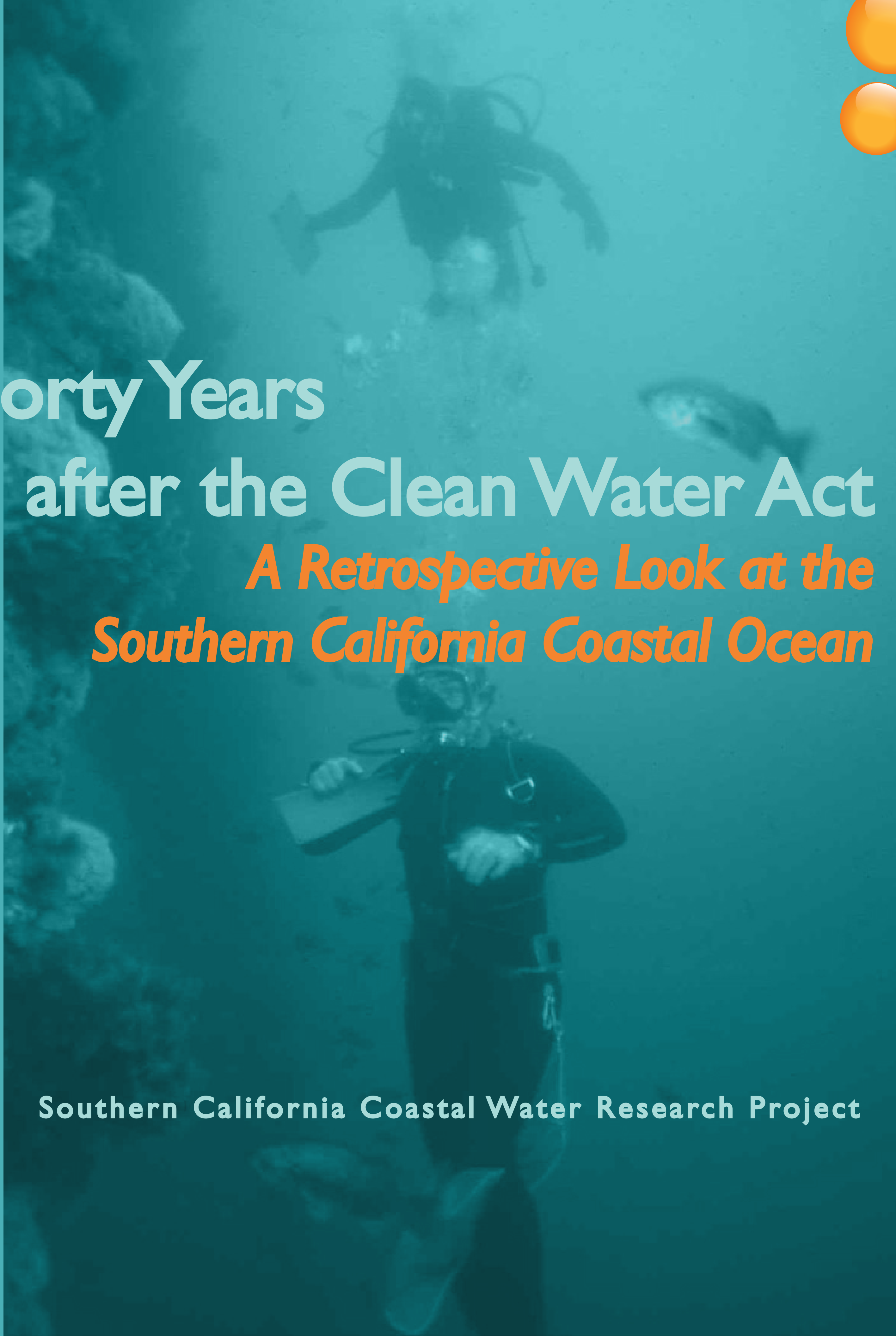


Forty Years after the Clean Water Act

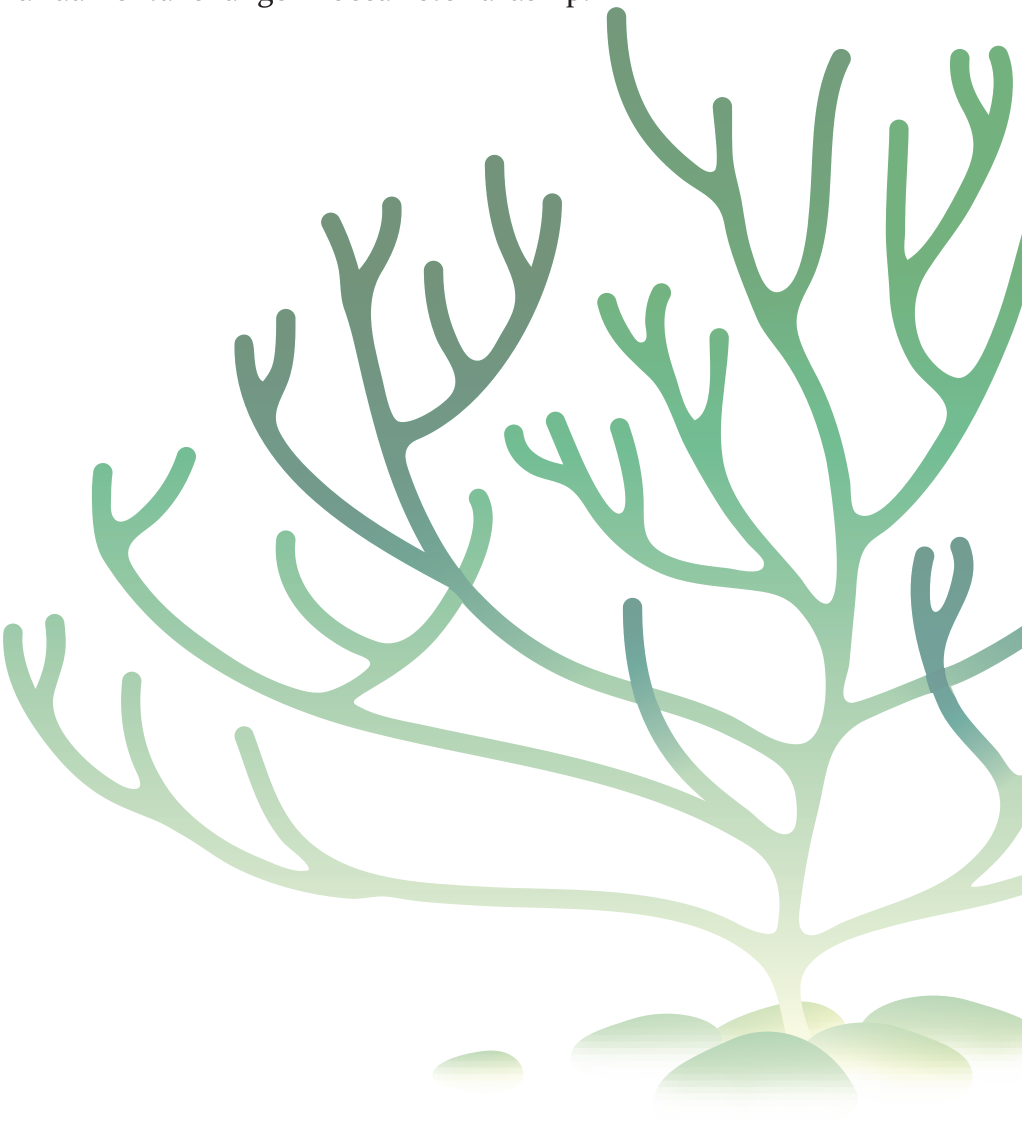
A Retrospective Look at the Southern California Coastal Ocean

Southern California Coastal Water Research Project

Cover photos courtesy Southern California Coastal Water Research Project (SCCWRP)

Prologue

The Clean Water Act (CWA), enacted on October 18, 1972, brought forth many changes in management of the nation's waterways. Primarily aimed at restoring the integrity of polluted waterways, one essential component of the CWA was implementing water quality monitoring programs in specific affected areas to guide decision-making and evaluate progress. In southern California's coastal ocean waters, dozens of organizations have spent millions of dollars each year to take hundreds of thousands of water quality, toxicity, and biological indicator measurements. A mix of targeted monitoring around discharge sites, special studies, and collaborative regional monitoring to assess large-scale environmental changes has provided a strong foundation for environmental management specifically adapted to the region. At the same time, the region's history and characteristics provide a unique opportunity to tell part of the CWA story. This document reflects on 40 years of change, while commemorating the dedication of many individuals and organizations to a fundamental change in ocean stewardship.



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SUMMARY

The ocean is a cornerstone of southern California's environment, culture, and economy. Its complex ecosystem features a unique diversity of plants, invertebrates, fish, birds, and marine mammals. Southern California is also home to 21 million people, and its coastal waters serve as a repository for the pollutants produced by human activities. As local and national attitudes changed and concerns about natural resource protection grew through the 1960s, the resulting flurry of environmental legislative activity included passage of the federal Clean Water Act (CWA) in 1972.

Since the CWA became law 40 years ago, tremendous effort has been devoted to managing and monitoring waste discharges and regional conditions in the southern California's coastal ocean. Even so, there has not been an integrated assessment of how ocean conditions have changed over that time period. This report summarizes a collaborative effort to assess historical data, the current status, and ongoing challenges to the integrity of the region's marine environment. By addressing several critical questions about the core CWA goals, it intends both to synthesize knowledge of the early environmental pioneers and to guide those who follow in their footsteps.

How Have Pollutant Inputs Changed?

Pollutant inputs from wastewater treatment plants and industrial facilities have declined markedly over the last 40 years, in large part because these "end-of-pipe" facilities were a primary target of the CWA. Inputs of targeted toxic substances from these sources have decreased more than 95%, despite a doubling in southern California's coastal population. Widely dispersed and much harder to control, pollutant inputs from overland runoff have not seen similar reductions. Controlling pollutants in runoff is now a focal point for water quality management, but more time and additional monitoring are needed to determine the success of these efforts.

Is It Safe to Swim?

Recreational water quality has greatly improved over the last 40 years. This has resulted primarily from improvements in wastewater treatment, relocation of treated wastewater discharges further from shore, and diversion of runoff during dry weather. Visual evidence of sewage, commonplace prior to the CWA, is now rare. Water quality monitoring is frequent and indicates 95% of southern California beaches are safe for swimming during the summer. Recent beach advisories are almost exclusively associated with flowing storm drains or accidental sewage spills.

Is It Safe to Eat Fish?

Contaminant levels in fish tissue have declined as pollutant inputs have decreased. High levels of contaminants such as DDT (a pesticide) and PCBs (a group of industrial chemicals) in fish tissue are now observed mostly in hotspot areas where large quantities of those pollutants were once discharged. In contrast, moderate levels of mercury, which has more diffuse and difficult to manage sources, are still observed in fish throughout southern California coastal waters. As a result, fish consumption advisories due to mercury, particularly for children and women of childbearing age, can be found along large sections of the Los Angeles and Orange County coastlines.

Is the Ecosystem Protected?

By several measures, the health of southern California coastal ocean ecosystems has improved substantially over the last 40 years. Communities of bottom-dwelling invertebrates living near wastewater outfalls, once severely degraded, have rebounded. Fish communities in these areas have also shown improvement. In addition, fish diseases common in the early 1970s are no longer observed. California brown pelican and bald eagle populations, once endangered by DDT effects, show signs of recovery. Other ecosystem indicators, such as the extent of giant kelp forests and population size of some fish species, remain impacted. These trends are likely related to a combination of factors including habitat loss, natural climatic cycles, and overfishing.

What Were the Costs and Benefits?

Although no formal economic analysis has been performed to calculate total costs and benefits on a regional scale, both financial investments and economic benefits associated with southern California's coastal ocean are substantial. For example, ocean-dependent activities in California generate an estimated $22 billion annually, over half of which comes from tourism and recreation; however, it is unclear how much of that revenue is linked to water quality improvements. Although it is difficult to estimate total investments in ocean water quality improvement, large wastewater treatment plants in southern California currently spend as much as $600 million annually. In addition, county flood control agencies spend roughly $100 to $350 million each year managing runoff. A thorough cost-benefit analysis is recommended to inform future management directions.

What Are the Future Challenges?

Future water quality management efforts are faced with both technical and financial challenges. While end-of-pipe treatment methods were highly successful in the first 40 years following passage of the CWA, new contaminants, subtle toxicological effects, ocean acidification, pollution-related harmful algal blooms, marine debris, atmospheric deposition, and other emerging issues require novel technology and creative management approaches. Meanwhile, capacity to address both new and lingering issues continues to be constrained by decreased federal funding. Continued cooperation among dischargers, regulators, scientists, and others will be essential to understanding and addressing water quality problems over the next 40 years.

INTRODUCTION

The southern California coastal ocean is a cornerstone of the region's environment, culture, and economy. It supports complex and dynamic marine ecosystems inhabited by diverse species of invertebrates, plants, fish, birds, and marine mammals (Figure 1). These waters encompass shallows and deeps, reefs and canyons, flats and drop-offs, banks and basins, seagrass beds, and giant kelp forests.

The southern California coastal ocean is also a venue for many human activities. Arguably the

Figure 1. Marine wildlife of southern California (photos courtesy Southern California Coastal Water Research Project (SCCWRP); Dan Pondella and Jonathan Williams, Occidental College)

Figure 2. Human uses of the southern California coastal ocean (photos courtesy Southern California Coastal Water Research Project; Gerald McGowen, City of LA)

region's primary tourist attraction, it hosts a myriad of recreational pursuits like swimming, surfing, boating, scuba diving, and fishing (Figure 2). In addition, the ocean produces abundant seafood and supports commercial shipping, tourism, and military activities. In connection with all of these activities, the coastal ocean environment provides the essential basis for a multitude of industries, businesses, and jobs.

These same waters serve as a disposal site for the residues of human activities, including runoff and discharges from municipal treatment plants and industrial facilities. In many cases, discharges to the coastal ocean are monitored and managed; however, in some cases, they arrive accidentally and even unknowingly. Prior to the 1960s, wastewater disposal focused on protecting human health and property, and it was commonly believed that the ocean's capacity to assimilate pollutants was inexhaustible. With the common mantra "the solution to pollution is dilution," people assumed any amount and type of waste entering ocean waters would be sufficiently dispersed and diluted to preclude adverse effects on the environment, marine life, or people.

Changes in Perceptions, Law, and Government

In the 1960s, conventional wisdom about the effect of wastes in the environment was increasingly called into question, particularly for synthetic chemicals. Rachel Carson's book *Silent Spring*,

Rachel Carson's Silent Spring

The book *Silent Spring*, authored by Rachel Carson and published in 1962, broke ground in reporting the harmful effects of pesticides in the environment, particularly on birds. The book exposed how the pesticide DDT can interfere with bird reproduction, causing them to produce eggs with unnaturally thin, easily broken shells. A best seller, the printing sparked widespread public reaction. In 1972, some ten years after the book's publication, the federal government banned nearly all uses of DDT. Domestic production for international markets ceased in 1983.

published in 1962, was instrumental in spurring reexamination of pollution effects. Garrett Hardin's 1968 essay "The Tragedy of the Commons" invited a broader discussion of assimilative capacity limits and conflicting interests with regards to shared environmental resources.

