Water

Quality

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

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

HEALTH INDICATORS

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

MARK RAUZON

TAKING ACTION TO REDUCE METAL POLLUTION

The Bay Area's progress in reducing metal loads in water discharged from publicly owned treatment works (POTWs) is a pollution-control success story that should be more widely known. Between 1995 and 2010, according to the Regional Monitoring Program, area-wide POTW loads of copper and nickel decreased by 48 percent. This statistic, building on earlier reductions in the 1970s and1980s, reflects a history of political commitment, technological improvement, and the changing face of local industry.

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

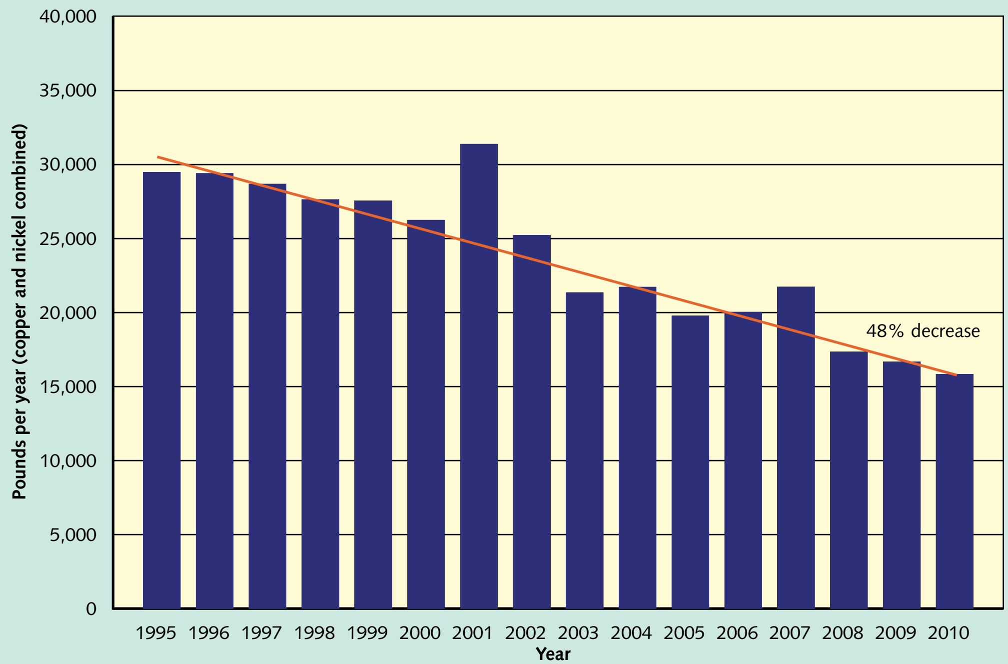
Connor says copper is a metal of concern in the Bay. One relatively recent source was the electroplating process associated with high-tech manufacturing. "The Silicon Valley used to have a lot of platers and printed circuit-board makers," says the San Francisco Bay Regional Water Board's Tom Mumley.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

Copper discharges also decreased after copper-based root-control products were banned in 1985, as a result of lobbying by treatment plant operators. But copper sources also include brake-pad linings in vehicles. To tackle that issue, Sustainable Conservation and the Brake Pad Partnership (initiated years ago by the Estuary Partnership) sponsored AB 346, which was signed into law in September 2010. The bill will allow no more than five percent copper in brake pads in vehicles sold starting in 2021, and will phase out brake pad copper completely starting in 2025.

With copper and other industrial metals under better control, mercury from dental offices is a newer target. Mercury may constitute up to 40 percent of the amalgam used in dental work. Although historic mining is still the source of most of the mercury entering the Bay, dental amalgam is a significant input. One study found that 61 percent of the mercury coming into the San Jose/Santa Clara plant came from dental practices. In 2004, when the Regional Water Board first adopted a TMDL (Total Maximum Daily Load) for mercury, 20 kilograms reached the Bay annually. That same year San Francisco required dental offices to apply for wastewater discharge permits, implement best management practices, and install city-approved amalgam separators. Other cities followed.

