associated plants and animals to migrate along with their required salinities.

Strong planning for transition zones is also needed for the significant commercial, industrial, and transportation resources located on the Estuary shore. Indeed myriad uses of the Estuary's shorelines, for humans and wildlife alike, contribute great wealth and quality of life to the region. The challenge for the future is to protect the existing undeveloped space, create more of it if possible, and protect it from future development. There are opportunities to meet this challenge in every sub-region of the Estuary. It's noteworthy, however, that Suisun Bay has the most undeveloped migration space that is unprotected. Further development of the migration space indicator should be guided by regional experts in land use, sea level rise, and landscape ecology. Scientifically sound criteria will be needed to prioritize opportunities to conserve and restore the transition zone.

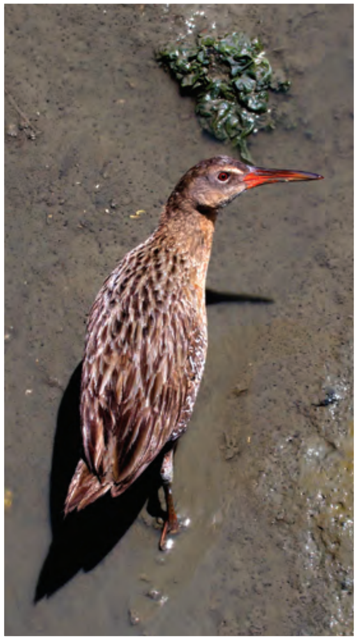
SEDIMENT ON THE MOVE

Prior to European colonization of the Estuary's watershed, high river and stream flows that occurred every winter and spring would mobilize sediments from streambeds and eroding riverbanks and slopes upstream. This sediment flowed downstream to the Estuary where it replenished marshes and other parts of the shore. Long-term monitoring suggests there is now much less suspended sediment in the Estuary's waters than there was for more than 100 years between the Gold Rush and the late 1990s. The Estuary's sediment balance is changing because dams now control the flow of water that would historically have transported sediments, rivers and streams have been armored and otherwise engineered to limit erosion, and the large volume of sediment created by Gold Rush mining has finally petered out. Reduced sediment availability promises to alter several important ecological processes in the Estuary.

Estuarine waters that are murky from suspended sediments can be good for native ecosystems. Suspended sediment is critical for marsh building processes, for example. A marsh with sufficient sediment supply can capture enough material to rise in elevation and keep pace with rapid sea level rise. Suspended fine sediment also reduces the penetration of sunlight into the water, limiting the potential for invasive weed species, toxic algal blooms, and negative effects from excess nutrients introduced by outflow from sewage treatment plants, agricultural runoff, and urban stormwater runoff. The muddy water also provides cover for small fish and zooplankton.

In addition, coarser sediments now trapped behind dams once fueled habitat-forming processes upstream. Currently, rivers and streams below dams are starved of gravels that salmon need in order to build nests for their eggs. At the same time, accumulation of these materials behind the dams' also reduces their storage capacity.

Human activities over the past 200 years have altered sediment supply to the Estuary. From the early 1800s into the 20th century, intensive ranching and farming, hydraulic mining in the Sierra, and urbanization caused chronic erosion of stream channels, resulting in large increases in the sediment load carried by winter and spring flows. Today, land surface erosion is better managed, the large bulk of sediment created by historic land uses upstream has moved through the system, stream flows are highly regulated (lacking the high flows that move large amounts of sediment downstream), and reservoirs, dredges, and sand mining remove sediment from the system, resulting in an Estuary starved of sediment.



Marshes restored as habitat for endangered Ridgway's rails also buffer the shorelines behind them from rising seas, king tides, extreme storms and wave erosion. Sediment remains an essential ingredient, both to keep these useful ecosystems in place and to rebuild aging earthen levees throughout the Bay and Delta. Photo: Rick Lewis

With less sediment in circulation, critical ecological processes are jeopardized. Projections of marsh-building processes show a strong likelihood that there will not be enough sediment for marshes to keep up with rapid sea level rise in the latter half of this century. Water quality experts are planning for how to address the effect of clear waters on nutrient impacts (eutrophication), and marsh restoration planners are concerned that there won't be enough sediment for marshes to keep up with rising seas in the decades to come. Water quality regulators seek to avoid potential impacts to human and fish health from toxic algal blooms facilitated by the lack of suspended sediment. Fish biologists worry that native fish species suffer greater exposure to predators whenever the Estuary's waters become too clear.

Just as they have in the past, human actions can change the amount of sediment available to the Estuary in the future. Watershed management influences the timing, amount and type of sediment delivered by rivers and streams to the Estuary, increasing or decreasing supply depending on the approach taken. Useful management approaches may include: managing stream flows, retrofitting or removing dams, restoring naturalistic connections between watersheds and the Estuary's tidal wetlands, reducing sand mining, and reusing sediment dredged from the Estuary and excavated from terrestrial areas.

Innovative thinking about sediment sources, transport and delivery to the Estuary is now an urgent priority. Restoring natural processes of sediment movement in the watershed and creating artificial methods to deliver sediment (such as reusing channel dredge spoils) are both valuable approaches for restoring this fundamental physical driver. Like fresh water, sediment is a precious resource that is essential for keeping the Estuary healthy.

BENEFICIAL FLOODS

Inundation of floodplains by high river flows drives important ecological processes such as sediment and nutrient transport and food production, and provides habitat for spawning and rearing for numerous fish species. Photo: Chris Austin.

CONTEXT Following winter rainstorms and spring snowmelt in the Sacramento-San Joaquin watershed, the Estuary's tributary rivers may flood, spilling over their banks to create ecologically important floodplain habitat and sending high volumes of fresh water into the Estuary. These seasonal high flows drive multiple ecological processes. They fuel primary and secondary production of microscopic plants and animals – important food for fish and wildlife – in inundated floodplains and the upper Estuary. They transport organisms, sediment, and nutrients downstream and signal anadromous species like salmon to come upstream. They create spawning and rearing habitat for numerous fish species. High flows also help mix ocean and river waters and create large areas of low-salinity habitat in Suisun and San Pablo Bays. They also help improve habitat conditions in riverine migration corridors for both adult fish moving upstream and young fish moving downstream. In sum, high flows, as well as rapid increases in flow, provide conditions favorable for many native fish, invertebrate and other wildlife species.

Several factors have substantial impacts on the frequency, magnitude and duration of high volume flows into the Estuary and prevent ecologically important, regular seasonal flood events. These include: dams, many of which were built for the purpose of managing downstream flooding; water extraction and diversion that can decrease flows to levels below important ecological thresholds for floodplain inundation, habitat creation, and sediment transport; and confinement of rivers between levees, which restricts inundation of adjacent floodplains during high flow events. In addition, dams also physically block the flow of sediment, which starves riverine and estuarine wetlands and marshes of the materials they need to sustain (and restore) themselves.

INDICATOR This analysis uses two indicators to measure and evaluate the frequency, magnitude and duration of ecologically important high volume flow or flood events. The first indicator measures floodplain inundation in terms of seasonal inflows to the Delta from the Yolo Bypass, the large, partially managed floodplain immediately upstream of the

Estuary in the lower Sacramento River basin. The second indicator measures flood events in terms of high volume freshwater inflows to the Bay. The benchmarks for evaluation of both indicators are based on three types of data: unimpaired flow and flood data records; biological information on floodplain habitat, productivity dynamics, and utilization for spawning, rearing and migration; and current regulatory standards for minimum Bay inflows.

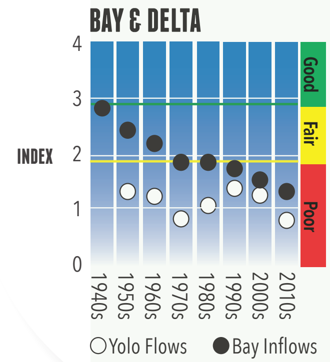
STATUS & TRENDS Analysis shows that the frequency, magnitude, and duration of floodplain inundation and high volume inflows to the Estuary are all usually too low to drive or support important ecological processes in the lower watershed and estuary. Inundation of the Yolo Bypass is (and has been for decades) too rare, too little and too short to provide the levels of primary and secondary food production, floodplain spawning, rearing and migration of native fishes, and export of sediment, nutrients and organisms to the Delta and estuary needed to sustain or restore the ecosystem and species. Similarly, the frequency and duration of high volume inflow events to the Bay have declined significantly since the 1940s. For the last decade or two, the condition of flood-related ecological processes has been "poor" in almost all years.

THREATS & CHALLENGES

Man-made reductions in the ecological processes measured by these two indicators correspond to declines in food and habitat availability, and reduced growth, survival and reproductive success for a number of fish and wildlife species, all of which contribute to ongoing population declines. Scientists and resource managers agree that high volume flows and inundated floodplain habitat are important for native fish and wildlife, and that ecosystem restoration and management actions that restore these ecological functions and resultant habitat would likely be effective and offset some of these impacts. Changes in water management operations could help selectively restore periodic high volume flows or even inundate floodplain habitat at lower flows. Unfortunately for the state of the Estuary, few such specific restoration actions have been implemented to date.

Yolo Bypass and Sacramento Deepwater Shipping Channel during drought. Photo: Birds Eye View

FLOOD EVENTS

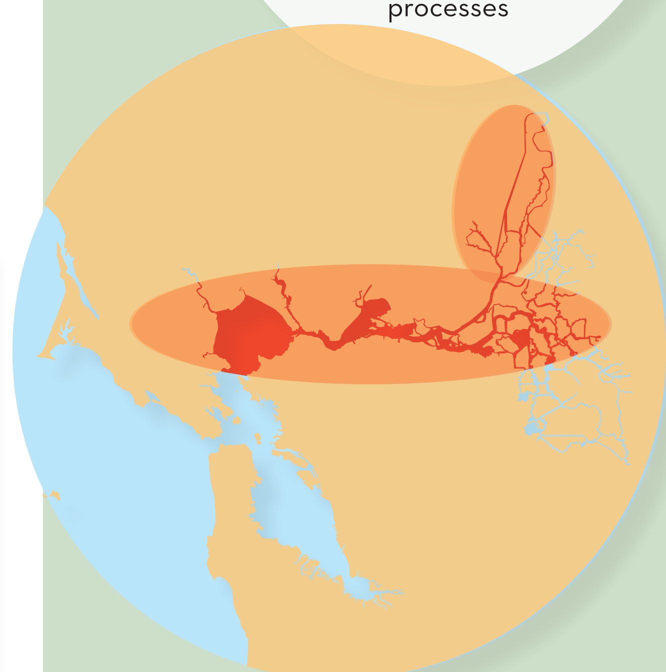


BAY & DELTA

..STATUS..
Poor

....TREND....
Mixed

.....BENCHMARK.....
High volume inflows necessary to support ecological processes



BLOOMS

In many estuaries around the world, water quality is negatively affected by excess nutrients. Until recently, San Francisco Bay appeared to be immune to these effects. However, observations over the past 10 years suggest that San Francisco Bay and the Delta may no longer be as resistant to negative impacts from the high nutrient loads they receive from over 40 wastewater treatment plants, and from agricultural and stormwater run- off, as they once were.