Garrett Hardin's Tragedy of the Commons

"Freedom in a commons brings ruin to all."

The essay "The Tragedy of the Commons" by Garrett Hardin, published in the journal *Science* in 1968, called attention to a fundamental dilemma associated with publicly accessible and commonly owned natural resources. In the absence of effective management, common property is likely to be overused, resulting in loss of benefits and degradation of the resource.

Santa Barbara Oil Spill

In January 1969, an oil platform blowout about six miles from the mainland in the Santa Barbara Channel resulted in a massive oil spill. It was the largest to have occurred in US waters at the time. The spilled oil fouled Santa Barbara Harbor as well as mainland beaches and the Channel Islands. It killed thousands of seabirds and unknown numbers of other wildlife. The event received intense media coverage nationwide, including photos and television footage of oil-covered waters, shores, and wildlife.

Other iconic events, such as the June 1969 fire on the Cuyahoga River in Ohio, grabbed the nation's attention and showed how pollution could drastically alter the health of the nation's waters. Similar problems took center stage in southern California: the Santa Barbara oil spill in January 1969 and the DDT-induced collapse of the California brown pelican population in the 1960s through early 1970s. These incidents captured media attention, galvanized public concerns, energized environmental groups, influenced elected officials, and helped to reinforce the need for more effective natural resource management.

As a result of these and other catalyzing events, the period from 1960 to 1980 saw a flurry of legislative activity. A number of new environmental statutes were enacted and strengthened, and several government agencies were created or expanded to better protect natural resources. For water quality, the Porter-Cologne Water Quality Control Act became a state law in California in 1969, and the Clean Water Act (CWA) followed at the federal level in 1972. In one sense, these laws simply continued a decades-long evolution of legislative efforts to address water pollution. In another sense, they represented transformational steps forward. Today, these two landmark statutes continue to provide the central legal basis for protecting and restoring California's waterways.

Changes in the Ocean

In response to these laws, large sums have been expended on environmental programs intended to restore the integrity of waterways. As the

California and Federal Water Quality Laws

California's Porter-Cologne Water Quality Control Act and the federal Clean Water Act differ in some ways but complement each other in most respects. Both aim for water quality that supports various human and ecological beneficial uses. Both establish water quality standards and regulatory enforcement mechanisms. Although both laws apply to surface waters including the coastal ocean, the Porter-Cologne Act explicitly requires a water quality control plan for ocean waters – the California Ocean Plan. Finally, both have been amended over time to adapt to new issues. In 1987, for example, the Clean Water Act was re-authorized with amendments to address runoff as a pollutant source that did not fit the original regulatory model.

nation marks 40 years since passage of the CWA, assessments of its effectiveness are needed to preserve historical knowledge and guide future water quality improvement efforts. Have releases of wastes changed? Has the health of coastal ocean waters improved? Has the effort been worth the cost? The answers to these questions have repercussions for managers, policy-makers, and the public alike.

The southern California coastal ocean, with its many human influences and long-running ocean monitoring programs, offers a prime location for a case study on how pollutant discharges and ocean conditions have changed over the last four decades. This report synthesizes data from multiple sources to assess what has or has not changed over time, examine current conditions, and clarify remaining challenges.

This synthesis examines coastal ocean waters extending from Point Conception in the north to the international border with Mexico in the south. The information presented focuses on open ocean waters along the coast (i.e., waters outside of enclosed harbors, bays, lagoons, and estuaries). Enclosed coastal waters have much different ecological characteristics and human influences, warranting a separate assessment.

HOW HAVE POLLUTANT INPUTS CHANGED?

The sizeable human presence in southern California has brought numerous and diverse pollutant sources to the southern California coastal ocean. Over time, rural and urban development throughout the region has resulted in extensive land use alterations adjacent to the coast (Figure 3). Much of the area's natural open space has been converted to industrial, commercial, residential, military, or agricultural land uses. Land use and human activities are closely linked to water quality in the coastal ocean, since pollutants enter the ocean through rivers and storm channels, treated wastewater discharge, atmospheric deposition, and other pathways. Pollutant sources include residences, businesses, industrial facilities, power generating stations, oil platforms, and ships (Figure 4). Some pollutants stem solely from human sources. Others occur naturally but enter ocean waters at greater than normal rates as a result of human activities.

Initially the CWA focused on reducing "end-of-pipe" or "point source" pollution, so named because the discharge comes from a single location. Wastewater treatment plants are a good example of a point source. In southern California, there are 23 wastewater treatment plants, also called Publicly Owned Treatment Works (POTWs), that discharge treated wastewater directly to coastal ocean waters. Of these, the four largest facilities (managed by the City of Los Angeles Bureau of Sanitation, Sanitation Districts of Los Angeles County, Orange County Sanitation District, and City of San Diego Public

Figure 3. The Ivanhoe section of Los Angeles (now Glendale) circa 1895 (top, courtesy California State Library); modern aerial view of the Los Angeles region exemplifying extensive urbanization (bottom, courtesy Sanitation Districts of Los Angeles County)

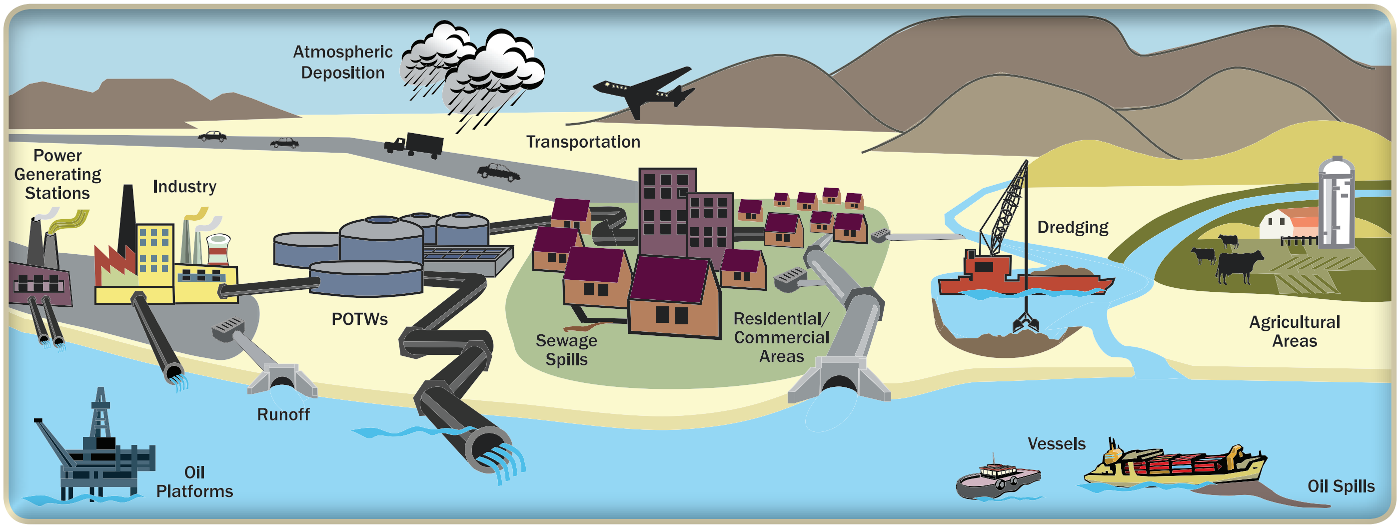

Figure 4. Diverse pollutant sources and pathways to the southern California coastal ocean (diagram courtesy Dionne Kardos, Orange County Sanitation District)

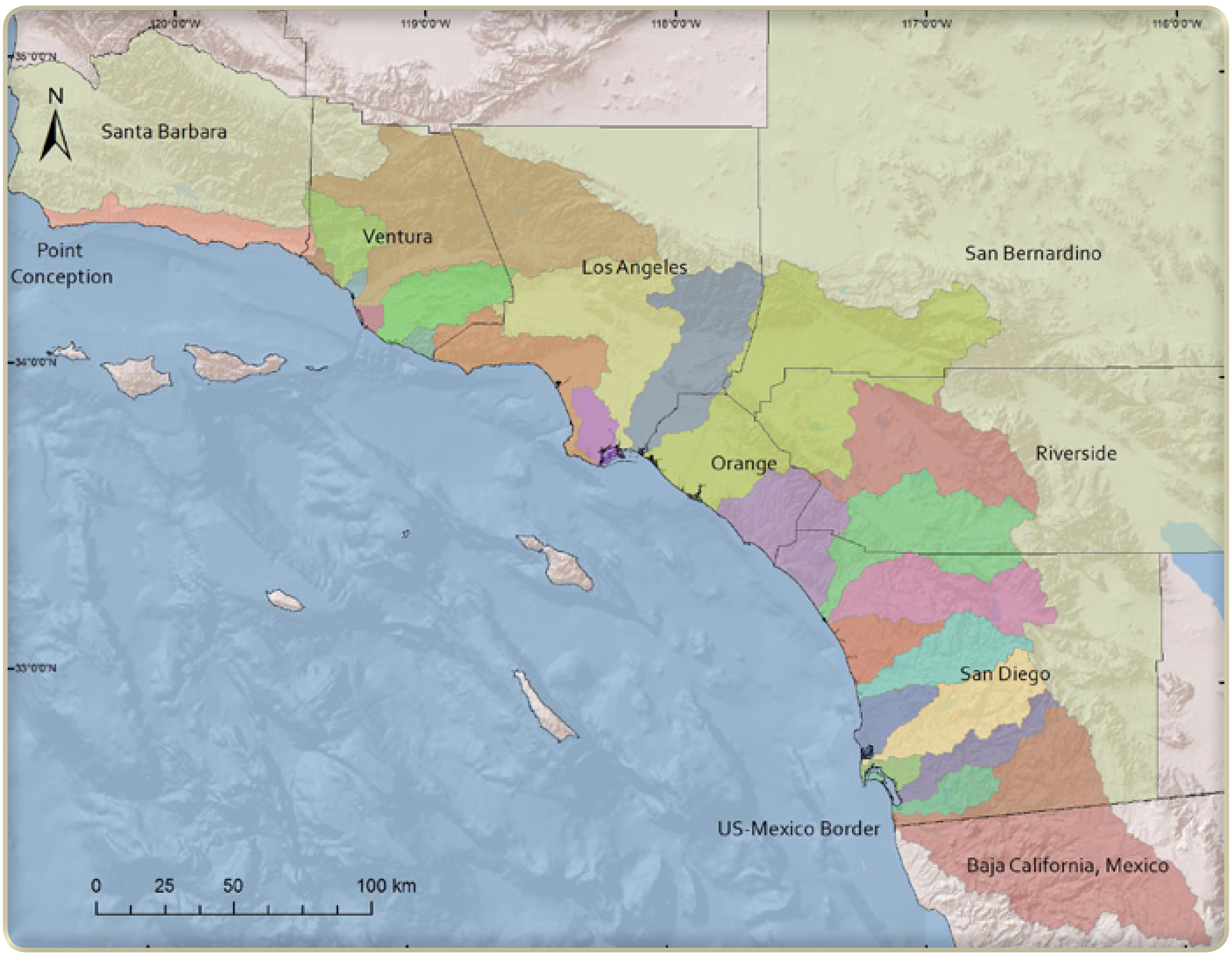

Figure 5. The major watersheds draining into southern California coastal waters extend over portions of five coastal and two inland counties, plus part of northern Baja California, Mexico (map courtesy Becky Schaffner, SCCWRP)

Utilities Department) account for more than 85% of POTW discharge to the ocean (by volume). In addition to the 23 coastal facilities, nine inland POTWs discharge highly treated effluent to large rivers and streams that drain to the ocean. In 1971, approximately 96 industrial facilities discharged to the coastal ocean, but this number has since decreased to four facilities (an oil refinery, a salt factory, and two aquaria). Other examples of point sources include the region's 13 coastal power generating stations and 23 offshore oil platforms.

Nonpoint pollutant sources, including runoff, represent a second category of inputs to the coastal ocean. Runoff from land surfaces occurs during both wet and dry weather. Unlike POTW or industrial discharges that can be traced back to individual large pipes, runoff enters the ocean through numerous small outlets draining large watershed areas with many diffuse pollutant sources. The total watershed area draining to the southern California coastal ocean spans tens of thousands of square miles, covering portions of five coastal and two inland counties, plus part of northern Baja California, Mexico (Figure 5). Runoff can come from areas with agriculture, industry, military, construction, transportation, commercial, and residential activities. Typically, runoff does not receive any type of treatment or purification before entering ocean waters.

Pollutant Inputs Have Declined Dramatically Despite Population Growth

Pollutant inputs are normally expected to intensify along with population growth and development pressure. In the seven counties that most closely influence the southern California coastal ocean, total human population has increased exponentially over the past century from approximately 300,000 in 1900 to over 11 million in 1970, just before the CWA was enacted (Figure 6). From 1970 to 2010, the region's population nearly doubled again to more than 21 million. The population of northern Baja California has grown even faster, tripling since 1970.

Despite large population growth over the last 40 years, water conservation and reuse practices have kept discharge volumes to the ocean fairly constant (Figure 7). A number of POTWs now reuse treated wastewater locally for irrigation and groundwater recharge rather than discharging it as "waste" to the ocean. In coastal southern California's dry climate, these conservation and reuse practices are critical not only for pollution reduction, but also for reducing reliance on imported freshwater.

In addition to limiting the growth of discharge volume, the quality of discharged wastewater has greatly improved in the last four decades. When the CWA was enacted in 1972, 340 billion gallons per year of primary-treated effluent (wastewater with some solids physically removed) were discharged by the four largest POTWs. In 2008, the same POTWs

Dry Versus Wet Weather Runoff

Although it doesn't rain frequently in southern California, the runoff volumes and pollutant amounts associated with wet weather runoff dwarf typical dry weather discharges. During dry weather, small volumes of runoff are generated by human (e.g., over-irrigating lawns and gardens, washing cars) and natural (e.g., freshwater springs, snow melt) activities. Wet weather runoff also includes water from precipitation events. In urban areas, rain is quickly drained off the land to prevent flooding. Water that does not soak into the ground onsite washes (and carries pollutants) into storm drains and rivers, which ultimately discharge to the ocean.