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

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



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

BENCHMARKS

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

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

To evaluate whether the Bay is safe for swimming, we used a statewide system for evaluating the safety of bathing beaches that compares bacteria concentrations to state goals. Heal the Bay, a Santa Monica-based non-profit, provides comprehensive evaluations of over 400 California bathing beaches in both Annual and Summer Beach Report Cards as a guide to aid beach users' decisions concerning water contact recreation. These report cards, which use the familiar "A to F" letter grade scale, provide a valuable and accessible assessment of how safe Bay waters are for swimming and were used as benchmarks.

KEY RESULTS AND TRENDS

IS THE BAY SAFE FOR AQUATIC LIFE?

Enforcement of the Clean Water Act and other environmental laws as well as technological improvements in treating wastewater have resulted in tremendous improvements in overall Bay water quality (see "Taking Action to Reduce Metal Pollution" and Table 2). These improvements have solved serious threats to aquatic life related to reduced dissolved oxygen and elevated concentrations of silver. Many other pollutants are also routinely monitored and found at concentrations below water quality goals, and are considered to pose very low risk to Bay aquatic life. However, several pollutants still pose a substantial threat to the health of aquatic life in the Bay. Methylmercury, exotic species, toxic sediments, and trash are the principal concerns.

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

Table 2. Is the Bay safe for aquatic life?

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

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

COURTESY HISTORY SAN JOSE

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

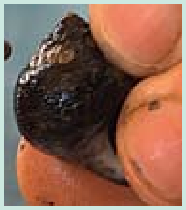
ity in embryos and chicks of some fish-eating birds. Methylmercury concentrations in the Bay food web have not changed perceptibly over the past 40 years, and we anticipate that they will decline very slowly in the next 30 years. It may be possible to tackle at least some facets of this problem. One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

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

The frequent and continuing toxicity of Bay sediments in standard tests is another indicator of the impacts of pollution on aquatic life. Since routine sampling began in 1993, at least 26 percent of each year's sediment samples have been found to be toxic. In 2009, 67 percent of the samples were toxic. These results indicate that pollutant concentrations in Bay sediments are high enough to affect the development and survival of aquatic invertebrates. This problem will persist into the future until the chemicals (or mix of chemicals) causing this toxicity can be identified and remediated.

Trash in the Bay also continues to threaten aquatic life. Plastic trash in particular persists for hundreds of years in the environment and threatens wildlife when they eat it or become entangled. Larger pieces of trash degrade into fragments that can harm fish and other aquatic animals when they eat these fragments and when animals are exposed to chemicals that leach from (or accumulate on) the plastic particles. Aggressive new regulatory requirements adopted in 2010[10] should significantly reduce the amount of trash and other urban pollutants entering the Bay in the next 30 years (see "Taking Action to Improve Stormwater Quality").

CONTROLLING A NEW, POTENTIALLY INVASIVE MARINE INVERTEBRATE


CHRIS KAY

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

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

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

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

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

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

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

SAVE THE BAY

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

ARE BAY FISH SAFE TO EAT?

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

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

TAKING ACTION TO IMPROVE STORMWATER QUALITY

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

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

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

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

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

JAY DAVIS

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

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

Table 3. Are Bay fish safe to eat?

<table>
<tr><th></th><th>HIGH CONCERN</th><th>MODERATE CONCERN</th><th>LOW CONCERN</th><th>GOALS ATTAINED</th></tr>
<tr><td>Rapid Progress Likely</td><td>*</td><td>*</td><td>*</td><td rowspan="2">DDT
Dieldrin
Chlordane
selenium
Other Priority Pollutants:
PAHs, chlorpyrifos, endosulfan, endrin, lindane, mirex, toxaphene</td></tr>
<tr><td>Rapid Progress Unlikely</td><td>PCBs</td><td>Methyl-mercury
Dioxins</td><td>*</td></tr>
</table>

*No contaminants fall in this category.