Nitrogen and phosphorus, which occur naturally in estuaries, serve as essential nutrients that promote growth of algae and phytoplankton, and thereby support estuarine food webs. However, human activities have dramatically increased loads to estuaries worldwide, in many cases exceeding the amount these ecosystems can handle, leading to severe impacts to habitat, fisheries, and recreation.

Until recently, the San Francisco Estuary has been relatively free of some of the classic symptoms of excessive nutrient concentrations, such as too much algae resulting in too little dissolved oxygen, which can lead to suffocation of fish, for example. Turbidity and tidal mixing in this estuary tend to limit light levels and algae growth, causing a low proportion of available nutrients to be converted into algae biomass. Large populations of filter-feeding clams have further limited phytoplankton accumulation because they filter the algae from the water column.

Red tide in San Francisco Bay.
Photo: Scott Conrad, USGS

Over the last ten years, however, conditions have changed; as debris from Gold-Rush-era hydraulic mining washes out of the system, for example, the Bay has gotten clearer. Scientists have observed a greater than two-fold increase in summer-fall algal biomass in South Bay from 1995 to 2005. In San Francisco Bay, they've also frequently detected algal species that have been shown in other nutrient-rich estuaries to form harmful blooms, and observed blooms in the Delta of the harmful phytoplankton *Microcystis spp*. that produces the toxin microcystin.

Beyond these precursors of potential negative impacts on the ecosystem, scientists have also detected two algal toxins, microcystin and domoic acid, throughout the Bay, as well as elevated levels of microcystin in the Delta. Back in 2004, they were also alarmed to note an unprecedented red tide bloom (*Akashiwo sanguinea*) in Central Bay. In addition, low dissolved oxygen has been observed in some Bay sloughs and creeks. Investigations are underway to understand the role that nutrients may be playing in causing or increasing the prevalence of these effects.

In some cases, these observations are concerning because they indicate marked changes in biological response, namely increased South Bay algal biomass and Delta plant biomass. In other cases, like the detection of algal toxins, these are new additions to a list of parameters that scientists and managers are using to assess condition in the Bay and Delta. It is impossible to determine whether these toxins appeared only recently or have always been present. Even at low levels, however, the detection of these toxins signals the need for further investigation.

The San Francisco Estuary is also a large and complex system, and there is no single measure of "good" condition. With its multiple bays and habitats, factors influencing biological response to nutrients — flow (residence time), mixing, suspended sediment concentrations (light levels), temperature, and grazing — vary spatially and seasonally, and have also changed over time.

To address growing concerns about adverse nutrient impacts in the Estuary, regional water quality regulators have launched efforts to better understand them and to identify appropriate management actions. Work is underway to identify more sensitive indicators of nutrient-related impacts and the methods needed to accurately measure and interpret them. In such a complex system, nutrient concentrations alone do not tell the whole story.

Nutrient concentrations will likely change substantially in the Delta and Suisun Bay within 10 years due to treatment upgrades at the Sacramento region's wastewater facility. They could also change as the drought prompts more and more recycling of wastewater. Such ecosystem-scale experiments provide a unique opportunity to study the Estuary's response to major changes in nutrient inputs.

INVASIONS

Invasive aquatic plants have far-reaching impacts on the Delta ecosystem and are now widespread. The total invaded area in the Delta has increased from the previous recorded maximum of 9,000 acres in 2004 to more than 12,500 acres today.

Photo: Shruti Khanna

Aquatic plants change shoreline habitat by slowing water velocities and increasing water clarity, conditions which further their spread. This dense mat of submerged vegetation can offer predatory fishes places to hide and hunt. Meanwhile, native species like Delta smelt, who like to stay in open water, are more vulnerable to attack in clearer waters. Such effects can propagate up or down the food chain, affecting the entire ecosystem. Invasive aquatic plants also impede boat travel and are difficult to control.

To assess the state of the Estuary on this invasion frontier, scientists measured the distribution and acreage of invasive and native aquatic plant species using remote sensing imagery from 2004 to 2008, and again in 2014. This analysis provides first estimates of the changes in acreage of submerged and floating aquatic species over that timespan.

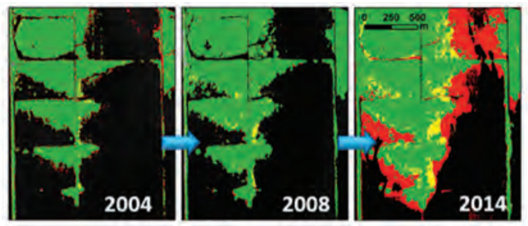
Between 2004 and 2008, submerged aquatic vegetation (SAV) cover, most of which was invasive Brazilian waterweed, reduced from almost 8,000 acres to 50% of its 2004 extent (4,300 acres). By 2014, however, SAV cover had increased to 6,070 acres.

From 2004 through 2008, floating species (FAV) cover varied between 800 and 1,700 acres. By 2014, however, floating species cover had increased many-fold to 6,460 acres.

The three dominant floating plants in the Delta from 2004 to 2008 were two invasives, water hyacinth and water primrose, and one native species, pennywort. Pennywort cover was comparable to invasive water hyacinth cover. Water primrose had the least cover. By 2014, however, cover was mainly composed of just the two invasive species, water hyacinth (69%) and water primrose (31%) while pennywort cover was greatly reduced.

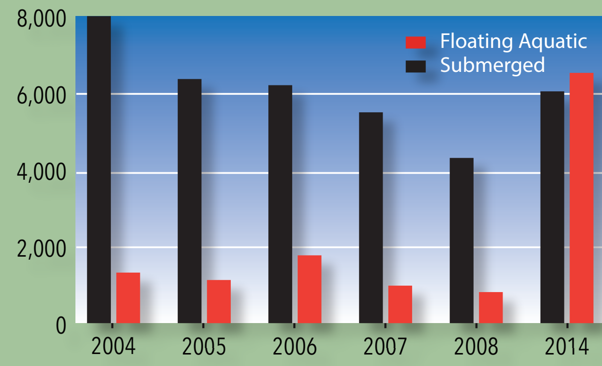
Both SAV and FAV have especially flourished in flooded islands in the Delta, colonizing new areas. These are old subsided islands that flooded when a levee breached and are now like shallow lakes, surrounded by remnant levees that protect them to some extent from tidal forces.

For example, In Liberty Island, (flooded in 1998), both types of aquatic vegetation have increased over the past 10 years but the cover of emergent vegetation has also increased as the wetland has expanded outward in a concentric



Trends in emergent, submerged and floating vegetation in Liberty Island.

AQUATIC VEGETATION COVER IN THE DELTA IN ACRES

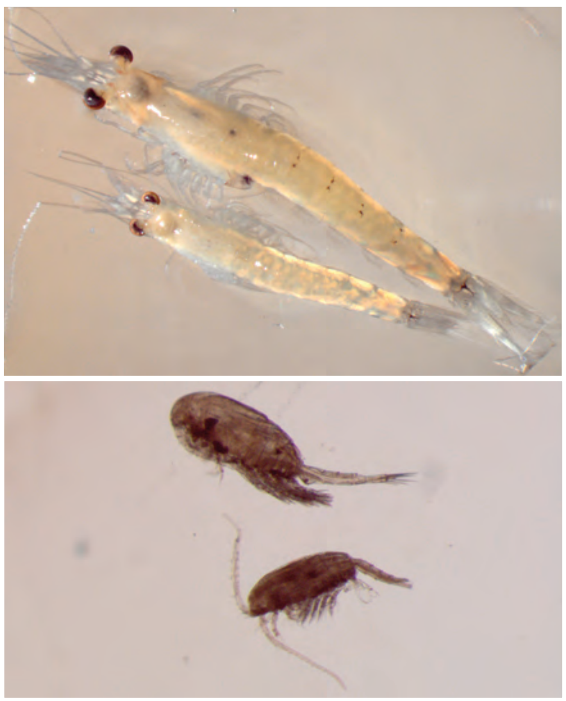


pattern. In previous years, coarse substrate underlying this large, shallow island and wind-driven wave action prevented the establishment of SAV. But emergent and floating species are now providing shelter from these forces to SAV species. Hence, in the past six years, between 2008 and 2014, there's been a large increase in SAV cover in the north of the island.

There are many possible reasons for the increase in invasive plant cover in the Delta. In the past few years, permitting problems have delayed spraying of water hyacinth, while the spraying of water primrose has not yet been mandated. The prolonged drought has likely reduced water levels and increased shallow habitat with slow moving water ideal for SAV and FAV. Mild winters with few large storms and floods have also favored these species. More studies are necessary to tease apart the mechanisms behind the changing distribution of invasive species threatening the Delta ecosystem.

FOOD

CONTEXT No estuary can support a functional ecosystem, let alone larger creatures like sturgeon and herons and seals, without good food. Good food, for the San Francisco Estuary, starts with the growth of plankton and zooplankton at the base of the aquatic food web, which are in turn eaten by small fish and crabs, which themselves provide food for larger predators like salmon and cormorants. Each trophic level is important and can be interrupted by changing conditions (such as upwelling offshore or shifts in the location of the low salinity zone in the upper Estuary), invasive species, or human disturbance, among many factors. For the purposes of assessing the state of the food web, this report examines three different trophic levels: zooplankton and small fish in the upper Estuary (see below) and big birds that eat fish in the lower Estuary (following pages).