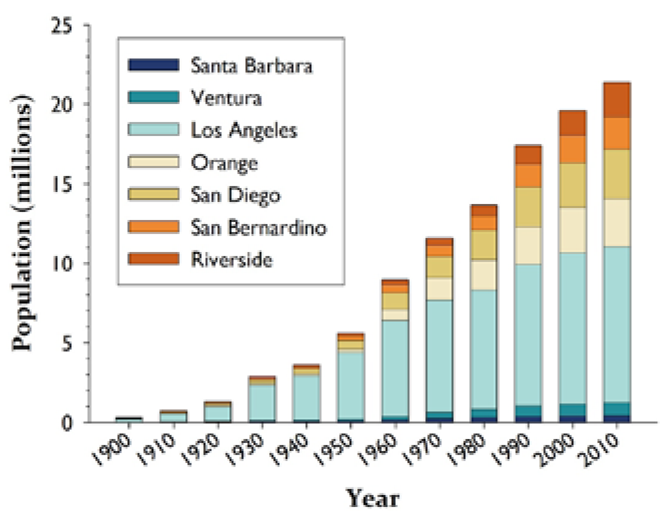

Figure 6. Population of the seven southern California counties with watersheds draining to the coastal ocean (data from US Census Bureau)

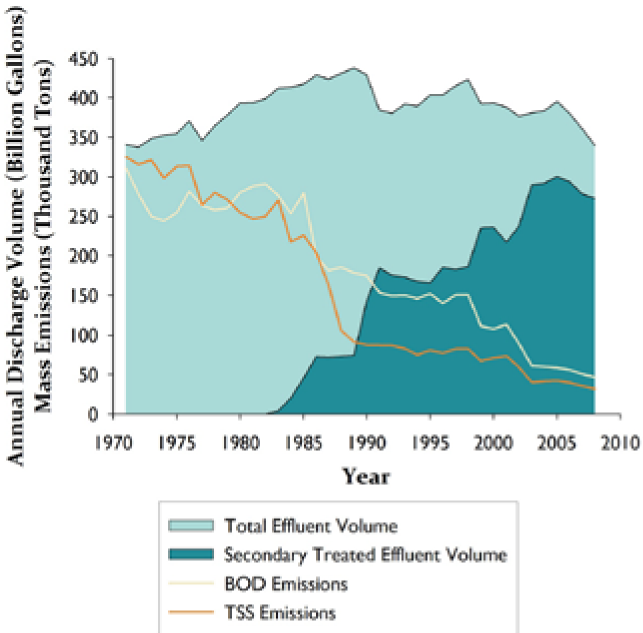

Figure 7. Quantities of total effluent, secondary treated effluent, BOD, and TSS discharged annually since 1971 from the four largest POTWs into southern California coastal waters

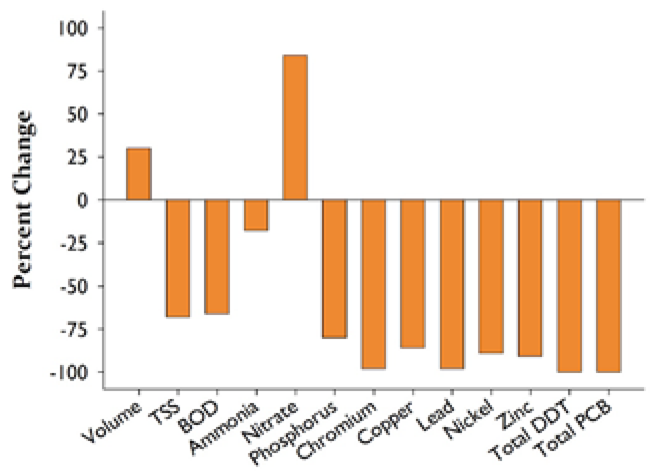

Figure 8. Percent change between 1971 and 2000 in combined annual discharge volume and mass emissions of select constituents from all major sources

discharged a nearly identical 339 billion gallons per year, but 80% was treated to secondary standards, with the remaining 20% treated to advanced primary standards (Figure 7).

In secondary treatment, biological treatment processes are used to rapidly break down organic material. This process is very effective in removing many polluting substances from wastewater. Total suspended solids (TSS) and biochemical oxygen demand (BOD) refer to the amount of solid particles and organic material in the water and are two fundamental indicators used to characterize wastewater quality. Largely as a result of increased treatment, the combined mass emissions of TSS and BOD from the four largest POTWs have declined by 90% and 85%, respectively (Figure 7).

Mass emissions of many other pollutants from all major sources combined (large and small coastal POTWs, runoff, and industrial discharges) have also declined substantially since 1971 (Figure 8). Toxic contaminants such as trace metals have decreased by up to 99%. Synthetic contaminants, including DDT (a pesticide) and PCBs (an industrial chemical), are minimal or undetectable. While improvements in municipal wastewater treatment have certainly contributed to toxic contaminant reductions in coastal waters, another important factor has been the increased emphasis on pretreatment, in which specific contaminant levels are reduced at the source (e.g., an industrial facility) before the wastewater is sent to a POTW.

Nitrate is one notable pollutant for which releases to the ocean have increased over the last four decades. Nutrients such as nitrate are necessary to life, but in large amounts can overwhelm an ecosystem, contributing to excess algal growth and reduced oxygen levels. Ocean-discharging wastewater treatment plants like those in southern California are not typically designed for nutrient removal (tertiary treatment), as are some POTWs discharging to more nutrient-sensitive inland water bodies. Therefore, nutrient levels in POTW discharge have remained steady, while estimates of nutrients discharged in runoff have increased.

Runoff Has Become a Principal Contributor for Some Pollutants

Coastal POTWs historically conveyed the majority of the southern California coastal ocean's pollutant inputs. An early focus of the CWA, much progress has been made in reducing inputs from these sources. Pollutant contributions in recent years have been more evenly split between POTW discharges and runoff (Figure 9). However, runoff pollutant sources are spread over wide areas, making it a more complex management challenge.

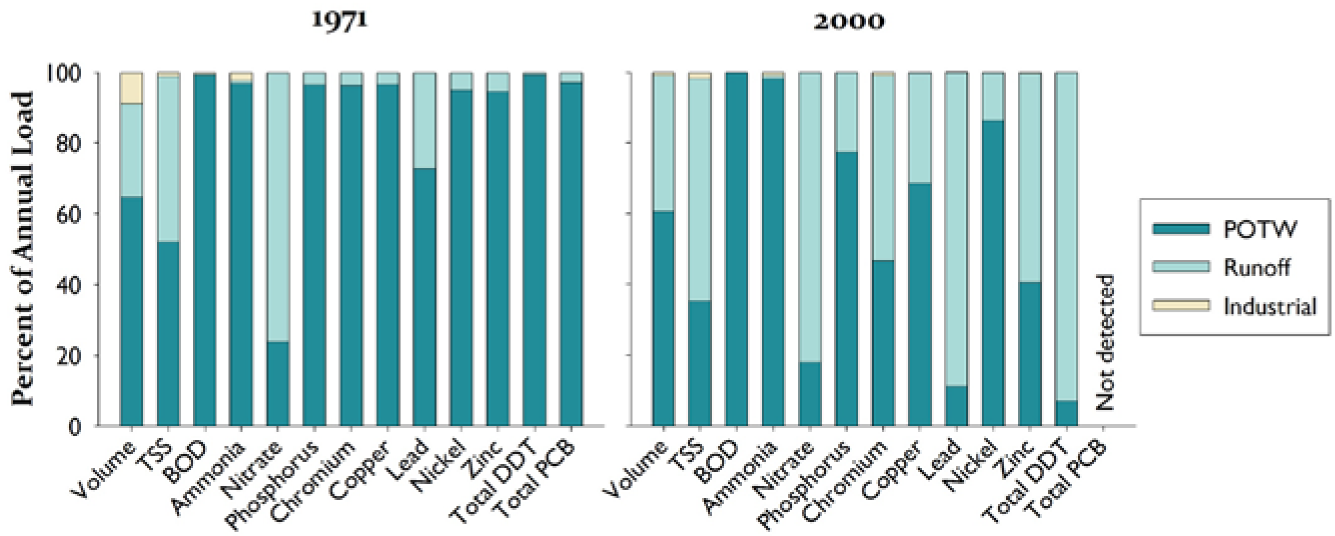

Figure 9. Relative pollutant contributions from POTWs, runoff, and industrial discharges in 1971 and 2000

This trend was acknowledged nationally when the CWA was re-authorized in 1987, and certain large runoff discharges came under stricter regulation. Runoff pollution reduction programs typically focus on best management practices near the suspected sources, such as construction site soil retention, neighborhood stormwater retention ponds, trash capture devices, and pet waste disposal facilities. In addition, various multi-purpose runoff projects, such as diversion of low-flow runoff to treatment plants and restoration of natural wetlands that filter runoff, have been implemented to reduce pollutant inputs to the ocean.

Future Challenges

In the future, environmental managers will be challenged with transitioning from the pollutant removal mechanisms at the heart of the CWA to pollution prevention mechanisms. End-of-pipe treatment is one way to reduce the amount of pollutants released to the environment, but not necessarily the most practical. Depending on a specific pollutant's properties and circumstances, a mix of approaches such as source elimination, source reduction, pretreatment, diversion, or retention may be more beneficial and cost-effective. For example, providing drop-off sites for unused or expired pharmaceuticals helps keep them out of municipal wastewater. Low-impact development approaches like installing retention basins can help prevent nutrients (e.g., in fertilizers applied to lawns and agricultural fields) from reaching waterways.

The continual emergence of new types of pollutants increases the need for preventative management. The CWA's list of 126 "priority pollutants" has not changed substantially since the 1970s, although other chemicals are frequently introduced into agricultural, industrial, and commercial processes. New pollutants, collectively called "contaminants of emerging concern (CECs)," include compounds

Turnstile of Pesticides

Banning dangerous chemicals is rarely effective unless the chemicals of concern are replaced by less harmful alternatives. For example, the pesticide diazinon was widely used in the 1970s and 1980s because it degraded faster in the environment than earlier persistent pesticides like DDT. Diazinon was highly toxic and very effective at controlling the imported fire ant; however, like DDT, it severely impacted a wide range of non-target organisms. Diazinon was eventually pulled from the marketplace but was never listed as a priority pollutant under the CWA. As diazinon use declined, another pesticide group called pyrethroids was commercialized. Equally or even more toxic to non-target organisms, pyrethroids are now widely found in southern California aquatic environments.

such as current-use pesticides, pharmaceuticals, and ingredients in household and personal care products. Initial research shows the widespread presence of CECs at low levels in marine environments. Because there are too many chemicals to track one-by-one, scientists and managers must devise new monitoring and management approaches to address CECs, for example monitoring methods that detect the biological effects of an entire class of CECs.

Substances that pose a serious threat to the environment are often severely restricted or banned, resolving the issue in the short term. This approach does little to resolve the long-term issue, though, unless new products are designed to be less dangerous. As a way to get ahead of the constant development of new chemicals, the California Environmental Protection Agency and Department of Toxic Substances Control recently started the California Green Chemistry Initiative to encourage proactive consideration of public health and environmental consequences at the product design phase, before the substance ends up in the environment.

IS IT SAFE TO SWIM?

"The importance of the ocean shoreline area... can scarcely be overemphasized." - Orange County Sewerage Survey, 1946-1947

Figure 10. Crowds at Avalon Beach on Catalina Island (photo courtesy SCCWRP)

Hundreds of millions of visitors flock to southern California's shorelines every year to sunbathe, swim, picnic, exercise, and engage in sports (Figure 10). Local and visiting beachgoers add billions of dollars to the region's economy each year, and coastal property prices reflect this value. Tourism, local businesses, and property values may be negatively impacted if the water is perceived as polluted. Polluted recreational waters can also lead to greater illness frequency, higher medical costs, and lost workdays. As a result, state and local public health agencies invest a great deal in monitoring and management programs to improve beach water quality, both to reduce illness and maintain access to these economically and culturally important areas.

Several types of pathogens (disease-causing microorganisms) can be transmitted through accidental ingestion of contaminated ocean water. Pathogens usually come from fecal material that reaches beach waters through direct or indirect pathways such as sewage spills, failing septic systems, or runoff. Because it is difficult to monitor for pathogens one by one, water monitoring programs test for bacteria that indicate the presence of fecal pollution (called "fecal indicator bacteria") to assess the overall risk to swimmers. Fecal indicator bacteria generally originate from the same fecal sources as pathogens and are relatively easy to measure in the laboratory. Several epidemiology studies dating back to the mid-1970s have documented relationships between fecal indicator bacteria concentrations and the number of swimmers who get sick.

One goal of the CWA is to make waterways "safe to swim." Federal marine recreational water quality standards for fecal indicator bacteria date to 1968, and were revised based on new information for marine beaches in 1986. In California, the state legislature promulgated statewide monitoring expectations and water quality standards for high use beaches through Assembly Bill 411 (AB 411) in 1997. Under AB 411, public beaches must be monitored using one of three standard fecal indicator bacteria tests on at least a weekly basis from April 1 to October 31 each year. Warning signs must be posted if the water quality standards are exceeded, and the beach must be closed if it is affected by a sewage spill.

Figure 11. Sewage field in nearshore water adjacent to the screening plant construction at Hyperion in 1924 (photo courtesy Anna Sklar)

Beach Water Quality Has Improved Dramatically with Changes in Wastewater Treatment

Over the last century, beach conditions have improved greatly as raw sewage collection, treatment, and discharge infrastructure has been upgraded. In Los Angeles for example, public sewer construction to collect municipal wastewater dates as far back as 1873. In 1894, the city began discharging its raw sewage from a beachfront property (the location of the current City of Los Angeles Hyperion Treatment Plant) into the nearshore waters of Santa Monica Bay. The volume of sewage discharge grew substantially by 1915, raising concerns about odor and aesthetics among local residents, but World War I and financial concerns delayed construction of a sewage screening plant into the 1920s (Figure 11). The screening plant started operating in 1925, but beaches within one mile on either side of the discharge were still deemed unsafe for swimming. Discharge of the highly polluted wastewater continued until a new secondary treatment plant was constructed in 1950.

Discharge of raw or primary-treated sewage close to the shore also impacted beach water quality in other parts of southern California. The following passage describes conditions in 1956 over the shallow water outfall where the Los Angeles County Sanitation Districts' Joint Water Pollution Control Plant discharged primary-treated effluent: "The surface of the sea is usually covered with large continuous patches of brown grease and stringy material. These patches may be several thousand feet in length and many hundred feet wide."