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

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

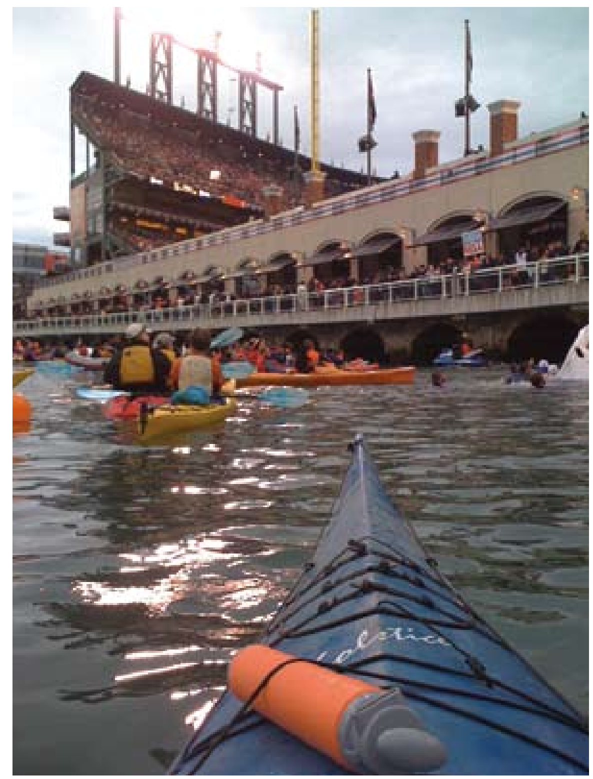
IS THE BAY SAFE TO SWIM IN?

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

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

Seven of the 27 monitored beaches had grades of B or lower, indicating that they exceeded bacteria standards by varying degrees. One beach, Keller, received an F grade. Five beaches received a D, including Aquatic Park and Lakeshore Park in San Mateo County, Keller Beach South in Contra Costa County, and CPSRA Windsurfer Circle and Sunnydale Cove in San Francisco County. These low grades indicate that swimmers could have an increased risk of becoming ill or infected through contact with the water. Overall, the average grade for the 27 beaches monitored from April through October was a B.