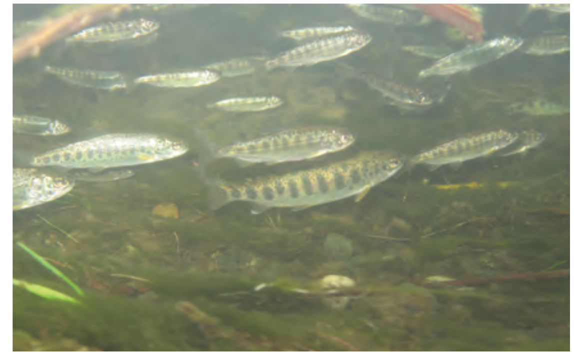


Mysids (top) and copepods (bottom) Photo: April Hennessy

Zooplankton are small aquatic invertebrates and a critical trophic link between primary producers and fish. These tiny drifting animals include some early life stages of shrimp, jellyfish and crabs, and like their plant counterparts, phytoplankton, grow and drift in many areas of the Estuary. When these food supplies are abundant in the low salinity zone of the upper Estuary, they tend to support a flourishing food web.

Most larval and juvenile fish eat zooplankton, and some species eat them throughout their lives. Small fish also feed bigger fish.

INDICATORS The first indicator of food web health examines annual zooplankton abundance in recent years, and compares it to estimates recorded since 1972 by the Interagency Ecological Program. Scientists chose two crustaceans called calanoid copepods and mysids for the zooplankton indicator because they are important food items for Delta smelt and longfin smelt. A state vessel collected samples in the upper Estuary in both the Suisun and Delta regions. Average annual biomass, in milligrams of carbon per cubic meter of water, was then calculated for 1974-2014. The benchmark derives from biomass measured between 1974-1986, before the disturbance to the food web caused by the arrival of the invasive clam *Potamocorbula amurensis*.



Juvenile chinook salmon. Photo: USFWS

The second indicator of food web health at a higher trophic level measured abundance of fish, both native and introduced, living in three major habitats — marsh, pelagic open water, and beach — found throughout the upper Estuary. The fish abundance indicator measured total fish caught per-unit-effort — reflecting the number of fish a predator would find in each year in each of the major habitats. Benchmarks for this indicator derive from average reference conditions in 1980-1989 (for marsh and pelagic zones) and 1995-2004 (for the Delta beach zone).

STATUS & TRENDS For trends in the first indicator, long-term sampling indicates a decrease in zooplankton biomass in most areas of the upper Estuary since the 1980s,

Zooplankton sample preserved in quart jar with 10% formalin and Rose Bengal dye added. Photo: California Department of Fish & Wildlife

In the Suisun region, calanoid copepod biomass has declined since monitoring began, with small peaks occurring during higher flow years such as 2006 and 2011. Like the mysids, there was a significant downward trend from 1974-2014 in the Suisun region. Also like mysids, biomass is lower than it was historically, but it does not appear to be declining further. In the Delta region, there was a significant increase in calanoid copepod biomass from 1974-2014, but little change in the last 14 years of that period.

particularly in the low salinity zone. Biologists attribute this decrease in large part to the 1986 invasion of the zone by the clam *P. amurensis*. Competition with *P. amurensis* for phytoplankton, a shared food resource, as well as clam consumption of copepod nauplii (babies) may have reduced zooplankton.

Mysid biomass has declined in both the Suisun and Delta regions since monitoring began. The 2010-2014 average biomass was 1.6 milligrams of carbon per cubic meter of water sampled from Suisun and 0.4 milligrams from the Delta. There was a significant downward trend in annual mysid biomass for both regions from 1974-2014. Although mysid biomass is lower than it was historically, it does not appear to be declining further.

For trends in the second indicator, abundance of fishes in the pelagic and marsh (Suisun) zones has decreased substantially since the early 1980s. Fish abundances in the marsh and pelagic zones of the upper Estuary that appeared to increase in the mid-1990s have resumed declining since the early 2000s. Abundance of fish in the third habitat examined, the Delta beach zone, has increased in recent years. Some of this change is attributable to increases in non-native fish populations in this habitat zone.

THREATS & CHALLENGES

The food web of the upper San Francisco Estuary has been highly altered by the long term diversion of freshwater inflows, as well as by the introduction of non-native species, including the clam *P. amurensis*, water weeds such as *Egeria*,

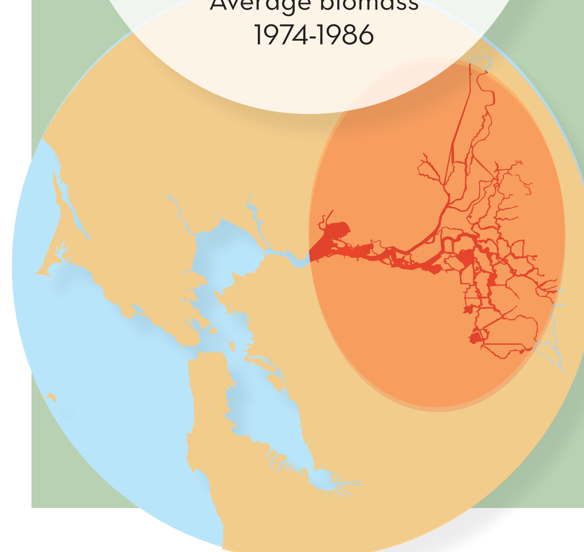
ZOOPLANKTON AS FOOD

SUISUN BAY & DELTA

..STATUS..
Fair

....TREND....
Mixed

.....BENCHMARK.....
Average biomass 1974-1986



FISH AS FOOD

SUISUN BAY & DELTA

..STATUS..
Fair

....TREND....
Deteriorating

.....BENCHMARK.....
Historical Average
1980-1989
1995-2004 (Delta Beach)

and the predatory sunfish and bass that hide in the weeds waiting for something to eat. The zooplankton decline in the low salinity zone, as well as other results of invasions and changes in habitat quality, are now linked to the dramatic decline of several pelagic fish species. Availability of fish as food for wildlife in Suisun Marsh and open water habitats of the Estuary also appears to be declining. Scientists find this very disturbing, as these areas are expected to be highly-productive, food-rich ecosystems.

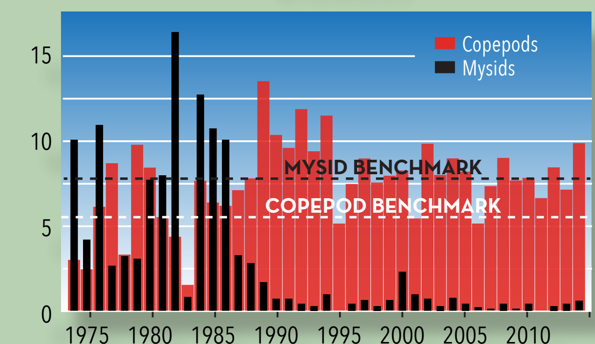
Inland Silverside are an especially abundant non-native fish in the Delta. Photo: René Reyes/USBR

Recovery of listed fish species such as the Delta smelt and longfin smelt may rely in part on food availability. Management measures to try to protect and enhance the estuarine food web — such as regulatory efforts to keep the low salinity zone within a certain range of positions in the Suisun region associated with estuarine health (see p. 27) — remain inadequate in a system so altered by so many forces. Meanwhile, freshwater flow, temperature, salinity, clams and other invasive species, tides, and contaminants may all be influencing decreased food web productivity to varying degrees.

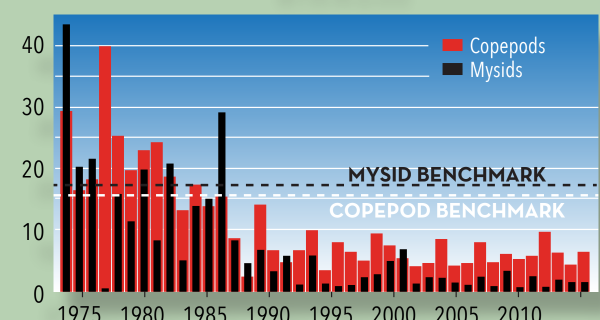
These findings reveal both the challenge and the value of evaluating multiple "health" indicators to increase resolution of underlying trends. As scientists attempt to tease out the trends in a complex food web impacted by many different factors, the take homes may just be that there is less and less food in the upper Estuary, and that regional goals of recovering and reversing declines of estuarine fishes in the Delta have not been met.

DETAILS

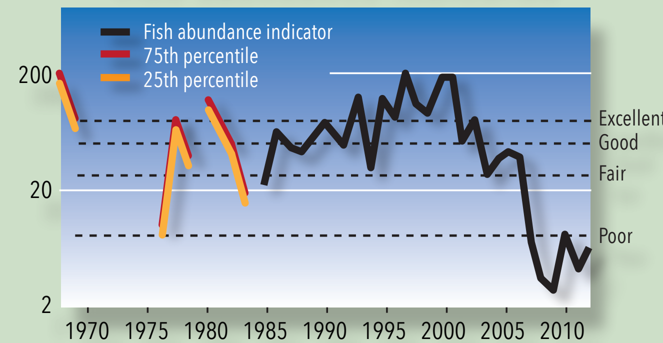
DELTA COPEPODS & MYSIDS BIOMASS



SUISUN BAY COPEPODS & MYSIDS BIOMASS



CENTRAL WEST DELTA FISH ABUNDANCE INDICATOR



Abundance of fish in the pelagic zone of the Delta declined dramatically beginning in the early 2000s; in other Delta habitats, such as the Beach Zone, fish abundance has increased or remained the same. Fish predators that specialize in these different habitats experienced very different trends in food availability in recent years.

FEEDING CHICKS

CONTEXT Many birds make their reproductive "decisions" about how many eggs to put in the nest, and therefore how many hungry chicks they will have to feed, based on the abundance of food early in the breeding season. Cormorants forage in the open waters of the Estuary, reflecting the condition of the pelagic food web influenced by the ocean. Wading birds like herons and egrets, by contrast, reflect the condition of more shallow water and wetland food webs around the edges of the Estuary.

The reproductive success of Brandt's cormorants provides a reliable index of prey availability for foraging seabirds in the San Francisco Bay. These fish-eating birds are at the top of the marine food chain. The ability of parent birds to adequately feed their chicks is a good measure of food supply. Their success at rearing chicks is also a requirement for healthy, self-sustaining populations.

The brood size of great egrets and great blue herons also reflects the supply or availability of prey to feed nestlings. Favoring the edges of water, the success of these species in raising young can also be sensitive to changes in the extent and quality of foraging habitat (land-use, water circulation and depth, geomorphology, environmental contamination, and vegetation characteristics). The two species targeted for this indicator feed in different habitats: great egrets prefer small ponds in emergent wetlands and areas with shallow, fluctuating water depths. In contrast, great blue herons forage along the edges of larger bodies of water and creeks and are less sensitive to water depth.