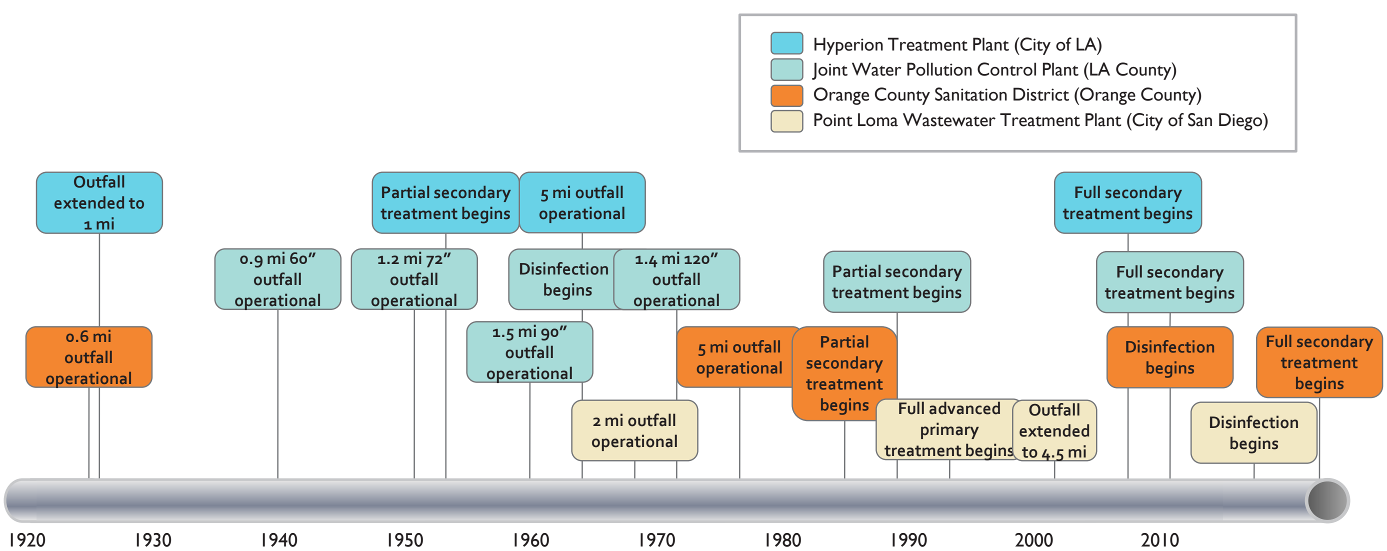

Figure 12. Major events including outfall extension, treatment plant upgrades, and disinfection for the four largest southern California POTWs from 1920 to 2012

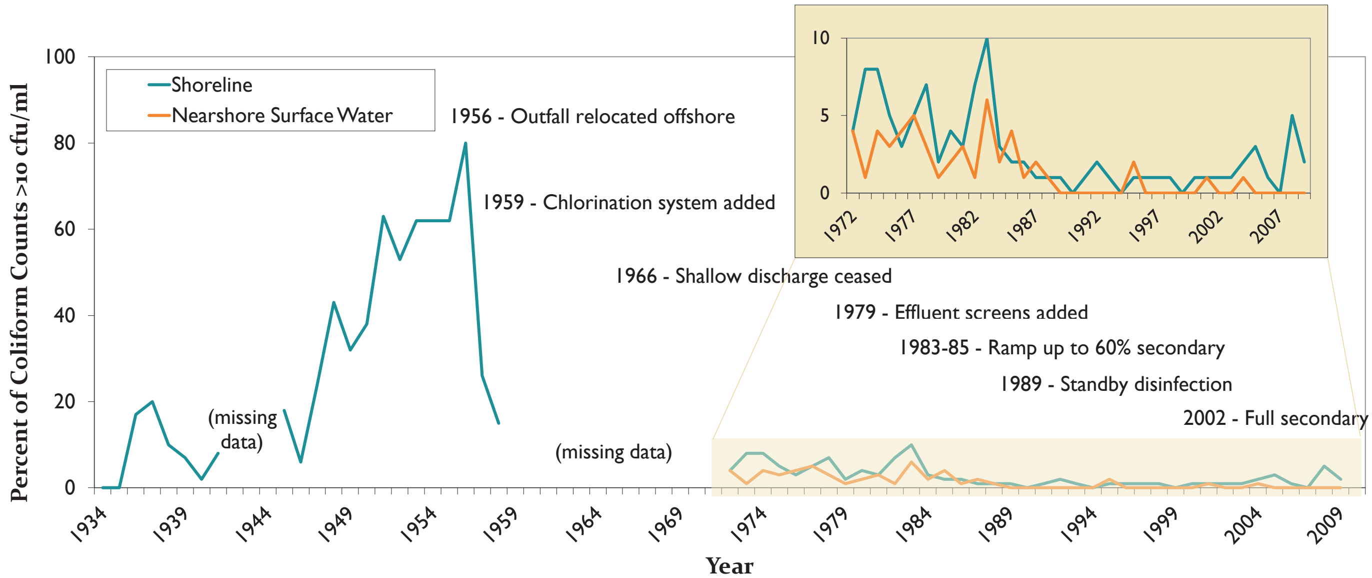

Figure 13. Annual percentage of positive fecal indicator bacteria tests at the shoreline and nearshore sampling points nearest the LA County Joint Water Pollution Control Plant outfall (inset magnified to show definition)

The survey made similar visual observations of black particles and floatable objects at the Hyperion and Orange County outfalls. In addition, extremely high levels of fecal indicator bacteria were found in sediments both around the offshore outfalls and inshore near beaches.

From the mid 1950s to early 1970s, pressure from the public, health departments, and the regional water boards led the four largest wastewater treatment plants in southern California to relocate their outfalls farther from shore (Figure 12). Newer outfalls were located in deeper water with improved designs that provided much higher dilution rates. Three of the four treatment plants also upgraded to full secondary treatment, and three began disinfecting their effluent to reduce pathogens by 2012. Timing and implementation of these changes varied among plants owing to the volume of discharge, site-specific oceanographic conditions, prevailing currents, fiscal constraints, and individual regulatory decisions.

Outfall relocation, upgrades to secondary treatment, and disinfection collectively brought about a tremendous improvement in beach water quality. Relocation of LA County's main outfall on the Palos Verdes peninsula, for example, led to an immediate drop in fecal indicator bacteria levels at the beach monitoring site nearest the discharge. More than 60% of all samples tested positive prior to the relocation, in contrast with 15% afterward (Figure 13). A second offshore outfall was added and discharges to shallower outfalls ceased by 1966. Further reductions in shoreline fecal indicator bacteria levels occurred with wastewater treatment improvements at the plant, including more extensive secondary treatment. Moreover, sewage materials have not been observed in the water around the outfall since the early 1990s (Figure 14).

Runoff-Associated Problems Remain, but Are Improving

In the 1990s, concern over beach pollutant sources shifted from POTWs to runoff, particularly flowing storm drains. Two southern California studies helped galvanize an increased regulatory focus on runoff within the state. First, a 1995 epidemiology study examined adverse health effects in swimmers

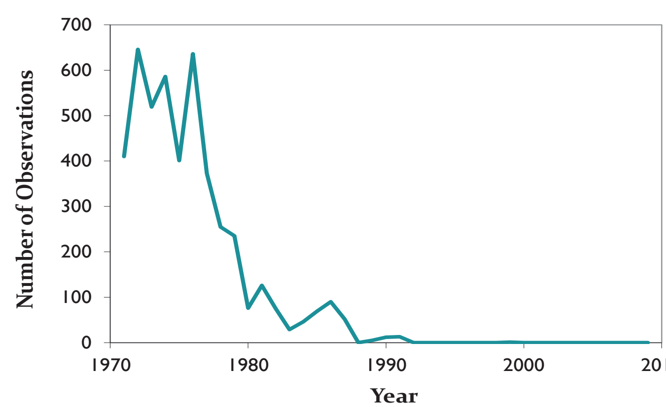

Figure 14. Observations of sewage materials on the ocean's surface near the LA County outfall

in Santa Monica Bay, and found those swimming near a flowing storm drain were 50% more likely to get sick than swimmers 400 yards away. Second, a 1998 regional-scale beach water quality survey was conducted in collaboration with city and county public health agencies, POTWs, and runoff management agencies. More than 1,000 samples were collected, and the results indicated 95% of beaches met water quality standards. Beaches not meeting water quality standards were almost exclusively near flowing storm drains.

In response to this growing awareness, the state, cities, and counties began taking measures to address runoff sources of bacteria. Since 2001, California's Clean Beaches Initiative Grant Program has provided nearly $100 million from voter-approved bonds for beach water quality improvement projects, to be used in combination with funding from local municipalities. One of the more effective and widely used best management practices for runoff has been diverting storm drain flows to the sanitary sewer system during dry weather so that runoff is ultimately treated before it reaches the ocean (Figure 15).

This increased investment in managing runoff has resulted in further improvements in beach water quality throughout the region. Heal the Bay, a local environmental advocacy organization, provides annual letter grades of southern California beaches based on water quality monitoring data. Since the Clean Beaches Initiative started in 2001, the number of beaches with poor grades (D or F) during the summer (AB 411) period has dropped from 12% to 5%, and now nearly 95% of all beaches in southern California receive annual grades of A or B (Figure 16).

Rapid Test Methods for Beach Water Quality

Most beach water contamination episodes last less than one day; however, the laboratory methods currently used for measuring fecal indicator bacteria levels require at least a day for bacterial growth. As a result, contaminated beaches may remain open while samples are being processed or closed after the return of safe conditions. New molecular-based technologies that detect genetic material would reduce sample-processing time to just a few hours. This would make it easier to monitor rapidly changing water quality conditions and help to track fecal bacteria contamination back to its source. Rapid methods are currently being used on a trial basis in southern California to inform warning and closure decisions at high-risk beaches.

Future Challenges

Despite the clear and dramatic improvements in bathing water quality over the past four decades, some seemingly intractable challenges, like wet weather runoff and aging infrastructure, remain. Others issues currently being tackled, like improving the speed of beach water quality monitoring tests and their specificity to human diseases, require further research and management program development.

One primary remaining issue is wet weather. Unlike dry weather runoff, the immense volume of runoff from a typical intense southern California rain event is virtually impossible to capture and treat on its

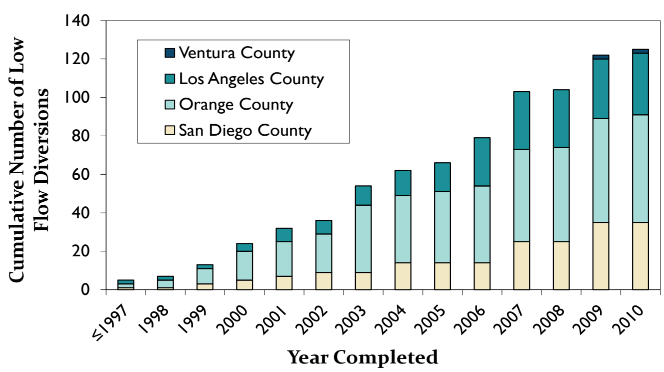

Figure 15. Projects to divert dry-weather runoff to sewage treatment plants implemented in the four coastal southern California counties from 1997 to 2010

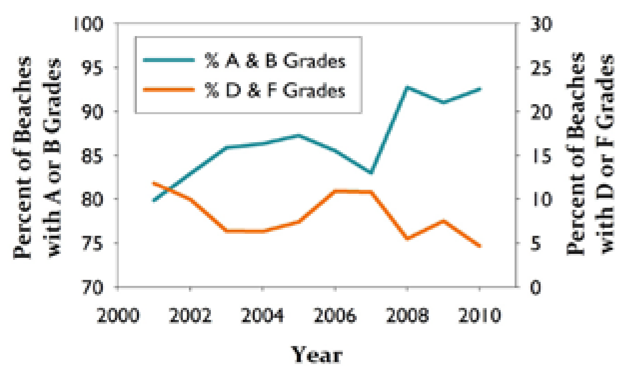

Figure 16. Percent of southern California beaches given A/B grades or D/F grades by Heal the Bay during the summer (AB 411) period between 2001 and 2010

The CWA's International Influence

While the CWA impacted waters across the nation, its influence also spread farther, in part because watersheds do not respect political borders. One local case is the Tijuana River, which has almost three-quarters of its watershed in Mexico yet discharges to the ocean just north of the US-Mexico international border near Imperial Beach. Contamination of the river with sewage, trash, and other pollutants has gradually worsened since the 1930s as Tijuana's population and industrial sector has grown. In 1990 the US and Mexico agreed to build an International Wastewater Treatment Plant just north of the border, which has treated diverted flow since 1999 and has partially resolved contamination issues. To address ongoing pollutant impairments, the San Diego Regional Water Board convened the Tijuana River Valley Recovery Team in 2008. The Team has developed a strategy for long-term recovery and protection, with the goals of enhancing partnerships, fostering natural hydrologic connectivity, and coordinating recreation and education activities with trash and sediment management efforts.

way to the ocean. Knowing that water quality is poor during these periods, public health officials warn against water contact at all beaches for three days following rainstorms.

Aging infrastructure is another remaining area of concern. Thousands of miles of sanitary sewer pipe have been installed in the urban regions of southern California, many in the 1920s, 1950s, and 1960s, but only a small fraction of the pipe network has been rehabilitated or replaced over the last several decades (Figure 17). Better reporting and emergency response measures have decreased the dangers of sewage spills over the last several years, but the age of pipe networks and other sewage treatment infrastructure poses an ongoing risk of accidental beach contamination.

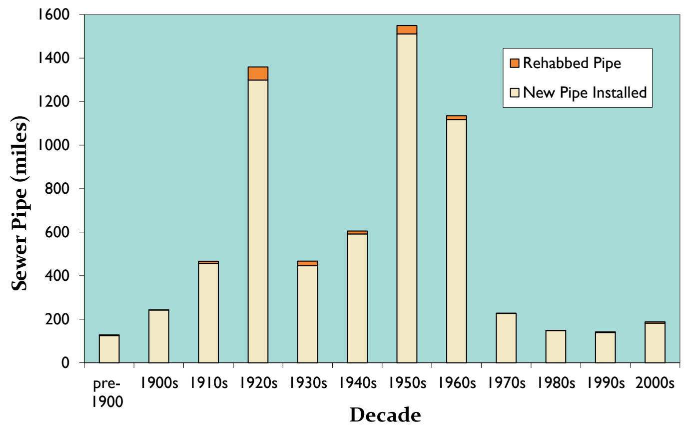

Figure 17. Miles of new and rehabbed sewer pipe in the City of Los Angeles over the past century

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IS IT SAFE TO EAT FISH?

Some pollutants common to southern California are known to bioaccumulate in aquatic organisms. Bioaccumulation occurs when an organism absorbs a contaminant faster than it can be expelled from the body, causing the substance to build up within its tissues. As predators feed, accumulated contaminants in the prey are then passed up the food chain. When humans eat seafood, especially fish that are larger, older, or higher on the food chain, they may also be ingesting harmful chemicals that have been concentrated many times greater than the amount measured in water (Figure 18). Eating contaminated seafood is especially a concern for children and women who are pregnant or breastfeeding, as the contaminants can be passed from mother to child. Top predatory wildlife such as marine mammals and birds are similarly at high risk of exposure.