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



BETH HUNING

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

SUMMARY

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

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

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

Map 2. Bay Beaches Monitored for Bacteria

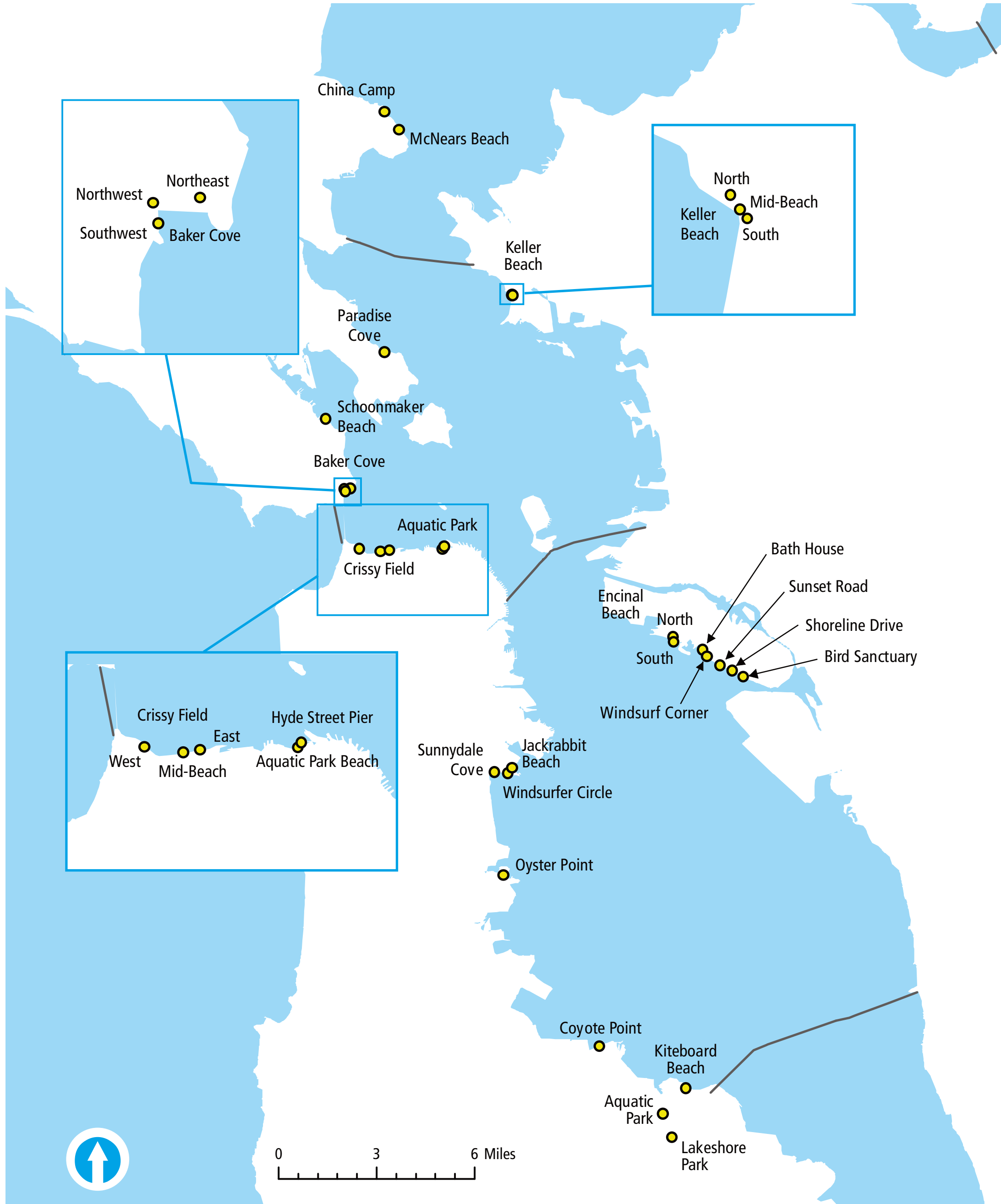


Table 4. Water quality summary

SAFE FOR AQUATIC LIFE	
Methylmercury	•
Exotic Species	••
Sediment Toxicity	••
Trash	•••
Copper	••••
Dissolved Oxygen	•••••
Silver	•••••
Other Priority Pollutants	•••••
Selenium	?
PAHs*	?
PBDE*	?
PFOS*	?
Emerging Contaminants	?

SAFE TO EAT	
PCBs*	•
Methylmercury	••
Dioxins	••
Legacy Pesticides	•••••
Selenium	•••••
PBDEs*	•••••
Other Priority Pollutants*	•••••
Emerging Contaminants	?

SAFE FOR SWIMMING	
Beach Bacteria (Summer)	••••
Beach Bacteria (Wet)	•••

KEY:

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

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

SWIM ACROSS AMERICA

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

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

Every day, we use thousands of chemicals (in a plethora of industrial and consumer products, including personal care products, pesticides, herbicides, and fungicides, just to name a few) at home and at work; many of these chemicals end up in the Bay. A lack of information on the exact chemicals present in these products, their movement in the environment, and their toxicity hinders efforts to track and manage the risk posed to people and aquatic life by these contaminants of emerging concern (CECs). Numeric goals for assessing CECs are not yet available but should be part of future assessments of Bay health. The occurrence of CECs also underscores the importance of "green chemistry" efforts to prevent potentially problematic chemicals from entering the Bay in the first place. Such measures would help prevent new legacy pollutants that could threaten the health of future generations of Bay wildlife and Bay Area residents.

TAKING ACTION TO CLEAN UP THE FLEET

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

The problem with the ships was first discovered in 2006 when *Contra Costa Times* reporter Thomas Peele advised the San Francisco Bay Regional Water Board that MARAD was scraping invasive species from the sides and bottoms of ship hulls—along with large flakes of steel and paint containing heavy metals—into the Bay, says the Water Board's David Elias. "Most marine bottom paints even today contain heavy metals designed to kill anything that tries to live on the paint," says Elias. The U.S. Coast Guard had ordered MARAD to clean the ships of invasives before sending them to Brownsville, Texas for dismantling. At that time, MARAD claimed that cleaning the ships in dry docks in San Francisco—which would have prevented discharging invasives and paint into the Bay—was too costly, according to Elias.

A report obtained at the time by the *Contra Costa Times* through a Freedom of Information Act request to the Coast Guard showed that a consultant hired by MARAD to evaluate the impacts from exfoliating paint had found that around 20 tons of copper and other heavy metals was missing, and that lots more—as much as 65 tons—was about to fall off (in paint chips) or was lying around on the ships' decks. When MARAD finally tested the stormwater collected from the ships in 2009, the samples contained high concentrations of heavy metals including lead, zinc, cadmium, mercury, chromium, and copper, says Elias. In response, the Water Board ordered MARAD to deal with the problem by scraping, sweeping, shoveling, and containing the flaking paint. The Water Board also ordered MARAD to come up with a plan to safely remove the invasives on the remaining ship bottoms and to test the sediments around the ships (a subsequent limited study by NOAA revealed that the sediments were not statistically more contaminated than Bay sediments in the vicinity). When MARAD did not comply with the orders, NRDC, BayKeeper, and Arc Ecology sued; the Water Board then decided to become a co-plaintiff.