Previous work in the Estuary demonstrated that pre-fledging brood size in local egrets and herons is influenced by the extent of wetland habitat types as far as 10 kilometers (km) from nest sites. Thus, this indicator reflects wetland condition and ecological health over large landscapes.

INDICATORS For Brandt's cormorants, the indicator is the number of fledged young produced per breeding pair at the breeding colony on Alcatraz Island, in San Francisco Bay. (Fledging refers to surviving long enough to leave the nest). The indicator has been studied on Alcatraz Island since 1995. A comparable time series has been collected on the Farallon Islands since 1972. The specific calculation used is the mean for the most recent three years. The benchmark is the number required to maintain a stable population, estimated at 1.5 cormorant chicks fledged per year per breeding pair.

For egrets and herons, the indicator is the number of young produced per successful nest. Successful nests are those from which at least one chick reaches the age of fledging. Nest success is evaluated at the critical time just prior to fledging when great blue heron nestlings are 5-8 weeks old and great egrets 5-7 weeks old. Scientists calculated this indicator as the mean prefledging brood size at 40-50 colony sites within foraging range (10 km) of the historic tidal wetland boundary. Brood size was averaged annually (1991-2014) among nests within and across the three major subregions of northern San Francisco Bay (Central San Francisco Bay, North Bay, and Suisun Bay). The benchmark is

CORMORANT CHICKS REARED

CENTRAL & NORTH BAYS

..STATUS..
Good

....TREND....
Stable with long-term gradual decline

.....BENCHMARK.....
Number required for a stable population

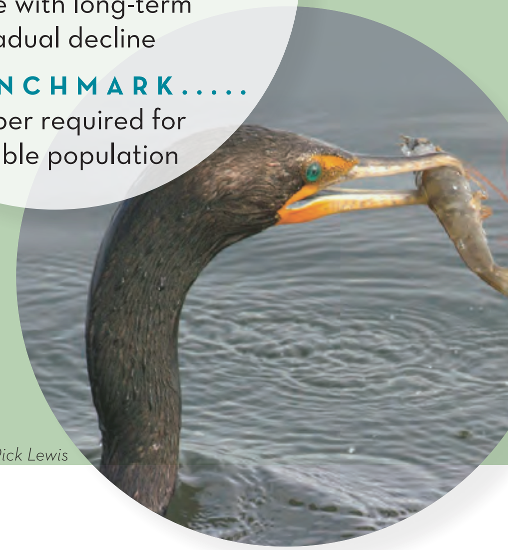


Photo: Rick Lewis

HERON AND EGRET CHICKS REARED

SAN FRANCISCO AND SUISUN BAYS

..STATUS..
Fair

....TREND....
Mixed

.....BENCHMARK.....
Number of young 1991-2000

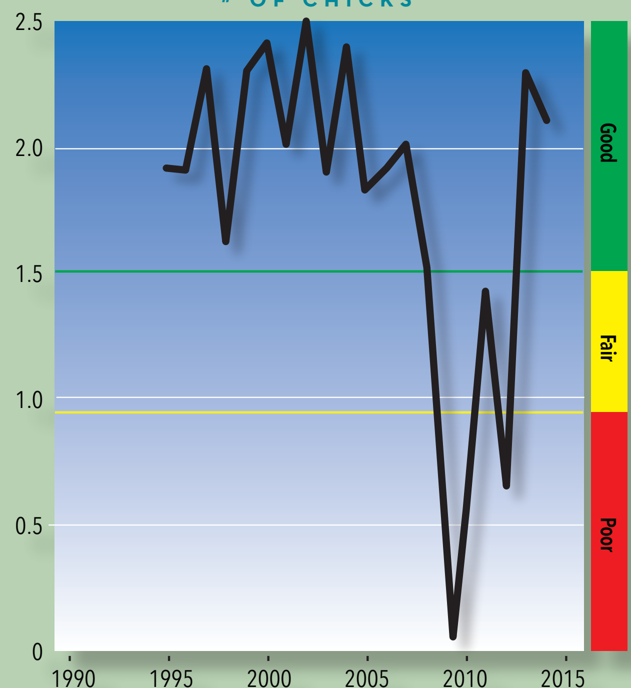
the number of young produced per nest from 1991-2000, across Central Bay, the North Bay, and Suisun Bay, and all three areas combined.

STATUS & TRENDS For Brandt's cormorants, though analysis of the number of fledged young shows a recent decline, there was a sharp rebound in 2013 and 2014. The most recent three-year average is 1.67 fledglings, more than the number estimated as necessary to sustain a stable population. In fact, more than two chicks per nest fledged in 2013 and 2014. Thus, after a five-year period of moderate to low reproductive success, Brandt's cormorants appear to have fully rebounded. The long term declining trend now appears partially reversed.

For egrets and herons, brood size is relatively stable across the region but exhibited a shallow annual decline across northern San Francisco Bay. Brood size declined to 2.02 young per successful nest in 2008 — 4.1% below the baseline average of 2.11 — then increased slightly in recent years. Productivity during 2009-2014 did not differ significantly from baseline levels in 1991-2000. Within the North Bay, an apparent decline since 2005 is consistent with the leveling off of nest densities there in recent years, suggesting a reduction in the quality of wetland feeding areas or, alternatively, the presence of foraging competition.

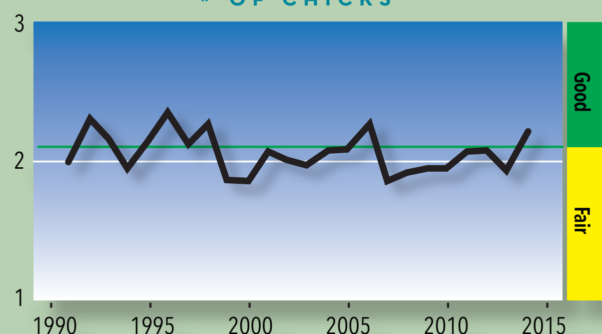
DETAILS

NUMBER OF YOUNG REARED
CORMORANTS
OF CHICKS



Pre-fledged egrets. Photo: Michael Baird

NUMBER OF YOUNG REARED
HERONS & EGRETS
OF CHICKS



THREATS & CHALLENGES

Big birds like cormorants, herons, and egrets are top predators in the Estuary food web. The relatively stable, if slightly declining, number of young reared in each nest suggests that Bay food webs are functional but variable and vulnerable to disturbance. For this reason, wildlife populations need to be robust so they can weather lean years when food is in shorter supply. For herons and egrets, trends in the number of young in successful nests may reflect changes in the extent or quality of foraging habitat, or the availability of suitable prey needed to provision nestlings, and are likely to be influenced by changes in land-use, hydrology, environmental contamination, and vegetation characteristics. For Brandt's cormorants, the extreme declines in reproductive success between 2008 and 2012 in both Alcatraz and Farallon Island colonies indicate especially low prey availability and suggest a poorly functioning food web. The reversal in 2013-2014 suggests the reverse, a well-functioning food web, supporting forage fish and their predators.

Future threats may include warming oceans, changes in upwelling, and resulting shifts in prey species for cormorants. Climate change and rising seas may also affect the distribution and extent of tidal wetlands required by herons and egrets for foraging. Given these threats to tidal habitats, the effectiveness of management efforts to protect seasonal wetlands where these birds forage in winter and spring may become increasingly important.

PEOPLE

CONSERVING WATER

RECYCLING WATER

VOLUNTEER WORK

PUBLIC ACCESS

EDUCATING YOUTH

OVERVIEW

People are both the most important driver of a healthy estuary and key recipients of its benefits. Human settlements have always been concentrated around the Estuary, because of the abundant estuarine food web and navigation options to the ocean or up the rivers. Most of us no longer eat from the Estuary, but it still processes the nutrients from our waste, provides flood protection to our shorelines, and offers natural areas for recreation. Many people also appreciate the natural heritage of native wildlife and beautiful vistas unique to the Estuary. Many indicators discussed here show the commitment of local people to sustaining a healthy estuary. However, these areas of environmental stewardship fail to encompass the greater set of management needs that will be required to achieve environmental health. The challenge of estuarine science in the future may be to fully communicate the choices ahead, so that citizens of local watersheds can decide if they want to invest in the health of the Estuary.

Birdwatchers. Photo: Rick Lewis

TAKE HOMES

- The Estuary's populace has demonstrated stronger stewardship by using less water despite a growing population.
- Water use efficiency has increased in the region, resulting in a 40% decrease in per-capita usage over the last 30 years.
- In the last two years, the Bay Area has demonstrated that it can respond to persistent drought by reducing its urban water use more than 20%.
- The recycling of treated wastewater and the on-site re-use of gray water and rainwater are growing, but only offset a small portion — less than 5% — of the Bay Area's total water demand.
- The region is still overwhelmingly dependent on imported water from sensitive ecosystems and will need to make greater investments in water use efficiency to address future demand due to population growth and population change.
- Current policy and upstream water management do not provide the Estuary the extra freshwater inflow that greater water use efficiency and reliance on locally sustainable sources could provide.
- Landscape irrigation is the largest component of urban water use in the Bay Area. Significant potable water use reductions can be achieved with more climate-appropriate landscapes and the use of gray water and recycled wastewater for irrigation.
- Sustainable water use requires greater cooperation and integration among our region's water and land use managers, who have the power to shape the water footprint of new and existing development.
- There has been a steady increase in public access to the Bay since the late 1980s, when most regional trail projects were launched.
- Currently, the San Francisco Bay Trail is 68% complete, with 341 of 500 planned miles on the ground. The Bay Area Ridge Trail is 65% complete, with 360 of 550 miles mapped. The Water Trail has designated 11 launch sites since 2011. The Delta Trail has designated 24.5 miles since the adoption of the 2010 *Western Region Blueprint*.
- Many Bay-Delta region cities and counties have passed their own plastic bag bans. Six out of 12 counties and 68 out of 119 cities now have ordinances.
- Thousands of volunteers regularly engage in activities that nurture, restore, and improve the Estuary's habitats, wildlife, and shorelines. Many local non-profits like Save the Bay and Acterra host regular volunteer restoration programs and workdays.