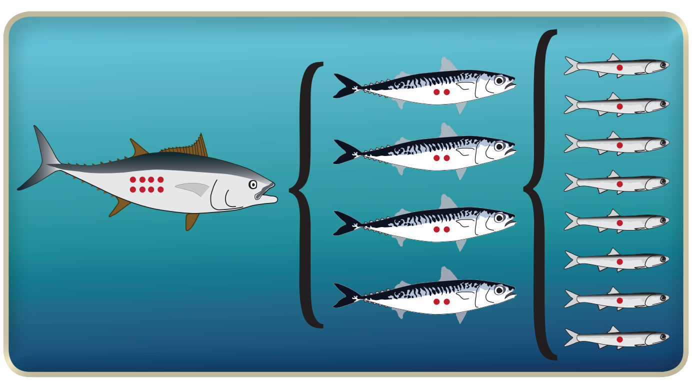


Figure 18. Simplified illustration of increase in contaminant concentrations (symbolized by red dots) with transfer up the food chain (diagram courtesy Valerie Raco-Rands, SCCWRP)

Mercury, DDT, and PCBs are the primary contaminants of concern that bioaccumulate in seafood from the southern California coastal ocean. Mercury, a heavy metal, can impair neurological development and is especially dangerous to young children. Public attention was first roused by extensive mercury poisoning near Minamata Bay, Japan during the 1960s, when over 2,000 people were sickened or died after eating seafood contaminated by industrial waste discharges. DDT and PCBs have a range of potential toxic effects on wildlife and humans. Concerns about DDT are particularly focused on reproductive effects in marine birds near the Palos Verdes shelf, where DDT was historically discharged from a large production facility in Torrance. PCBs were widely used in manufacturing from the 1930s until 1978, when many applications were banned.

One goal of the CWA is to ensure all waterways are "fishable". This goal deals mainly with the effects of seafood contamination. Other issues, such as overfishing, invasive species, or accumulation of algal toxins in fish or shellfish, may also affect the availability of safe seafood and are addressed by other public health, wildlife, and food safety laws. This chapter discusses the safety of seafood consumption related to bioaccumulation of chemical contaminants targeted by the CWA.

Fish Tissue Contamination Has Been Reduced with Declining Pollutant Inputs

A precipitous drop in DDT and PCB concentrations in fish tissue occurred in the 1970s and early 1980s after these compounds were banned and discharges to the environment were reduced. Long-term monitoring data for kelp bass near the Los Angeles County POTW outfall, where sediments were highly contaminated by DDT and PCBs around the time the CWA was enacted, illustrate this decline (Figure 19). Owing to the persistence of DDT and PCBs in the environment, fish tissue levels did not respond right away to changes in input levels, and the contaminants remain detectable to this day.

Other fish species and areas monitored around southern California POTW outfalls reflect a similar trend. Although different fish species have been collected by each of the four large POTW dischargers over different time periods with different tissue sampling and processing methods, the compiled data corroborate subtly decreasing DDT and PCB levels since the 1980s (Figure 20). One exception to the trend in DDT and PCBs is white croaker (a bottom-dwelling fish with a limited feeding range) sampled around the LA County outfall where legacy contamination exists. Contaminant levels in white croaker continue to exceed the no-consumption thresholds for DDT and PCBs established by the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA).

Another type of seafood, mussels, feeds by filtering large amounts of seawater and tends to bioaccumulate contaminants attached to suspended particles. As a result, mussels serve as good sentinels of water contaminant concentrations. Like fish monitoring data, long-term mussel monitoring data exhibit a reduction in DDT and PCB levels. The National Oceanic and Atmospheric Administration's Mussel Watch program shows that DDT and PCB levels were highest in San Pedro Bay (near the known hotspot for past discharge on the Palos Verdes Shelf)

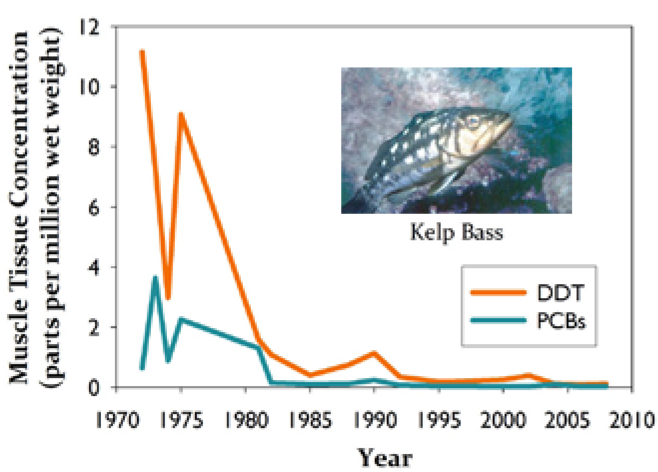


Figure 19. Reduction in DDT and PCB levels in kelp bass since the 1970s around the Los Angeles County Sanitation District's outfall on the Palos Verdes Shelf (photo courtesy Alex Steele, Sanitation districts of Los Angeles County)

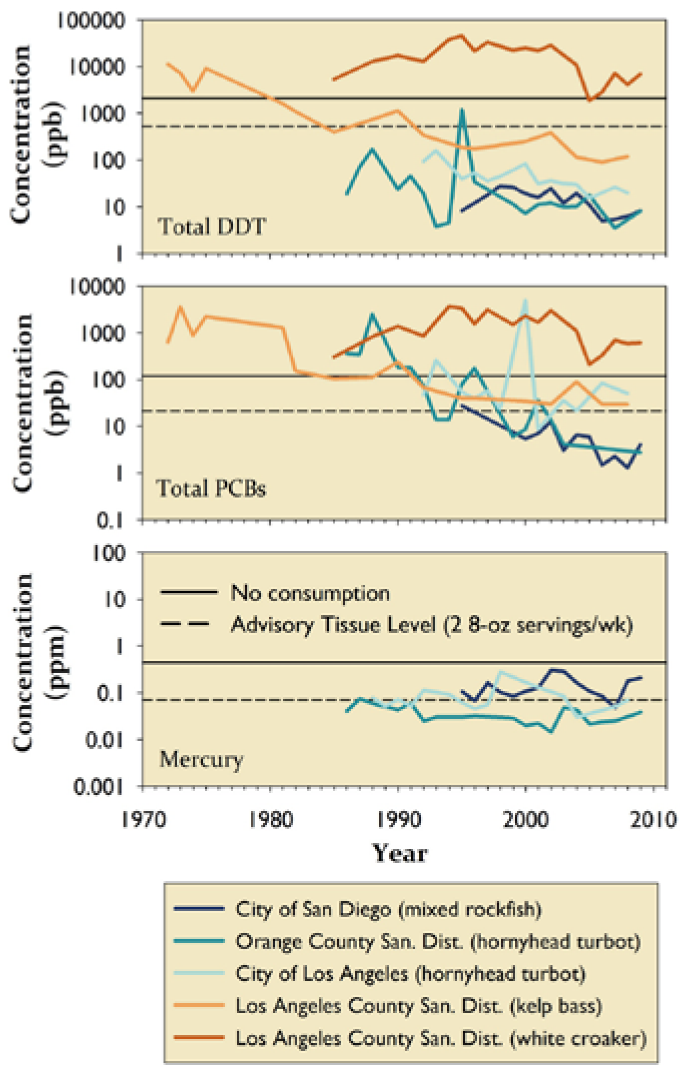


Figure 20. DDT, PCB, and mercury levels in selected fish species collected near POTW outfalls between 1970 and 2010, with reference lines showing the current advisory tissue levels for no consumption and two servings per week

in the 1970s, but have declined substantially since the 1980s (Figure 21). DDT and PCB concentrations in mussels from the Oceanside and La Jolla areas show moderate declines but have always been much lower than the levels in San Pedro Bay.

Recent data on tissue levels in kelp bass from the 2008 Southern California Bight Regional Monitoring Program show DDT and PCB levels on a much lower scale than that seen in the 1970s (Figure 22). DDT levels are now below consumption advisory thresholds across all monitored sites, though the most contamination is still found in the Palos Verdes area, where historical DDT deposits remain in the sediment. PCB levels are below state tissue advisory thresholds at all but a few of the sites monitored. The highest level was found in southern San Diego County (north of Tijuana), while northern Orange County also showed moderate PCB contamination.

Current Concerns Stem from Widespread Moderate Mercury Contamination

With lowered levels of DDT and PCBs, more attention is now focused on mercury contamination in fish. As the outfall monitoring data in Figure 20 showed, mercury levels in tissue have not gone down. Most fish sampled since the mid-1980s have been moderately contaminated with mercury, though at tissue concentrations below OEHHA's no-consumption threshold. The most recent fish bioaccumulation survey (Figure 22) also shows moderate mercury contamination in kelp bass at all sites throughout southern California. Levels are well below the no-consumption threshold but remain in excess of the two servings per week advisory level.

Large Sections of the Coast Still Have Fish Advisories

The CWA goal of fishable waters has not been entirely met, since fish advisories remain in effect for much of the southern California coastal ocean. Most of these stem from mercury contamination. In a few cases, fish warnings are related to other chemicals, such as PCBs and DDT. For example, the California Department of Fish and Game has closed the white croaker commercial fishery along the most

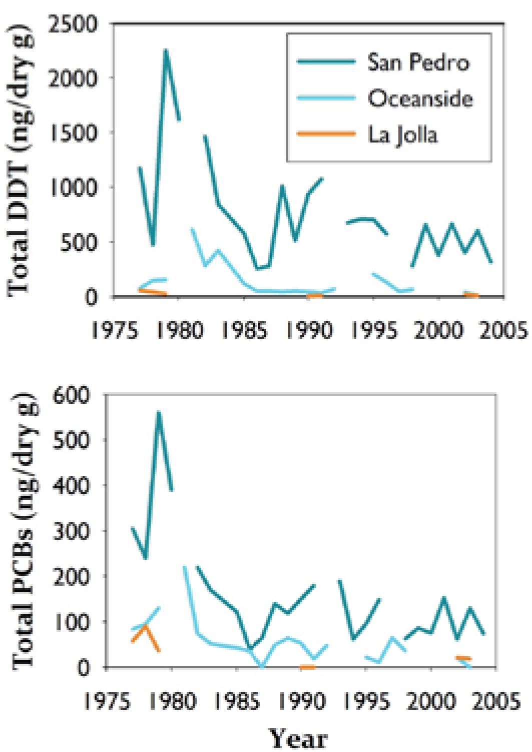


Figure 21. DDT (top) and PCBs (bottom) levels in mussels from 1977 to 2004 at long-term monitoring sites in San Pedro, Oceanside, and La Jolla

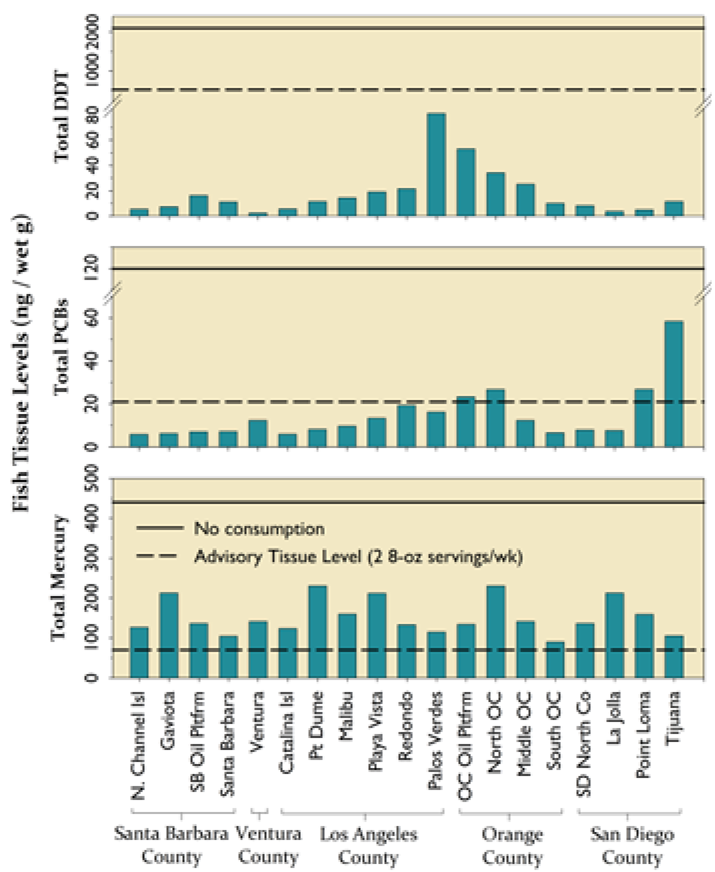


Figure 22. DDT, PCB, and mercury levels in kelp bass at 19 southern California locations in 2008, compared to OEHHA advisory tissue levels for no consumption and two servings per week

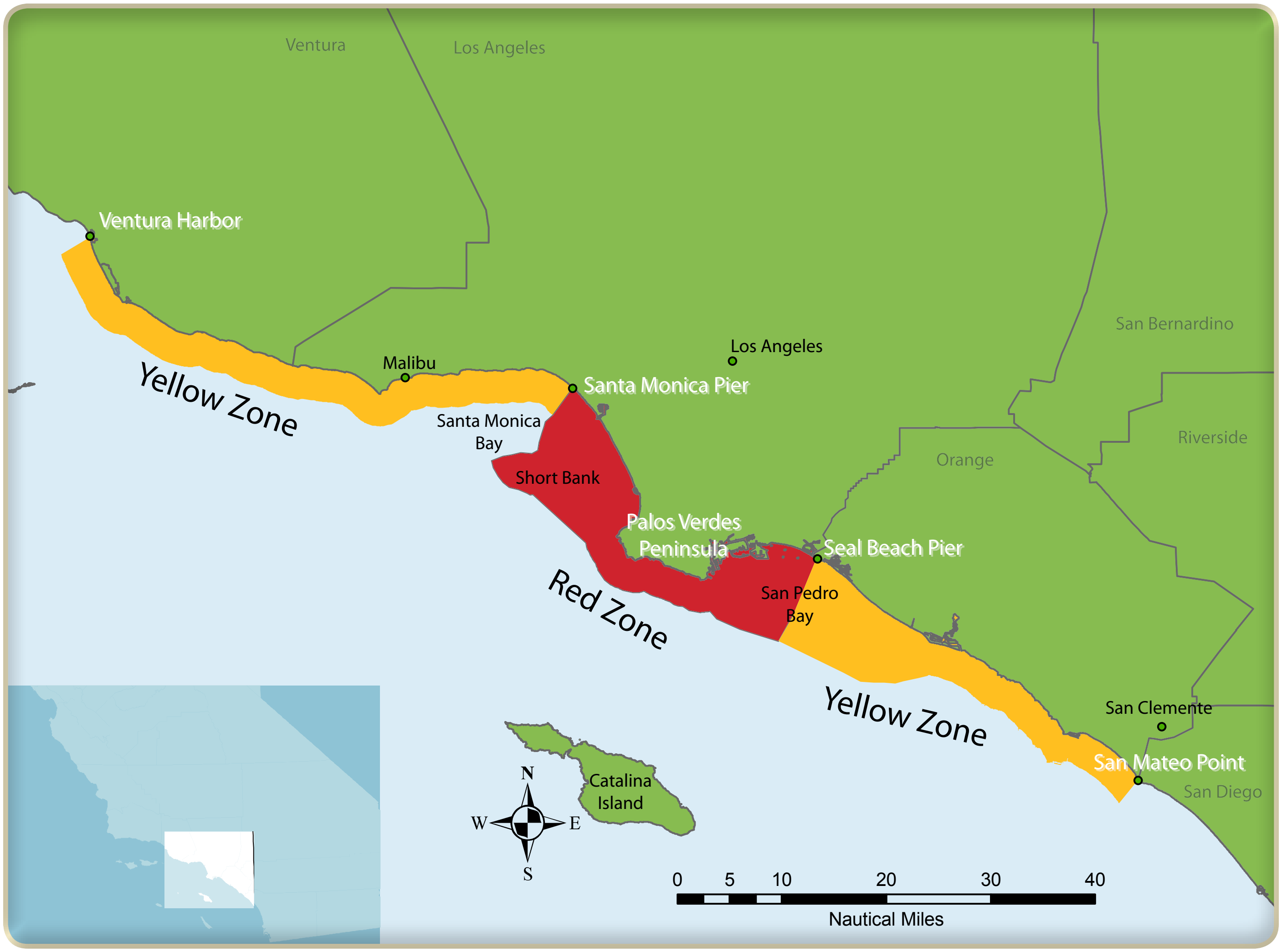


Figure 23. Fish consumption advisories extend across moderately contaminated yellow zones and a more highly contaminated red zone (map courtesy OEHHA)

contaminated area offshore Palos Verdes. Levels of chlordane, dieldrin, selenium, and toxaphene continue to be monitored but rarely reach high enough levels in fish tissue to pose a significant human health risk.