DAVID ELIAS

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

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

Quantity (Freshwater inflow)

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

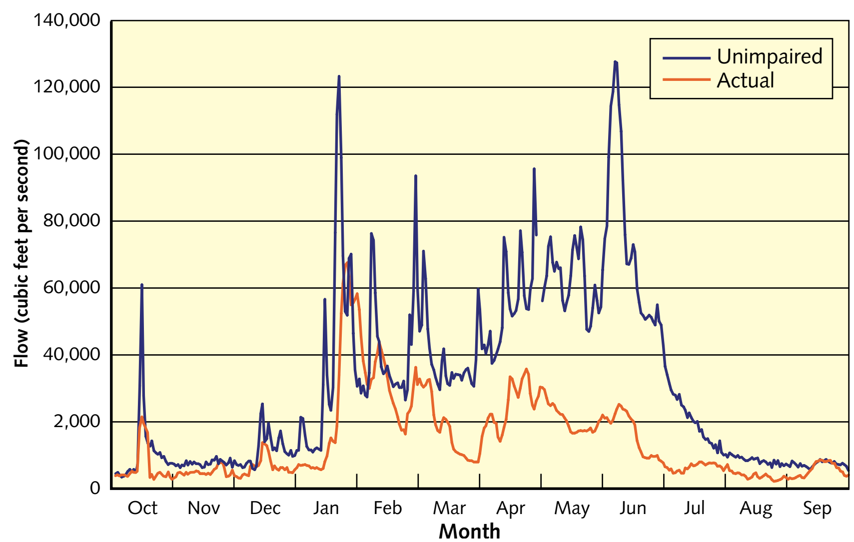
Most of the fresh water that flows into the Bay comes from the Sacramento and San Joaquin Rivers. Smaller waterways around the Bay, like the Napa and Guadalupe rivers, and Alameda, San Francisquito, Coyote, and Sonoma creeks, and many smaller tributaries, contribute the balance. All of these streams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

HEALTH INDICATORS

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

PETER BAYE

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



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

BENCHMARKS

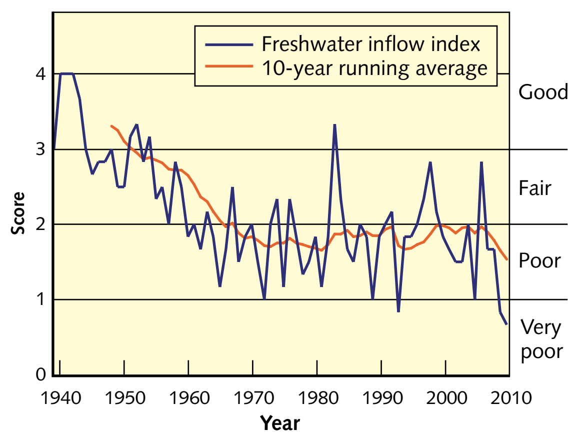
Regulatory requirements for minimum freshwater inflows into the Bay have been in place for several decades. However, the State Water Resources Control Board (SWRCB) recently determined that, in order to protect public trust resources like fish and wildlife in the Estuary, 75 percent of unimpaired runoff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

KEY RESULTS AND TRENDS

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

All of the key characteristics of freshwater inflow—amounts, variability, peak flows and dry year frequency—were adversely affected. Since the 1970s, overall flow conditions have been mostly poor and, in the past two decades, occasionally very poor. During the 2000s, annual inflows were reduced by more than 50 percent on average and springtime inflows by nearly 60 percent compared to historic levels. In 2010, only 31 percent of estimated springtime unimpaired runoff from the Bay's watershed actually flowed into the Bay. Both seasonal and year-to-year variability have been reduced and, in 2010, the frequency of peak flood flows was reduced by 90 percent (see also Flood Events in the Ecological Processes section of this report). In effect, based on the amounts and patterns of actual freshwater inflow, the Bay is being subjected to chronic drought conditions: 2010 was the eighth year out of the past ten in which the total annual amount of freshwater flow into the Bay was the same (or less) than what it would have been under unimpaired conditions in a "critically dry" year. Despite above average runoff in the watershed, inflow conditions in 2010 were very poor, and the Freshwater Inflow Index was the lowest on record (Figure 3).

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



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

SUMMARY

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

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