SUPPORTING MATERIALS

This chapter summarizes data and materials written by the authors listed on page 12 and provided in full in the technical appendix for the State of the Estuary 2015 report. Go to: http://sfestuary.org/about-the-estuary/soter/

Chapter cover photo of kayakers: Galli Basson

CONSERVING WATER

CONTEXT Everyone uses water dozens of times a day to wash, flush, cool, clean, dilute, or irrigate. The San Francisco Bay Area uses about 1 million acre-feet per year of water, 90% of which supports urban activities in homes, businesses, institutions, and industries. Most of this urban water — over 75% — is imported, primarily from the Delta and Central Valley watersheds with smaller amounts from the Russian River and Tomales Bay. Less than 10% is supplied from local Bay-draining (non-Delta) watersheds, such as the Napa River and Alameda, Coyote, Los Gatos and San Mateo Creeks. The remaining 15% is supplied from groundwater, which is a locally significant supply source to urban users in the Santa Clara and Livermore Valleys, and in Fremont and the North Bay; some of that groundwater is derived from the recharge of imported surface water. With four straight years of low runoff from the Delta watersheds and the record low snowpack in 2015, state and local agencies have made water conservation both a priority and a mandate for urban municipalities. More efficient use of water by urban residents and businesses reduces the demand on already-overdrawn supply sources, leaving more water to maintain the habitats, living resources, and ecological processes of the Bay and its watersheds. It also increases water supply reliability; reduces vulnerability to earthquakes, droughts, fires, and rising sea level; and cuts the costs of treating and transporting water.

Rendering of two San Francisco buildings that will capture, treat and reuse gray water and rainwater for toilet and urinal flushing, and for irrigation: 181 Fremont (tall tower at right) and Transbay Transit Center (rooftop park at middle). The former received a $250,000 grant from the San Francisco Public Utilities Commission because the system will offset 1 million gallons of potable water per year. Photo: Jay Paul Company and Heller Manus Architects.

URBAN WATER USE

BAY

..STATUS..
Total Water Use: Fair
Per-Capita Use: Good

....TREND....
Improving

.....BENCHMARK.....
125 gallons/day/person
25% reduction

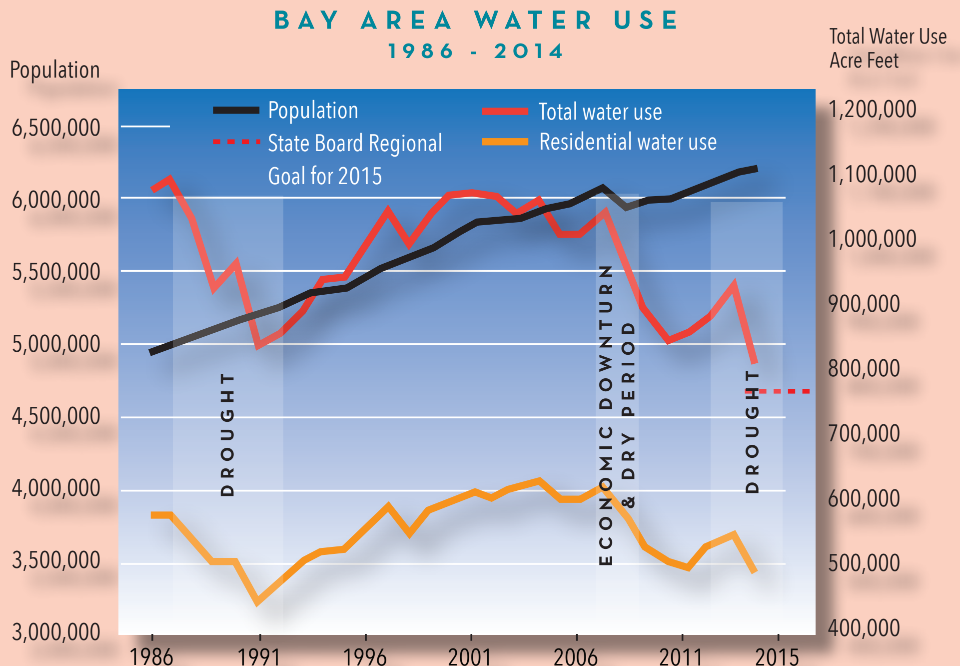
Photos: SCWA

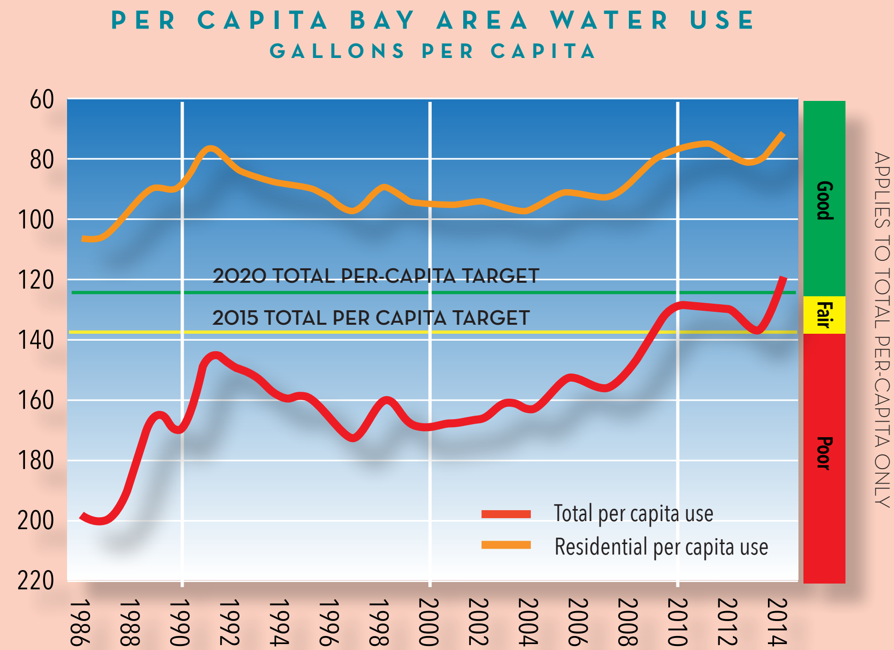
Installing a groundwater distribution pipeline in San Francisco that will diversify city supply and facilitate blending of ground and surface water. Photo: SFPUC

INDICATOR This indicator measures the total urban water use and just the residential portion in two ways: the annual potable volume in acre-feet; and the per-person use in gallons per day. Measures of potable or drinkable water do not include recycled water. Benchmarks used to evaluate progress on this indicator are based on state legislation, goals, and water board regulations. These include a per person (capita) water use goal of 125 gallons per capita per day (gpcd) by 2020 for the Bay Area. This regional target reflects what is required to achieve the 2009 Water Conservation Act's goal of reducing urban per-capita water use by 20% by 2020. The second benchmark derives from the 2015 emergency drought regulations to reduce urban use statewide by 25% through February 2016 and translated by the State Water Board for each Bay Area urban water supplier separately to reduce their use from their 2013 level. Reductions required range from 8% for San Francisco to 36% for Hillsborough. Taken as a whole, this roughly translates to a Bay Area-wide reduction target of 18%.

STATUS & TRENDS Analysis of the components of this indicator suggest that the Bay Area is currently using less water overall than it did 30 years ago and water use efficiency is much greater on a per-person basis. However, in 2014 the Bay Area did not achieve the voluntary drought reduction targets established by the State and local water suppliers. In 2015, urban

DETAILS





users responded to stepped-up calls for conservation with increasing reductions.

In terms of the annual volume of water use, for the 93% of the Bay Area's population whose municipal use was measured for this indicator, total potable water use declined 24% between 1986 and 2014 – a decline of 266 thousand acre-feet from its near historical peak use of 1.1 million acre-feet. This is a remarkable achievement given that the population increased 26% during the same period. Residential use declined 16%, or 93 thousand acre-feet, during this same period. The much greater decline in non-residential use reflected investments by industry, business, and other institutions in water efficiency and their use of recycled water. The ups and downs over the 1986-2014 period occurred in response to variations in climate, land use, and the economy. Water use declined 20% during the 2008-2010 economic downturn, for example, then rebounded nearly 10% in the subsequent three years. Prior extended droughts also produced significant declines.

The daily per-person use also indicates good news on water use efficiency. Since 1986, the average daily per-person use has declined by 40%, down to 119 gpcd, an even greater percentage reduction than the volumetric reduction because of the population increase. The average daily per-person residential use declined 33% to 72 gpcd during that same period.

Bay Area water agencies have collectively achieved the legislative requirements for a 10% reduction in the per-capita use required by 2015. Furthermore the 2014 overall use exceeds the 20% reduction in per-capita use required by 2020. If drought restrictions are lifted, however, these gains could slip.

All of these trends have been impacted by further reductions required by the State Board as of 2015 due to the increasing severity of the drought. Although more high water using months are still to come, data through July 2015 indicate that the Bay Area has exceeded its target reductions and reduced water use – particularly outdoor water use – more than 20% since 2013. If the trend continues the region overall will achieve State Board goals although individual suppliers may not be fully compliant with their targets.

THREATS & CHALLENGES

Responding to persisting drought will require still more efficiency, and the Bay Area faces the additional challenge of accommodating population growth. Every new person, family, or business presents increasing demand for new supply at a time when the region remains more vulnerable than ever to the warming climate. The Bay Area is still highly dependent on imports from watersheds reliant on shrinking natural snow storage. The warming climate will also increase outdoor water use, which currently represents about 40% of the total urban use in the region and offers the greatest potential for additional water savings. Efficiency improvements need to go beyond traditional conservation measures that reduce potable water use, however. Improvements must also encompass greater use of locally derived non-potable sources such as recycled wastewater and the on-site reuse of gray water, rainwater, and stormwater. The ongoing drought is stimulating behavioral changes in how we use water. Whether this collective action will lead to permanent reductions in urban water use and an increase in freshwater flows to the Bay and through rivers and streams – flows vital to fish and ecosystem health – remains to be seen.