OEHHA has issued different consumption guidelines for a more contaminated "red zone," extending from Santa Monica Pier to Seal Beach Pier, and two less contaminated "yellow zones" that extend from Ventura Harbor to Santa Monica Pier and from Seal Beach Pier to San Mateo Point (Figure 23). Some fish species (e.g., top predators) from these areas contain higher levels of contaminants, while other species contain lower levels and can be eaten frequently as part of a healthy diet. Accompanying charts detail recommended consumption limits for commonly caught fish species in each zone for two types of consumers (based on age and gender).

Meanwhile, a simplified warning sign posted at several southern California pier locations recommends avoiding the five fish species with the highest contamination levels (Figure 24).

OEHHA and other agencies also offer general strategies for reducing exposure to contaminants in seafood. For example, because DDT and PCBs often concentrate in fatty tissue, these contaminants can be partially removed by cleaning and cooking fish in ways that remove fat, including removing the skin. Mercury, in contrast, binds tightly to proteins in all tissue and cannot be removed from fish by any known preparation method. Fishermen and their families are advised to eat only fillets with the skin removed, to eat smaller fish that have had fewer years to bioaccumulate contaminants, and to eat a variety of different fish species from different locations.

Future Challenges

At least two challenges lie ahead for seafood safety assessments. The first will be to address mercury contamination. Unlike other areas of the country that have chronic mercury inputs, such as coal-fired power plants on the US East Coast or legacy contamination from gold mining in San Francisco Bay, known local mercury inputs into southern California's coastal ocean continue to be small. Some mercury inputs may be attributable to global-scale atmospheric distribution of mercury or upwelling of deep ocean waters. At present, reducing levels in the environment seems to be a difficult task owing to the diffuse and widespread nature of mercury sources.

In addition, despite developing a better understanding of contaminants and seafood safety issues over the last four decades, monitoring activities to determine whether fish and shellfish in southern California coastal ocean waters are safe to eat remains fragmented and uncoordinated. Monitoring activities by discharging agencies, public health agencies, and researchers across the region should be consistent, comparable, and integrated, with mechanisms for follow-up where appropriate. Preparation of periodic reports on the suitability of fish and shellfish for human consumption would provide both a useful public service and a driving force for improving "fishability." A recent sport fish bioaccumulation synthesis report from California's Surface Water Ambient Monitoring Program, which collated data from the 2008 Southern California Bight Regional Monitoring Program and other California studies, represented a positive step in this direction.

Figure 24. Simplified warning sign posted at piers from Santa Monica to Seal Beach (image courtesy Fish Contamination Education Collaborative)

IS THE ECOSYSTEM PROTECTED?

The southern California coastal ocean is a complex and dynamic ecosystem with tremendous biological diversity (Figure 25). It hosts many marine fish, invertebrate, mammal, and bird species. One primary goal of the CWA is to restore and maintain the physical, chemical, and biological integrity of the nation's waterways, including the unique coastal ocean ecosystem of southern California.

The inherent diversity and variability in southern California's coastal ocean makes determination of "natural" biological conditions difficult. Two different habitats, sometimes just a short distance apart, can have very different biological communities because of natural differences in factors such as water depth, temperature, or sea floor composition. Natural factors such as currents, waves, and climate cycles also affect biological communities. For example, the El Niño-Southern Oscillation produces alternating periods of warm and cool currents; El Niño periods bring warm water species from the south, which are replaced with cool water species during La Niña periods. Efforts to assess

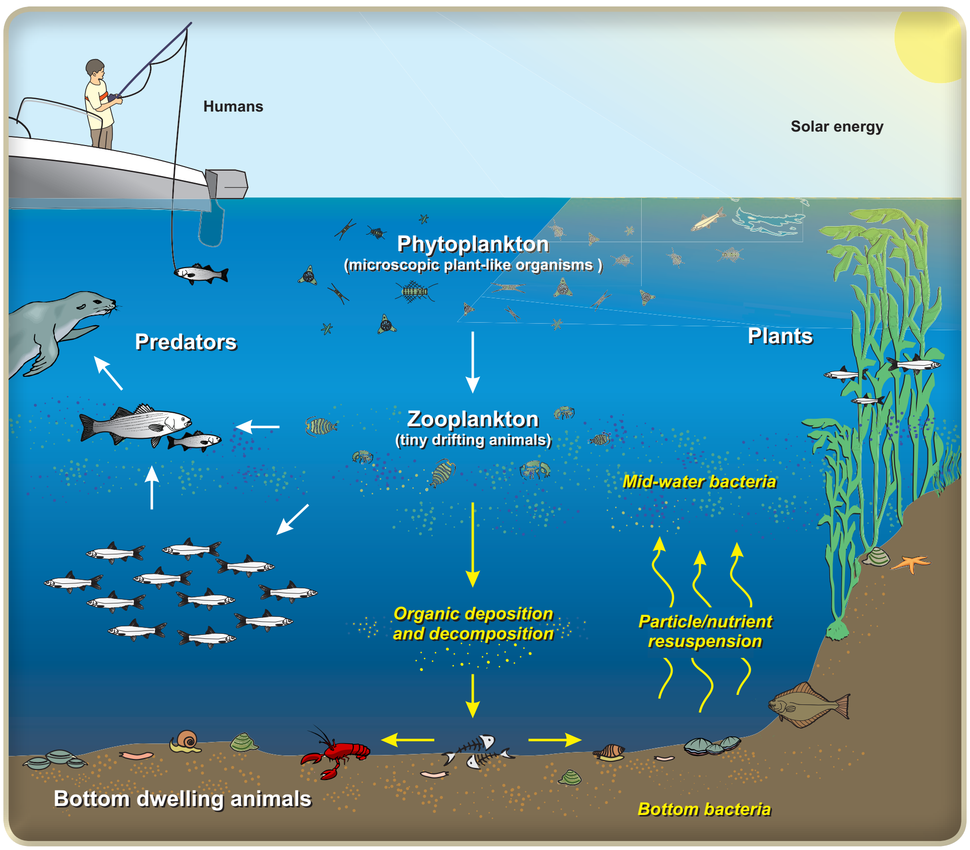


Figure 25. Simplified representation of southern California's coastal marine ecosystem, which is influenced by complex biogeochemical cycles, energy flow, and food web dynamics (diagram courtesy Dionne Kardos, Orange County Sanitation District)

changes in biological integrity and compare these changes to human activities and natural cycles rely on monitoring data that capture long-term environmental variability.

Biological Communities Have Improved Substantially in Some Cases

Marine Invertebrates

Benthic, or bottom-dwelling, invertebrates are useful indicators of ecosystem integrity for several reasons. These organisms are an important part of the food chain for fish and other marine life. They also live in or on sediments where many pollutants accumulate. With a limited range of movement, benthic invertebrates are unable to escape environmental stressors in their immediate vicinity and closely reflect site-specific conditions.

Prior to the enactment of the CWA, pollution-impacted benthic invertebrate communities were found near many POTW outfalls. Certain pollution-sensitive species such as brittle stars, though abundant across much of the southern California coastal ocean, were rarely found near POTW outfalls.

Long-term monitoring around POTW outfalls in southern California has found significant improvements in invertebrate biological integrity since that time (Figure 26). Benthic stations located nearest the four largest POTW discharge sites shifted from extreme impacts ("defaunation" or severe reductions in the numbers and types of living organisms) in the 1970s to moderate impacts throughout the 1980s and 1990s. In recent years, most monitoring sites fall within natural or near-natural "reference" conditions.

Indices Help Summarize Complex Biological Community Information

Benthic invertebrate communities usually consist of a complex mix of species such as clams, crabs, or worms. This mix provides valuable information about environmental quality in a particular location. A site might contain more or fewer individuals and more or fewer species. In addition, certain species are known to be more or less tolerant of pollution and other stressors. "Indices of biological integrity" have been developed to characterize complex species assemblages using a single, easily understood score. In addition, threshold levels have been developed to compare a score from a specific site to known gradients of natural or disturbed conditions. The Benthic Response Index (BRI) is one index developed for and widely used in the southern California coastal ocean.

Contrast: Open Ocean and Embayments

The changes discussed in this document were limited to open coastal areas. Conditions in enclosed embayments like harbors, ports, marinas, and estuaries are often different, and in many cases less favorable (Figure 27). This is because embayment areas tend to experience more direct pollutant inputs (e.g., shipping and boating, shore-based facilities, pollutants from runoff) combined with less water circulation and flushing. California is in the process of adopting Sediment Quality Objectives for bays and estuaries to better monitor, track progress, and improve sediment and ecosystem quality in enclosed coastal habitats.

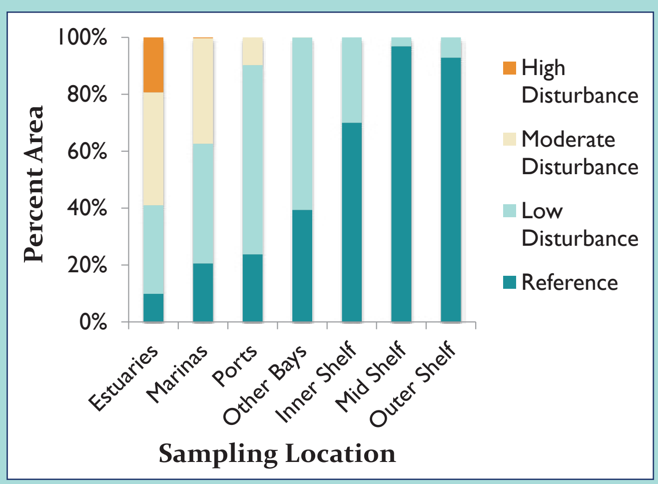


Figure 27. Benthic community condition classifications for coastal ocean (continental shelf) and embayment areas from the 2008 Southern California Bight Regional Monitoring Program

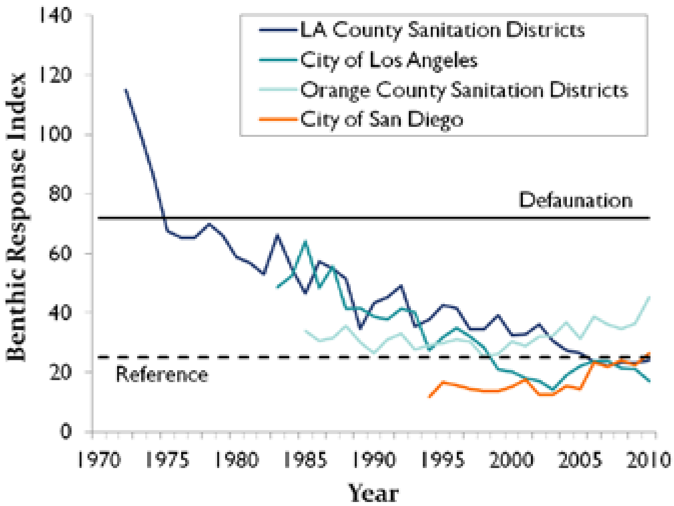


Figure 26. BRI values over time at stations adjacent to the four largest POTW outfalls with "defaunation" and "reference" condition thresholds, where lower values indicate better community health

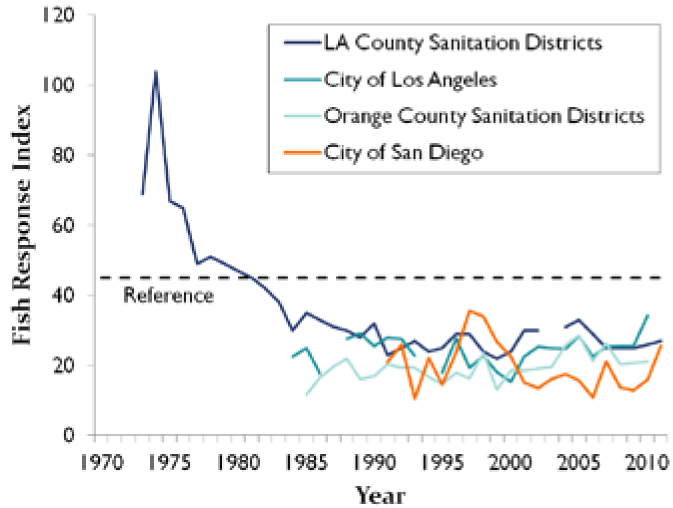


Figure 28. FRI values over time at stations adjacent to the four largest POTW outfalls, with "reference" condition threshold, where lower values indicate better community condition

Fish Community Integrity and Fish Disease

The positive response to pollution reduction demonstrated by invertebrate communities is also reflected higher up the food chain in measurements of fish community integrity (Figure 28). Like the BRI for invertebrates, the Fish Response Index (FRI) is another ecosystem health tool developed to describe southern California's coastal marine fish communities. The FRI translates complex fish community species diversity, pollution tolerance, and abundance data into a single score, which can be compared to the expected background or "reference" threshold value for the region. FRI scores were high during the 1970s in the vicinity of the LA County Sanitation Districts' POTW outfall, indicating pollution impacts, but have fallen over time. Scores at all sites have been within the natural reference range from the mid-1980s to the present.

Figure 29. Specimens of Dover sole collected in the 1970s, including (A) a normal fish, (B) a fish with a large tumor on its abdomen, and (C) a fish showing evidence of fin erosion (fin rot) (photo courtesy SCCWRP)

In addition to community-level improvements, deleterious health effects in individual fish have declined as high pollutant levels in the years leading up to enactment of the CWA have dropped. For example, fish diseases and physical deformities, such as tumors and fin rot, were commonly observed during fish collection surveys in the 1970s and 1980s (Figure 29). Fin rot refers to erosion of the edges of fish fins due to contact with contaminated sediments. With reduced pollutant inputs and the corresponding decline in sediment contamination levels, the frequency of such physical deformities in

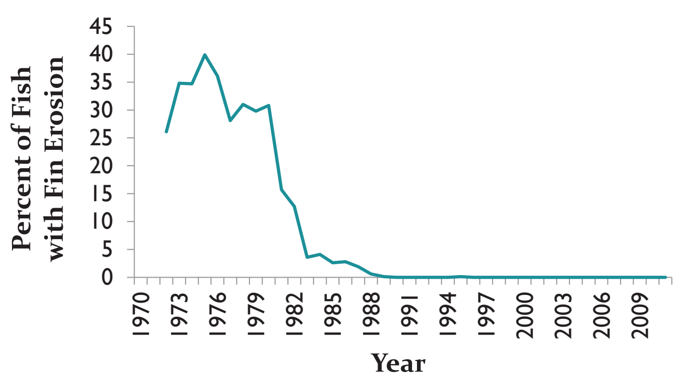


Figure 30. Reductions in the percent of fish with fin erosion collected near the Los Angeles County Sanitation District outfall over the last 40 years

southern California coastal ocean fishes has been dramatically reduced (Figure 30). None of the fish sampled in the last decade have been affected by fin rot.