Reducing water use can also reduce energy use. In commercial and residential kitchens reduced hot water use can also produce significant energy savings. Photo: SFPUC

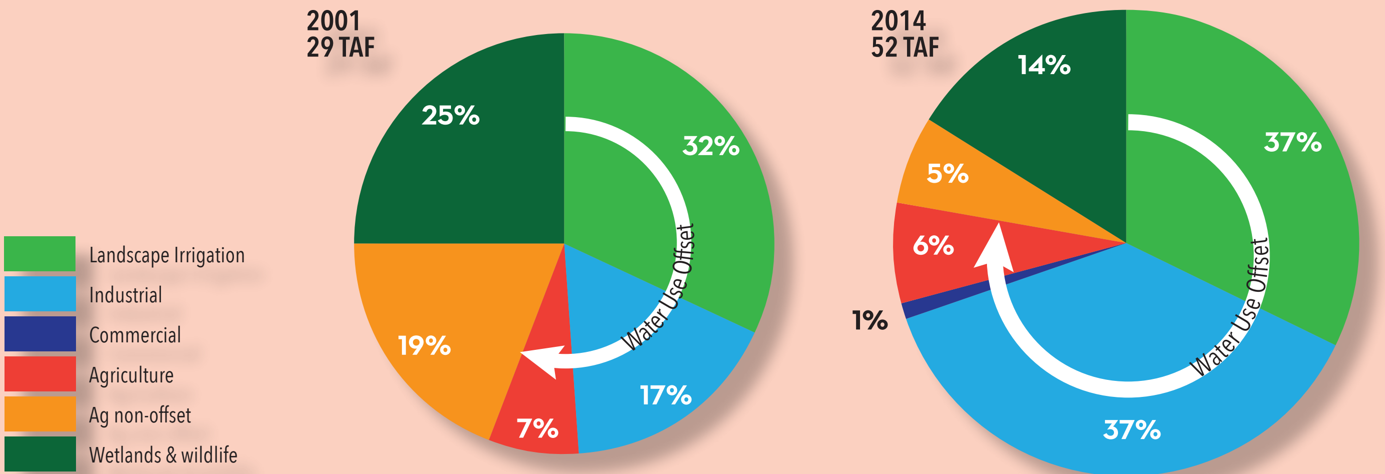
RECYCLING WATER

CONTEXT In a state as water-limited as California, recycling water seems like a no-brainer. Most of the surface and ground water consumed by urban users in the Bay Area is treated to drinking water standards, used once, treated again to remove pollutants, and discharged to the Bay from wastewater treatment plants. Much of this consumption, including the 40% used for landscaping, does not necessarily require drinking water for its use. Until recently, repurposing the wastewater, which includes the black water from toilets and gray water from showers, bathroom sinks, washing machines, and industrial processes, was expensive compared to treating and distributing freshwater diverted from local and imported sources. At the same time, using gray water was prohibited until recently. As a result of these limitations, a relatively small amount of intentional water recycling has occurred over the last 50 years in the Bay Area. Efforts over the last two decades have increased and made recycled water a more important part of the Bay Area's water portfolio. On-site reuse of graywater, rainwater, and stormwater is also increasing but still a very small percentage of the total recycled water use.

Advanced purification facility in the South Bay. Treated wastewater is further treated and purified to allow for indirect and direct potable reuse, which could significantly reduce the region's dependence on imported water. Photo: Santa Clara Valley Water District

DETAILS

RECYCLED WATER USE BY CATEGORY
SAN FRANCISCO BAY AREA

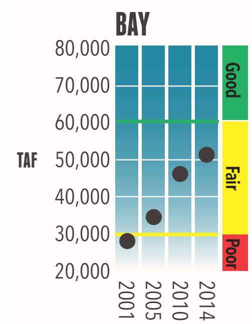


Recycling wastewater and reusing graywater are sound stewardship activities important to the health of the Estuary. Such efforts allow limited local and imported water supplies to be used more appropriately. Recycling this wastewater can not only provide a local and readily available source of water for landscape and golf course irrigation, refinery and power plant cooling, and habitat restoration, among many possible uses, but also reduce the amount of nitrogen and phosphorous-rich wastewater discharged into the Bay.

INDICATOR Recycled water is quantified for four years (2001, 2005, 2010, and 2014) with two metrics: 1) the surface and groundwater supply usable for drinking water, which the recycled water offsets (potable offset); and 2) the total amount of water recycled, treated, and distributed from wastewater treatment plants to provide for a beneficial use. (Beneficial uses, as defined by state water quality law, include domestic supply, agriculture, aquaculture, recreation, navigation, water quality, and fish and wildlife preservation). For a wastewater recycling benchmark, progress is evaluated by comparing the amount recycled to the amount of wastewater flowing out of treatment plants. Amounts recycled are also compared to amounts projected and targeted for recycling in various regional planning analyses. On-site reuse by businesses and residents cannot yet be quantified.

Nursery beds of marsh plants for the Oro Loma Sanitary District's horizontal levee project, which will use treated wastewater to irrigate an experimental estuarine transition zone. Photo: OLSD

RECYCLED WATER USE



BAY

STATUS
Fair

TREND
Improving

BENCHMARK
Wastewater recycled versus discharged
Regional recycling targets

The recycled water that is used in a way that does not offset potable water but still provides a beneficial use is quantified in two categories. The largest quantity is for creating and enhancing marsh habitat around the Bay. Also included is recycled water applied by treatment plants to non-irrigated surroundings to grow grass or forage crops. In both of these cases, the discharged water is getting additional treatment, expanding the region's available water portfolio, and providing a beneficial use.

STATUS AND TRENDS Analysis suggests recycled water use is increasing in the Bay Area. Total use steadily grew from 2001 to 2014 by 23 thousand acre-feet (TAF), an 80% increase; this 52 TAF represents about 9% of the wastewater produced at treatment plants. The amount that offset potential potable water grew more — 26 TAF or a 158% increase; this 42 TAF represents about 5% of the urban demand in 2014. The biggest increase since 2001 in offsetting potable use was by the Chevron refinery, and the new and expanded use by power plants for process and cooling water. Offsetting landscape and agricultural irrigation demand grew over 10 TAF since 2001, nearly doubling; over 1,500 sites received recycled water for irrigation in 2014. The use of recycled water to create and enhance wetlands and further clean the water prior to its discharge into the Estuary increased modestly with the addition in 2014 of the Napa-Sonoma salt pond complex.

Recycled water lake in Sonoma County. The county water agency's recycling system provides water for Napa-Sonoma marsh complex restoration, among other things. Photo: SCWA

Compared to 2010 projections by the Bay Area Clean Water Agencies, current recycled water use is about 70% of estimates. Compared to ambitious but outdated targets established in 1999 by the Bay Area Regional Water Recycling Program, use is only 40% of program projections for 2010.

THREATS & CHALLENGES

Despite the Bay Area's extreme dependence on imported water, its relatively high reliability and low cost up to now has inhibited the use of recycled water as an alternative. The region has not been able to achieve projections for its use and lags behind other urbanized regions of the State. Funding limitations, market demand, and issues with customer and public acceptance have been stumbling blocks. In 2010, urban water suppliers projected about 100 TAF of recycled water use in the Bay Area by 2030, well short of the 270 TAF estimated market.

Today, however, awareness of the region's vulnerability to drought, warming climate, and natural disasters, combined with increased government grants, should accelerate the use of recycled water as well as on-site reuse. The greatest potential for growth in the near term is to use recycled water for groundwater recharge into local aquifers for indirect potable reuse. Direct potable reuse of wastewater, with associated appropriate treatment, remains a more distant prospect. Despite the clear potential for more efficiencies on the recycling front, it should be noted that a portion of the wastewater supply may never be economically feasible to develop because of the current mismatch between wastewater discharge locations and recycled water demand locations. At home and in the workplace, on-site treatment and reuse for non-potable uses is becoming more feasible, however, particularly in new developments. New building codes are also enabling residential users to increase their on-site reuse for outdoor watering. To fully realize all 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 and healthy estuary.

Harding Park golf course by Lake Merced is irrigated with recycled water from Daly City. This project, along with the Sharp Park golf course recycled water project in Pacifica, are examples of the multi-agency government cooperation that is required to expand recycled water use. Photo Credit: SFPUC

NEXT GENERATION EDUCATION

Teens these days, at least those who've gone to school in the 12 counties around the Estuary, are as quick—probably even quicker—to recycle as any hardened conservationist. Anyone who has been in the game a while will notice that it's almost second nature for this generation to be more aware of conservation, recycling, plastics in the ocean, global warming. Even the young Googlies are choosing to live in cities where they can enjoy urban life, commute to work on transit or bikes, eschew car ownership, and have access to shoreline parks and outdoor recreation. This enlightened new generation promises to improve the health of the Estuary in decades to come.

Kids learn about stewardship and pick up trash as part of a Napa County RCD outreach program. Photo: NRCD

Many different programs are responsible for this change, from school districts and water districts to RCDs and nonprofits. Stormwater management and clean water mandates with public outreach requirements have been a particular impetus for such educational initiatives.

One outstanding non-profit program is the 23-year old STRAW (Students And Teachers Restoring A Watershed) out of Point Blue in the North Bay. Between 2011 and 2014, approximately 3,500 K-12 students participated in 150 stream and wetland restoration projects in conjunction with ranchers and scientists. The students team up with experts to learn science skills that tie to their in-class curricula. STRAW projects in 2013-2014 worked on North Bay sites at Tolay, Crane, San Antonio, and Miller creeks, and on baylands in Marin and Sonoma counties, among others.

Napa and Solano County Resource Conservation Districts (RCDs) also offer hands-on education programs for both K-12 students and adults. Solano County RCD has a watershed explorer program for elementary school students, a Suisun Marsh watershed education program for sixth-graders, and a water quality/biomonitoring program for teens. Last year, Napa County RCD's LandSmart program engaged 2,012 K-12 students in planting riparian areas, installing bird boxes, weeding, mulching, and picking up trash along creeks and waterways. Students removed 13,000 pounds of pollutants across 36 miles of waterways, and planted 380 oak trees.

At The Watershed Project in Richmond, a "Green Collar Corps"—four young men hired from the community—builds rain gardens and bioswales to capture polluted runoff before it can enter creeks and the Bay. As part of their work, they educate younger kids in elementary schools about water pollution, using a watershed model, and engaging students in hands-on cleanup and planting activities. Photo: The Watershed Project

RCD staff also mentor high schools students interested in careers in resource management and conservation.

In 2014, in Contra Costa County, The Watershed Project's long-established watershed education program experimented with a new angle—trying to reduce food waste and packaging materials before they enter landfills, local creeks, storm drains—and ultimately the Bay. Their "Waste Matters" program, funded through a federal (USEPA) environmental justice grant, was piloted at Fairmount Elementary School in El Cerrito. The program taught close to 600 students about source reduction, trash separation, recycling, and composting, and has diverted 7,125 pounds of compostables from landfill. The students went on to share what they had learned with their families and students at other schools.