Marine Birds

In the years leading up to the CWA, one of the most apparent impacts of chemical pollution in southern California coastal ocean waters was decimation of the brown pelican population as a result of DDT-induced eggshell thinning. This phenomenon also affected other birds such as bald eagles. With the banning of domestic DDT use and subsequent drop in DDT emission levels, the California brown pelican population has slowly recovered and it was removed from the Endangered Species List in 2009 (Figure 31). To assist recovery of the bald eagle population, transplantation of bald eagles and fertile eggs to Catalina Island and the northern Channel Islands began in 1980 and 2002, respectively. Even so, it took about three decades after DDT emission levels declined for the first eggs to hatch naturally.

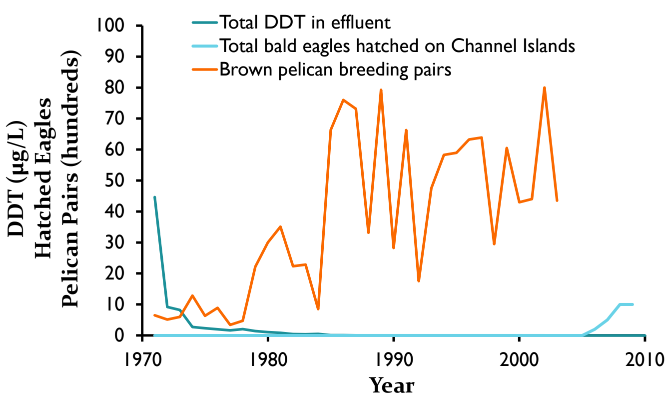


Figure 31. DDT concentrations in effluent from the LA County POTW outfall compared to the number of nesting pairs of brown pelicans and naturally hatched bald eagles on the Channel Islands

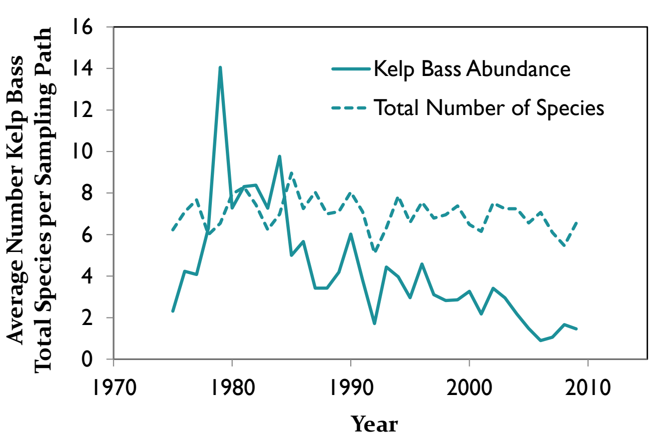


Figure 32. Abundance of kelp bass and the total number of fish species on the Palos Verdes Shelf

Ecosystem Health Is Influenced by Water Quality and Other Factors

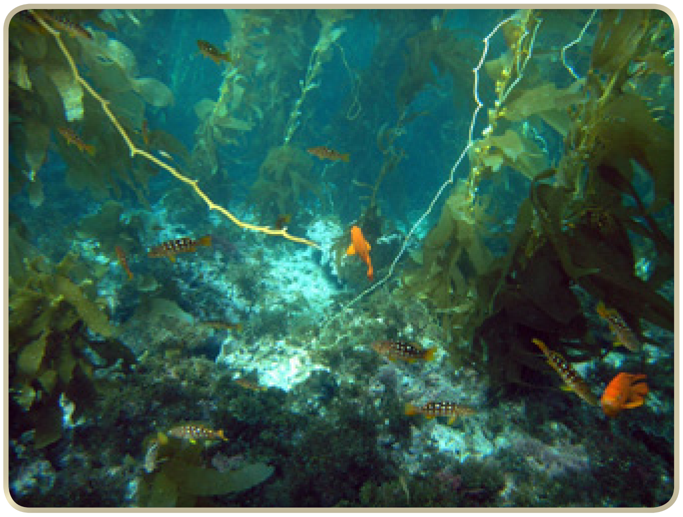
Fish Populations

Fish populations are another important indicator of ecosystem health. The effect of water quality on fish populations can be difficult to determine because many natural and human factors can affect fish populations. One obvious factor is fishing pressure. For example, decreases in the abundance of kelp bass (a popular sport fish) off Palos Verdes since 1975 appear to stem from fishing pressure, since the number of fish species in the same area has remained fairly stable over time (Figure 32). If the decreased abundance of kelp bass was caused by poor water quality, a corresponding reduction in species diversity would be expected.

Rocky Reefs and Giant Kelp Forests

Giant kelp, an iconic feature of the southern California coastal ocean, grow in cool water on rocky surfaces at depths of 20-120 feet along large stretches of the southern California coastline, including the Channel Islands. They provide refuge and food for many fish and invertebrates. Giant kelp have also been harvested for human uses such as production of fertilizer and food thickeners. Rocky reefs (especially those with giant kelp forests) are frequently visited for commercial fishing, sport fishing, and recreational scuba diving.

Reductions in the extent of giant kelp forests can result from a number of human and natural factors (Figure 33). Natural factors include warm water temperature associated with oceanographic conditions (e.g., El Niño-Southern Oscillation), major storms that rip kelp from their roots, and grazing (especially from large numbers of sea urchins). Human factors include warm water discharges from coastal power generating stations and toxic contaminants discharged through POTW or industrial facility outfalls. Finally, turbid plumes of treated wastewater, runoff, or other coastal discharges can block sunlight necessary for growth,



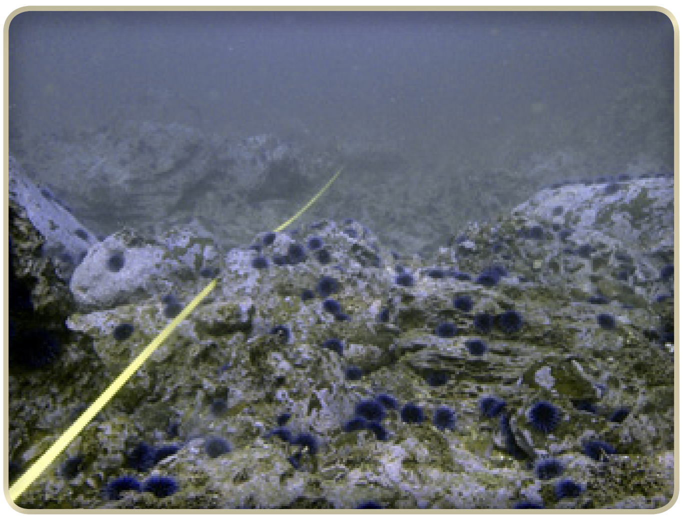


Figure 33. A rocky reef with an intact giant kelp forest (top) and a reef where purple sea urchins have destructively grazed, forming an "urchin barren" (bottom) (photos courtesy Jonathan Williams and Dan Pondella, Occidental College)

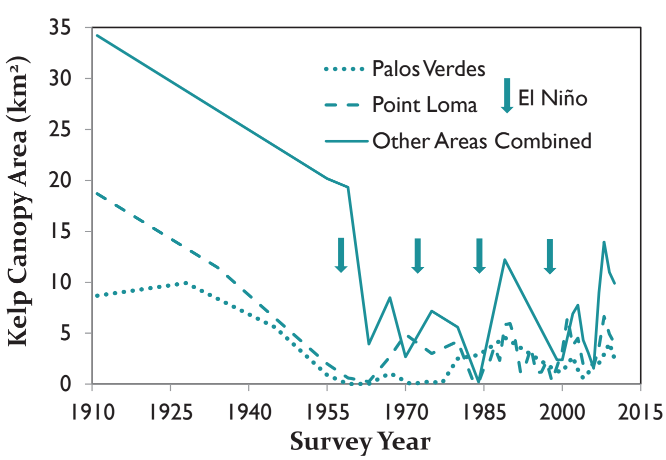


Figure 34. Kelp canopy area in Palos Verdes, Point Loma, and other southern California locations combined, with El Niño periods in 1957-59, 1972-73, 1982-83, and 1997-98 marked for comparison

smother the plants, or bury the rocky surface required for kelp to attach to the sea floor.

Overall, the regional extent of giant kelp canopy in the southern California coastal ocean has declined over the last century (Figure 34). Canopy coverage was reduced at most coastal and offshore island sites by as much as 75% from the earliest 1911 survey to the 1960s. (More frequent survey data is available for recent years.) The complexity of factors at play, including a long-term warming trend and a number of El Niño events, make it difficult to tease out direct causes and effects. In some cases, though, pollution reduction has had a positive effect on giant kelp forests. For example, kelp was very severely impacted off Palos Verdes between the 1930s and 1960s, virtually disappearing by the late 1950s. Human factors known to affect giant kelp in Palos Verdes included wastewater discharge from the LA County POTW outfall and chronic turbidity resulting from erosion caused by coastal development. Giant kelp beds recovered as the outfall was moved to deeper water and treatment technology improved. The southern end of San Diego's Point Loma giant kelp forest, which experienced significant losses in the 1950s and 1960s, also recovered to a limited degree when pollution discharges were reduced.

Future Challenges

Future ecosystem management challenges will differ from those the CWA was originally designed to address. Emerging problems will require proactive collaboration, novel approaches to problem solving, technology development, and support for long-term monitoring. For example, subtle toxic effects like disruption of gene regulation or hormone production and shifts in gender ratios have potential to damage wildlife populations, but they are difficult to detect and interpret. To date, toxic effects monitoring has tended to observe distinct, visible signs of pollution impacts, such as death or failure to reproduce. New tools are needed to assess less perceptible, chronic toxic effects and to put them into context with other impacts.

Addressing global pollution from large-scale sources, in contrast to pollutant discharges from a single facility, region, or country, is another challenge. Global climate change and ocean acidification are two phenomena with great potential to disrupt southern California ecosystems. These issues stem from excessive carbon dioxide in the global atmosphere, though, and would not be easily addressed through management action limited to southern California.

Marine debris poses a third future challenge. Although different from many conventional water pollutants, debris has a similar far-reaching potential to harm marine wildlife. Debris comes from a diverse array of land- and sea-based sources. Many marine animals are physically harmed by ingestion of, or entanglement in, marine debris. Impacts to shoreline aesthetics and safety can also result in economic losses to fisheries and coastal tourism.

Much debris consists of resilient man-made materials like plastics that do not break down quickly in the environment, and tend to accumulate over time in the absence of effective source control or cleanup efforts. Historic management measures like combing beach sand or regular volunteer beach cleanups have had only limited benefits, and more comprehensive and preventative approaches are needed. In recent years, for example, several southern California municipalities have implemented technological controls or bans on certain products to keep trash from entering storm drains and the ocean.

Harmful algal blooms (HABs) represent a fourth emerging coastal ocean management issue. These events, so named because they cause adverse ecosystem impacts, may originate naturally, be triggered by anthropogenic nutrient inputs, or be influenced by a combination of factors. Release of algal toxins during blooms can induce a range of health effects in marine wildlife, ranging from disorientation to death, as well as respiratory irritation in humans. Physical effects of HABs include water discoloration, reduction in sunlight penetration, clogging, and smothering. Along the US West Coast, incidences of wildlife illnesses related to the algal toxin domoic acid seem to be on

Clean Water Programs Must Work Within a Larger Context

Reducing pollution is just one component of stewarding the region's oceans. Restoration and maintenance of healthy and productive ecosystems also requires management of stressors such as fishing and physical habitat modifications. For example, Section 316(b) of the CWA deals with aquatic wildlife entrapment (including fish eggs and juveniles) in water intake structures used to provide cooling water for facilities such as power plants. In response to ongoing stress on marine habitats and their biological diversity, California has established Marine Protected Areas (MPAs), where some or all resource harvesting activities are banned. Similarly, global climate change effects on wildlife breeding grounds and habitat ranges necessitate management through legislation and international agreements on greenhouse gas emissions.

Reducing Debris

As new pollutants and water quality issues arise, the CWA framework can be adapted and interpreted to stretch beyond the issues it was initially designed to address. For example, southern California is the first area in the nation to use the CWA to introduce regulatory controls on the trash that litters many urban waterways. The Los Angeles Regional Water Quality Control Board placed several water bodies on the 1998 CWA Section 303(d) list of impaired water bodies based on trash impairment. Total Maximum Daily Loads (TMDLs) for trash in the Los Angeles River and Ballona Creek were adopted in 2001. Cities and counties in the region have implemented a variety of trash controls (catch basin inserts, continuous deflection system units, trash nets, etc.) across about 75% of the affected area, resulting in a 65% reduction in the total mass of trash entering the Los Angeles River. The success of these projects has inspired other regions of California to engage in similar efforts, and led the State Water Resources Control Board to initiate development of a trash control policy.

the rise since the early 1990s. Collaborative research to monitor HABs in California is ongoing, with the goal of ultimately clarifying causal factors and developing predictive capabilities.

Finally, holistic ecosystem management approaches and new tools for discerning and monitoring human impacts are needed to protect the ecological integrity of southern California's coastal ocean. For example, scientists are working to develop a rocky reef condition index that, like the BRI and FRI approaches, will make it easier to standardize monitoring, understand the cause of impacts, and track trends.

WHAT WERE THE COSTS AND BENEFITS?

"Can we afford clean water? Can we afford rivers and lakes and streams and oceans which continue to make possible life on this planet? Can we afford life itself?"
- Senator Edmund Muskie, 1972

The CWA has produced obvious benefits in restoring many of the country's degraded waterways and their beneficial uses. These benefits all have some corresponding economic value. On the other hand, the many activities undertaken to support, implement, comply with, and enforce the CWA have also come with an associated economic cost. Weighing these costs and benefits is an important part of understanding the effectiveness of the CWA in southern California's coastal ocean. Unfortunately, a full economic analysis has never been conducted. This chapter lists some of the major cost and benefit considerations associated with the CWA and related events, although this remains an area ripe for future study.

Benefits Have Been Substantial

Legislative protection and restoration of the chemical, physical, and biological integrity of southern California coastal ocean waters brings added value to many ocean-related activities and services. Existing economic valuations tend to vary widely depending on the methodologies used and constraints applied to the analysis. Still, some of the available data at a national, state, and local level provide relevant estimates of the monetary benefits of clean water.