PUBLIC ACCESS

CONTEXT The Estuary's shorelines never used to be a place people wanted to go to walk their dogs, jog, cycle, or watch the sunset. Nor were they the easiest places to launch a wind surfer or kayak, let alone find a bench, bathroom, or drink of water. These days, however, it's almost a given that living in the Bay Area comes with lots of public access to bay or riverfront beaches and parks with well-groomed trails and newer amenities. The public, through its state and local park and water bonds, invested in these wonderful assets and is making the most of them in record numbers. The last three years have added many new miles to trails, both on the shore and overlooking the Bay and Delta, along major riverbanks, and even in the water itself. Access to the Bay and its surrounding watershed via these trails not only enables locals to enjoy these natural resources, but also inspires them to take an active interest in estuary protection and restoration efforts.

Photo: ABAG

INDICATOR This indicator describes public access by evaluating the increases in mileage over time of the San Francisco Bay Trail, the Bay Area Ridge Trail (with views of the Bay), the San Francisco Bay Area Water Trail, Sacramento River trails, and the Great California Delta Trail. Benchmarks derive from establishment goals for these trails. For the Bay Area, these included: 500 miles for a regional hiking and bicycling trail around the perimeter of San Francisco and San Pablo Bays; 550 miles of recreational trail along the ridgelines surrounding the Bay; and 111 launch points in the water trail's network of "trailheads" for human-powered boats and beachable sail craft.

Scoring for this indicator focuses on Bay Area trails, as not enough data on Delta trails progress is available for analysis at this time. Nonetheless, it is important to acknowledge some overall progress toward goals for a continuous recreational corridor trail network through all five Delta counties, linking the San Francisco Bay Trail system and planned Sacramento River trails with present and future Delta trailways including the Mokelumne Coast to Crest Trail, San Joaquin River Blueway, and Delta shorelines in Contra Costa, San Joaquin, Solano, Sacramento, and Yolo counties. For the moment, this effort is focused on the vision of a Great California Delta Trail laid out by state legislation in 2006 and adopted by the Delta Protection Commission in 2010.

STATUS & TRENDS Analysis shows a steady increase in public access to the Bay since the late 1980s, when most trail projects were launched. At the time of the Bay Trail Plan adoption, the public enjoyed access to 130 miles of shoreline, up from a mere four miles in 1965. Currently, Bay Trail organizers can celebrate 341 of 500 planned miles,

Kayakers enjoy a new Water Trail launch site at Alviso Marina in the South Bay. Photo: Galli Basson.

Aquatic Park, San Francisco, segment of Bay Trail. Photo: ABAG

or 68%, as complete. Progress on the Ridge Trail comes close, at 65% complete. Since the dedication of its first segment in 1989, 360 of 550 miles of the Ridge Trail have been mapped, built and opened to the public. The San Francisco Bay Water Trail began designating sites that meet criteria for public access to the water in 2011, taking into account topography, infrastructure, overnight opportunities, sensitive wildlife, and other factors. Since 2011, 11 out of 111 planned sites have been designated, or 10 percent of the goal.

As discussed above, progress on Delta trails cannot be quantified for the purposes of this report at this time. Miles of trail remain on the drawing boards or awaiting implementation funding. Current miles of existing trail that may one day be linked in through the vision of the Great California Delta Trail include: 13 miles along the Sacramento River Parkway; nine miles of the East Bay Regional Park District's Delta DeAnza Trail; two miles in the Benicia State Recreation Area; and Glen Cove Waterfront Park in Vallejo. The park stands at the junction between the Bay and Ridge Trails and the Great California Delta Trail along the Carquinez Strait. In 2012, in a move to embrace the multi-use aspects of the recreational corridor, the Delta Protection Commission also adopted resolutions supporting bicycle lanes for several highways and Delta levees. Overall, since adoption of the Western Region Blueprint for the Delta Trail in 2010, 24.5 miles have been designated. Planning for the Eastern Region Blueprint is currently underway.

THREATS & CHALLENGES Comprehensive planning efforts by a wide range of stakeholders over the past four decades have led to a significant increase in the extent of the Bay accessible to the public, but funding to complete regional trails remains a challenge. The Association of Bay Area Governments, the agency responsible for coordinating the completion of the Bay Trail, estimates that approximately $150 million is needed to complete the trail by 2025. The Bay, Ridge and Water trail organizations continue to work with agencies like the California Coastal Conservancy and local governments to replace dwindling state park bond funds with regional and local tax measures and bonds. An additional challenge is recognition and planning for future changes in the landscape of shoreline parks and trails as a result of sea level rise. Shoreline trails offer both opportunities for public engagement in adaptation to changing conditions, as well as a line of possible defense or retreat from an advancing bay.

TRAILS

BAY

STATUS
Fair

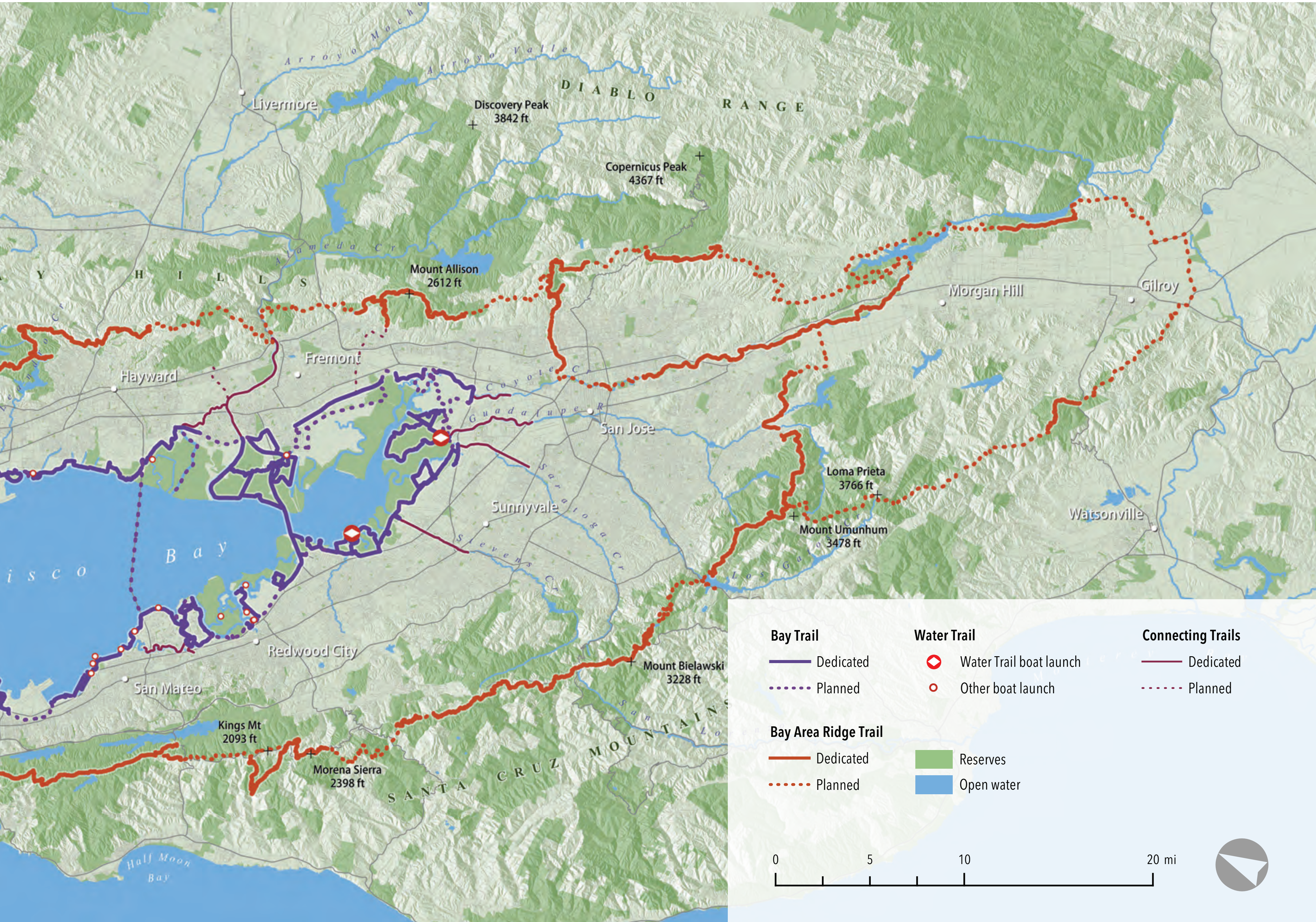
TREND
Increasing

BENCHMARK
500-Mile Bay Trail
550-Mile Ridge Trail
111 Sites Water Trail

Newly opened Bay Trail along the Carquinez Strait. Photo: ABAG

THREE ESTUARY TRAILS

ABOVE, BESIDE & ON THE WATER


Livermore
Discovery Peak
3842 ft
DIABLO RANGE
Copernicus Peak
4367 ft
Arroyo Valle
Arroyo Mocho
Alameda Cr
Mount Allison
2612 ft
HILLS
Fremont
Hayward
Morgan Hill
Gilroy
Coyote Cr
Guadalupe R
San Jose
Saratoga Cr
Stevens Cr
Sunnyvale
Loma Prieta
3766 ft
Mount Umunhum
3478 ft
Watsonville
Bay
isco
Redwood City
San Mateo
Mount Bielawski
3228 ft
Kings Mt
2093 ft
Morena Sierra
2398 ft
SANTA CRUZ MOUNTAINS
Half Moon Bay
Bay Trail
Dedicated
Planned
Water Trail
Water Trail boat launch
Other boat launch
Connecting Trails
Dedicated
Planned
Bay Area Ridge Trail
Dedicated
Planned
Reserves
Open water
0
5
10
20 mi

VOLUNTEERING FOR WATERSHED HEALTH

A young volunteer rescues a rabbit from the Bay on Coastal Cleanup Day. Photo: The Watershed Project

Plucking trash from the Bay and creeks, planting willows, crafting oyster reefs, rescuing wildlife in distress, monitoring birds, restoring habitats—these are just a few of hundreds of volunteer activities regional residents engage in that bolster watershed health. The success of local environmental conservation and restoration efforts relies in large part on this public interest and involvement. While thousands of people volunteer regularly around the Bay and Delta to help improve the state of the Estuary, few tangible indicators currently exist to quantify the scope of this effort. Tallies from a few major events, however, can provide a good snapshot.

Coastal Cleanup Day, an annual event organized by the California Coastal Commission, engages Californians in collecting debris from the State's marine environments, including the Bay's shoreline and watersheds. Since its launch nearly 20 years ago, participation in the event has increased by almost 40%. Between 1996 and 2014, the number of volunteers scouring beaches and shores in the 12-county region grew from 13,053 to 21,634, almost doubling, according to the Coastal Commission. In the last four years (2011-2014), 12-county participation has ranged from 18,757 to 26,813. Highlights from the event include flotillas of kayakers scooping trash out of the Bay along the Richmond shoreline (sponsored by The Watershed Project) and from the Napa River (Napa County RCD). Two of the strangest finds at this year's event were a pair of dentures and a cloth cord attached to a buoy of the type used on boats on the Loire River in France. In 2014, nearly 67,000 volunteers removed more than a million pounds of trash and recyclables from California's beaches, lakes, and waterways.

Audubon volunteers track migratory birds during 2014 Golden Gate Audubon Christmas Bird Count. Photo: Ilana DeBare

Baywide, the non-profit Save the Bay runs one of the region's most established volunteer restoration programs. Through the program,

Photo: The Watershed Project

BAG BANS

On Coastal Cleanup Day 2014 along the Contra Costa shoreline, close to 3,000 volunteers collected over 26,000 pounds of trash in one morning – much of it plastic. California and the Bay Area, however, remain on the cutting edge of plastic trash reduction. In November 2014, California passed a law that prohibits single-use plastic bags. The law was set to begin going into effect in July 2015 but is now stalled by opponents—the plastics industry and bag manufacturers, among others—who gathered enough signatures to put the ban to a 2016 referendum. Despite statewide setbacks, Bay-Delta region cities and counties have already begun passing their own ordinances. Six out of 12 counties, and 68 of 119 cities, now have ordinances. Source: Californians Against Waste, December 8, 2011

Top: Kids in the Napa County RCD Land Matters education program clean up a local creek. Bottom: Exhausted but happy Girl Scouts relax after picking up trash and recyclables at the Bay's edge. Photo: The Watershed Project.

volunteers clean up trash, weed, and plant natives along the Bay's edges in Palo Alto, Hayward, Oakland, Redwood City, and Marin. Between 2011 and 2014, 24,343 volunteers helped create a more resilient shoreline.

In the South Bay, the non-profit Acterra holds regular workdays on Permanente and San Francisquito Creeks, in addition to smaller tributaries. Between 2011 and 2014, 18,082 volunteers—including a youth steward program and college interns—weeded, mulched, monitored water quality, and helped establish new native plants along these streams. On top of this impressive volunteer contingent, church groups, service clubs, schools, and corporate volunteers also help out.

Birders are another group of enthusiastic volunteers. Every year near Christmas time, local Audubon chapters send hundreds of volunteers out to tally numbers of birds in order to estimate population trends for both resident and migratory birds. But birders do a lot more than count birds. Between 2011 and 2014, 1,503 Golden Gate Audubon birders and volunteers helped clean up trash and plant natives on the Alameda shoreline and at Pier 94 in San Francisco. In 2014 at Pier 94, for example, 344 volunteers planted 2,020 native plants, removed thirty-nine 30-gallon bags of weeds, fourteen 30-gallon bags of trash, and four 30-gallon bags of recyclables. Volunteers also act as docents, teaching the public about the birds of the Bay and their habitat needs.

These are just a few of the events and programs that engage adults and children in firsthand experiences and hands-on work for the Estuary. The interest shown by Bay Area residents in volunteering their time to take part in stewardship activities is an important outcome of public outreach and education efforts around the region.

Coastal Cleanup kayakers get ready to launch from the Richmond shoreline. Photo: The Watershed Project.

LOOKING AHEAD

The San Francisco Estuary Partnership expects to publish periodic State of the Estuary Reports in the coming years. Just as the 2015 Report now includes Delta measurements and new indictors for the lower estuary, future health reports should continue improving the array of indicators as we expand monitoring programs and bring forward new data.

Some aspects of estuary health remain unmeasured – as noted in this Report, we do not yet have a method to evaluate health measures that allows comparisons among the Estuary's watersheds. Nutrient cycling and carbon sequestration are also possible areas for future indicators and benchmark development.


Photo: Mark Holmes

Beyond the issue of what we measure and how we evaluate, there is the question: what do we do with the information chronicled in this Report? As the indicators show, while we are making progress on some key issues facing the health of the Estuary, we are losing ground on many others. The challenge is clear-- the physical and biological processes that influence the health of the Estuary are deeply damaged. Choices ahead will be hard ones, but we must make them. Will we choose to fix the Estuary or not?

If we choose strong and substantial action, we should act now. We can build on current efforts to more creatively tie habitat improvement with flood management projects. We can continue to reduce demand on our shrinking fresh water supply by smarter use and more reuse of existing resources. Higher levels of action will require money, time, and commitment from our political leaders and our citizens. Public support for new water bonds and for financing of local restoration efforts will be critical. Municipalities and water agencies will need funding for infrastructure upgrades that address our changing conditions.

The Governor's California *Water Action Plan*, the Delta Stewardship Council's *Delta Plan*, and the US Environmental Protection Agency's 2012 *Action Plan on Water Quality Challenges* each call for actions suggested by our Report findings. In the months ahead, important new plans like the *Baylands Ecosystem Habitat Goals Science Update* will be released with new actions to consider. The Partnership will collaborate with agencies leading these efforts. We will also ensure that the Report findings are addressed in the Partnership's 2016 *Comprehensive Conservation and Management Plan* and work with state and local decision-makers to apply the Report findings to important pending decisions.

Now more than ever, our region and state have the opportunity to lead the way. California has the science, business acumen, creativity, economic strength, and commitment to a healthy planet necessary to make these hard choices-- and to succeed in changing how things are done for the better.

If you would like to find out more about the San Francisco Estuary Partnership's 2016 CCMP development process, www.sfestuary.org

ASSESSING THE STATE OF THE ESTUARY

This 2015 Report is a summary of findings related to 33 indicators of the health of the Estuary. Details on how this analysis was accomplished are found in the online technical appendix. The following is a brief overview of the process.

How do we decide if the goals of the Clean Water Act to "protect and restore the chemical, physical, and biological integrity" are being met? To answer these questions, the authors drew upon science and public policy to make informed judgments. First they defined the attributes of the Estuary that best reflect integrity and health. Second, they chose indicators for these attributes. In the third step, they defined benchmarks against which to compare indicator measurements.

STEP 1: DEFINING ATTRIBUTES AND THEIR CONCEPTUAL RELATIONSHIPS

As in the 2011 State of the Bay Report, we followed the guidance of US EPA's Science Advisory Board (A Framework for Assessing and Reporting on Ecological Condition, 2002) to determine that the key attributes of an estuary include:

- water (both the amount of water and its chemical quality)
- physical habitats
- ecological processes
- living resources

These attributes, or qualities of an ecosystem, both interact with and influence one another (directly and indirectly), affecting the environmental goods and services we all value. People are, of course, also part of this ecosystem, and influence the Estuary's attributes. The report also assesses some stewardship indicators in the "people" section to evaluate effectiveness actions taken to reduce human impacts.

STEP 2: DEFINING HEALTH

Sourced from the scientific literature, this report defines a healthy estuary as having these components:

- Water is not toxic to living creatures, nor causes these animals to be toxic to humans.
- Water is of good enough quality to allow for recreation in and on the waters of the Estuary.
- Seasonal freshwater inflows are adequate to support native plants and animals and the ecological processes driven by flows.
- Habitats are diverse, appropriately connected, and of sufficient extent and quality to support thriving native wildlife communities over time as conditions change.
- Ecological processes build and sustain habitats, support vibrant food webs, replenish sediment and fresh water, and assimilate wastes.
- Living resources include robust and resilient populations of diverse native species, including plankton, macroinvertebrates, fish, birds, and mammals.
- People act as stewards to reduce adverse impacts on the ecosystem. This includes actions by volunteers as well as regulators, managers, and the regulated community, such as cities, counties, and industry.

STEP 3: SELECT INDICATORS

After selecting what ecosystem elements [attributes] to review and defining what we mean by "health" our next step was to identify what to measure – what indicators to review and assess. Based upon the National Academy of Sciences (Ecological Indicators for the Nation, 2000) and other work, a set of criteria was applied to possible indicators considered of value. Valuable indicators were those meaningful and relevant to the public, consistent with scientific understanding of the ecosystem, and could be measured with existing, reliable data. Our indicators also needed to broadly represent the Estuary's characteristics by integrating the many detailed scientific measurements that are available about the ecosystem.

In several cases, a suite of indicators comprises a single attribute. For simplicity, in some cases multiple indicators were combined into a single index. And for some important estuarine attributes we do not yet have indicators — like the ecological processes of nutrient cycling and sediment transport. There are also indicators that we would like to report on but for which we have no data. Some of these are treated in sidebar write-ups in this Report and will hopefully be included as full indicators in the future State of the Estuary Reports.

STEP 4: DETERMINE BENCHMARKS FOR EVALUATING INDICATORS

The last step was to establish benchmarks against which we compared the measured values for the indicators. Having benchmarks is key to evaluating the status of the Estuary's attributes. Benchmarks allow us 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 another public process — established quantitative standards or goals 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 came from the 1999 *Baylands Ecosystem Habitat Goals* report. When adopted goals were not available, benchmarks were set by using best professional judgment to identify a reference condition against which to compare the measured value of the indicator.

The authors note that setting reference conditions is complicated, because long-term studies show that climatic and ocean conditions influence the Estuary on the scale of years to decades. Changes measured against reference to a previous decade could be caused by ecological changes beyond the influence of management actions. Nonetheless, this Report presents the reference conditions in the spirit of continuing an important regional dialogue in which we continue to develop and refine goals and benchmarks for use in future assessments.

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THE PHYSICAL AND BIOLOGICAL PROCESSES ON WHICH THE HEALTH OF THIS ESTUARY DEPENDS ARE DEEPLY DAMAGED. WILL WE CHOOSE TO FIX THEM OR NOT?