Benefit Categories

- Coastal real estate values
- Coastal industries
  - Seafood harvesting
  - Kelp harvesting
  - Transportation
  - Oil production
- Tourism and recreation
- Ecosystem services
  - Wildlife habitat
  - Aesthetic enhancement
  - Waste assimilation
  - Support for biodiversity
  - Water supply
  - Buffering of natural disasters
  - Carbon sequestration
  - Climate regulation
- Recovery of endangered species
- Potential for energy production
- Potential for medical, scientific, and technological discoveries

Across the US, ocean-dependent economic activities generated about $138 billion in 2004. California contributed the most, $22.1 billion, to this amount, of which $12 billion came from recreation and tourism alone. Statewide recreational fishing expenditures totaled $2.4 billion in 2006, and California's commercial fish landings in 2007 were valued at over $120 million. Both of these values were even higher in earlier years. A 2007 study in Long Beach, California found that improvements in beach water quality would add $924,000 to the local economy over one year, and $8.8 million over ten years. In addition, studies by the National Association of Home Builders find the single largest positive impact on home prices is proximity to a water body such as a lake, river, or ocean, which raises a typical home value by about 30%. The sum of these and other benefits represents a significant economic boon and demonstrates the importance of southern California's coastal ocean.

Costs Have Also Been Substantial

Expenditures since 1972 to achieve or maintain the many beneficial uses of the southern California coastal ocean have also been substantial. A number of new wastewater treatment facilities have been built, while others have undergone major upgrades. City and county agencies that formerly focused on flood control have created large new divisions aimed at improving stormwater quality, rather than just transporting it to the ocean. Several state agencies have been created or expanded to implement and coordinate regulatory oversight. In addition, southern California now has a large contingent of environmental advocacy and water quality research entities, which have been formed over the years in response to the enhanced public concern and regulatory focus on clean water.

To give a rough idea of costs, the US Environmental Protection Agency estimated nationwide total annual water quality control costs, which grew from about $9 billion in 1972 to nearly $39 billion in 1990, would reach $57 billion per year in 2000 (in 1986 dollars). Much of this growth stems from increasing operation and maintenance expenses rather than capital investments. Comprehensive data detailing costs have never been compiled for southern California, but Table 1 provides examples of expenditures among a variety of sectors.

Collaboration and Cost-Efficiency

Effective communication and collaboration among the many organizations that work diligently to improve and maintain water quality can help conserve resources in challenging economic times. Prevention of costly and contentious legal battles leaves more funding for allocation to environmental improvement efforts. For example, the US Environmental Protection Agency, State Water Resources Control Board, and Regional Water Quality Control Boards can allow dischargers to pass money normally put toward a fine to be dedicated to a "Supplemental Environmental Project" related to the violation. Regulated and regulatory entities are increasingly working together, along with nongovernmental interest groups and research organizations, to share new information and reach consensus on a variety of issues.

Future Challenges

The cost of infrastructure, facility operation and maintenance, monitoring efforts, and remediation activities is not expected to decrease in the future. Moreover, many of the future challenges discussed in this document will require additional investment. Several blanket issues, including aging infrastructure and decreased federal funding, exacerbate current economic challenges and will play a part in addressing future needs.

Aging Infrastructure Requires Further Investment

As wastewater collection, conveyance, and treatment infrastructure ages, the cost burden to repair, upgrade, or replace it is shifted to future generations. Many of coastal southern California's municipal wastewater collection pipes were installed during the 1950s and 1960s, whereas some pipe networks date back to the turn of the century (late 1800s to early 1900s). Likewise, large investments in POTW infrastructure were made in the 1970s and 1980s utilizing CWA grant programs. As this infrastructure grows older, a shortage of funding for

Table 1. Example water quality improvement expenditures from various sectors working in southern California

Sector	Past and Current Cost Examples
POTWs	The City of Los Angeles Bureau of Sanitation wastewater budget ranged from $110 million to $150 million per year from 1990 to 2000. The Sanitation Districts of Los Angeles County's budget for wastewater management totaled $580 million for the 2011-2012 fiscal year. The Orange County Sanitation District has invested $627 million to upgrade its facilities over the past 10 years and is planning to invest a total of $2.8 billion in infrastructure improvements over the next 20 years, in addition to an annual operating budget that exceeded $150 million in 2012. The City of San Diego Public Utilities Department's wastewater budget totaled $392 million for 2012.
Industrial Facilities	In 2000, the Montrose Chemical Corporation and others reached a $140 million settlement to help remediate DDT contamination on the Palos Verdes shelf.
Runoff Management Agencies	Ventura County Watershed Protection District Stormwater Permittees have spent $200 million since 2000. The Los Angeles County Flood Control District and its 86 partner cities spent $340 million in 2010 for stormwater planning, construction, inspections, enforcement, education and monitoring. Total annual spending at Orange County Public Works ranged from $45-95 million annually between 2000 and 2010, totaling over $800 million for the decade. The California Department of Transportation spent $69 million during the 2006-2007 fiscal year for coastal water quality compliance in southern California.
Regulators	The California State Water Resources Control Board issued $4.3 billion in grants and loans for capital projects ranging from sewage infrastructure upgrades to beach water quality improvements in southern California's five coastal counties between 1972 and 2010. The State Water Resources Control Board's internal operating budget for the southern California coastal region totaled $81 million for the 2006-2007 fiscal year.
Research Entities	The Southern California Coastal Water Research Project's combined research budget over the last four decades totaled over $100 million, topping $10 million for 2011 alone.
Nongovernmental Organizations	Heal the Bay's budget in 2009 was $5.4 million.

maintenance, repair, and replacement has become a chronic issue. The Report Card for America's Infrastructure from the American Society of Civil Engineers estimates $18 billion in funding needs for California's aging wastewater infrastructure. Nationwide, a US Environmental Protection Agency analysis of the funding gap from 2000 to 2019 puts wastewater capital investment needs at $122 billion total, or $6 billion each year (in 2001 dollars). The estimated operation and maintenance gap is even larger at $148 billion or $7 billion per year.

The Cost Burden is Shifting to State and Local Entities

Over the last four decades, federal financial support for clean water has generally declined, shifting a greater burden onto state and local entities. While the total federal budget grew, expenditures on oceans and coasts decreased by 57% from 1970 to 2006. The funding provided in connection with the CWA, in the form of grants and low-interest loans for pollution abatement by POTWs, has likewise declined. Congress spent an average of $5 billion per year from 1972-1987 on construction grants for municipalities to build wastewater treatment infrastructure. In an effort to stretch federal dollars, the Clean Water State Revolving Fund was initiated in 1987 to provide an ongoing source of low-interest loans for wastewater treatment, and more recently to assist with runoff and watershed management. Despite drops in the overall percentage of federal funds invested, this program has been successful in leveraging federal funding (plus investment returns) with state and local funding to achieve positive results. In recent years, California voters also approved several bond acts to raise money for various runoff pollution control and watershed management projects.

Runoff Programs Have Fewer Funding Resources

Runoff pollutant loads have become comparable to POTW discharge loads in southern California; however, fewer financial resources are available to meet runoff management needs. While POTWs have dedicated revenue streams through utility ratepayers, county stormwater management programs usually rely on general funds. Owing to the CWA's early focus on end-of-pipe pollutant sources, only a fraction of the amount spent on POTWs and industrial facilities has been spent to control pollutants in runoff to date. Since its initiation, the Clean Water State Revolving Fund in California has issued over $4 billion (75% of total funding) for wastewater treatment and recycling. In contrast, the fund allocated only $278 million (approximately 5%) for runoff management. In the absence of federal funding allocations like those that spurred initial progress in pollution reduction, significant local investments will be required to shift water quality improvement efforts toward addressing runoff.

PERSPECTIVES

Clearly the CWA and related efforts have had significant effects on the southern California coastal ocean. Those effects can be interpreted from a variety of perspectives, since many factors can be considered and weighed based on personal values. Because so many individuals with diverse backgrounds have been involved in affecting change in water quality management practices over the past four decades, commentary on the changes discussed in this document was solicited from selected representatives of several different sectors: policy, regulatory, wastewater treatment, runoff management, scientific research, and nongovernmental. Their reflections provide a well-rounded sense of the CWA's historical context, as well as ideas about how current knowledge can be used to inform future directions.

Perspectives provided by:

Policy – William Attwater, former Chief Counsel for the California Water Resources Control Board

Regulatory – Arthur Baggett, former Chair of the California State Water Resources Control Board

Wastewater Treatment – Jim Stahl, former Chief Engineer and General Manager for Sanitation Districts of Los Angeles County

Runoff Management – Richard Boon, Chief of the Stormwater Program at Orange County Public Works

Scientific Research – Dr. Donald Reish, Professor Emeritus at California State University, Long Beach

Nongovernmental – Linda Sheehan, Director of the Earth Law Center; Former Director of the California Coastkeeper Alliance

Policy Perspective

Bill Attwater

In 1970, California began operating under the new Porter-Cologne Water Quality Control Act, which entailed water quality planning, permitting, and funding programs. From 1970 to 1972, US Senator Edmund Muskie's staff made numerous trips to California to talk with the State Board Vice-Chair and myself about how the program was working and how our experience could translate to a federal program for the entire country. Muskie's staff drafted the CWA and should be credited as the visionaries who brought this law forward. Their main concern was crafting a law to address pollution problems in the Ohio River valley and other industrial areas in the eastern states. Pollution problems in the western states did not seem to be on the staff's radar. The end result in 1972 was enactment of the CWA (overriding President Nixon's veto).

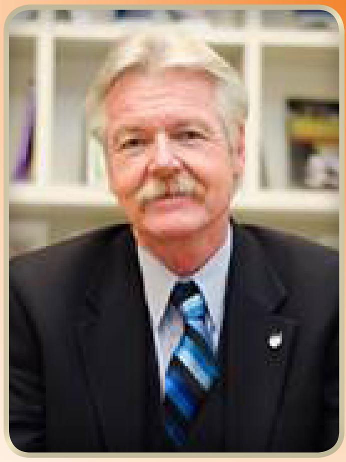
We were concerned initially that the federal CWA with its discharge permit program would either duplicate or override California's new water quality control program. Therefore, a section was inserted in the CWA allowing states with sufficient authority to implement a permit program in-lieu of the CWA permit program. Additionally, I drafted amendments to the California Water Code to provide the necessary authority. The amendments quickly passed in the legislature, and California became the first state to assume responsibility for implementation of the CWA. This meant the State Water Resources Control Board and nine Regional Water Quality Control Boards had to comply with all the relevant federal regulations set forth by the CWA.

On the plus side, federal funds poured into California for public treatment plant upgrades and for new plants. The state had its own bond-funded grant program, and when combined with the federal funds, it amounted to grants funding over 80% of the project cost in most cases.

Did all of these laws, words, meetings, hearings, decisions, and court cases result in improved water quality? I think the answer is yes, at least with respect to point source discharges. Still, Californians are left with beach closures, nets, plastic, and other trash that litters our coastline and impacts sea life. Also, because our coastal areas have major freeways, much oil, grease, brake dust, and other pollutants wash into our coastal waters. These and other remaining pollution issues mean there is plenty of work to do in the future.

William R. Attwater was Chief Counsel for the State Water Resources Control Board from 1974 to 2000. Prior to that, Attwater served as an attorney for the Department of Water Resources and Water Resources Control Board.

Regulatory Perspective



Art Baggett

We have seen dramatic improvement in water quality since the Clean Water Act was passed 40 years ago. Rivers no longer burn, and raw sewage is not discharged into our bays and estuaries. The Act required technology-based fixes to clean up wastewater plant discharges. It worked. The Act also gave regulators the ability to require implementation of effective monitoring programs, public outreach, and education.

Later, in the early years of the 21st century, the California Water Resource Control Board instituted the "Clean Beach Initiative". By using the tools available under the federal Clean Water Act and California's Porter-Cologne Water Quality Control Act, the State and Regional Water Boards worked to target enforcement activities on cleaning up the beaches of California. Bond funds, grants, and loans were structured to gain maximum pollution reduction by incentivizing projects that conserved water, were regionally based, and used integrated approaches to reduce pollutants beyond the requirements of the law. The "Erase the Waste" campaign used fines levied on polluters to help local agencies fund programs to educate citizens that maintaining clean beaches is everyone's responsibility.

In addition, the strategic use of Supplemental Environmental Projects as an alternative to dollar fines gave regulators another option to maximize water quality improvements in coastal areas. Section 303, which requires pollutant-impaired water bodies to meet the Total Maximum Daily Load for targeted pollutants, gave the Boards the power to require watershed-based implementation plans and monitoring to begin to restore these pollutant impaired water bodies to meet water quality standards. Current efforts are focusing on reducing nonpoint sources of pollution such as nutrients and pesticides that wash off our lawns and parks and travel down storm drains to end up in bays and estuaries.

New challenges lay ahead, such the emergence of pharmaceutical pollutants and impacts of a warming climate on sea level rise and more variable runoff. Still, I am confident future regulators will find the Clean Water Act to be dynamic. It will be able to adapt and change to meet whatever water quality challenges lie ahead and keep our waters fishable and swimmable for future generations of ocean visitors and aquatic species.

Art Baggett is a water rights attorney who served for 12 years on the California State Water Resources Control Board. He is a past president of the Association of State and Interstate Water Pollution Control Administrators, a former guide for the Yosemite Mountaineering School, and served two terms on the Mariposa County Board of Supervisors. He is currently a mediator with AG Baggett and PJ Weber, Inc., and also consults with Kennedy/Jenks Consultants.

Wastewater Treatment Perspective

Jim Stahl

I remember 1969 quite clearly, as the year's events profoundly impacted everyone in southern California striving for improvements in the water environment. The Porter-Cologne Act was signed into law, and on a personal level, I started my Environmental Engineering career with the Sanitation Districts of Los Angeles County. Three short years later, the Federal Clean Water Act came to be.

Today, I look back at this time period grateful to have been present for the "Big Bang" of action toward significant water quality improvements. To this day, I remain impressed by the laws' success in situating water quality and water management as a top priority in our society. From a southern California perspective, this success is manifested in the vast accompanying data and analyses that clearly show the substantial changes in the nature of POTW point source discharges and improvements to this region's marine ecology.

There is much to be proud of over the last four decades, but there are also lessons for future actions. Declines in mass discharges by POTWs have been necessarily accompanied by increases in treatment residuals, chemical and energy usage, and air emissions. All are considered during process design activities and environmental documentation, but the overall cost-benefit balance is often lost in the siloes of regulatory structure. This imperfection warrants continued corrective action. In addition, it is essential for the future to implement sustainable, adaptive systems and programs steeped in economic reality.

All would clearly wish the many improvements to the southern California coastal ocean had occurred sooner, but considering the assorted constraints and different interests involved, the timeframe was relatively short. SCCWRP is a vivid example that much more can be gained through the path of collaboration than the individual roads of separation and polarization. My experience leads me to believe firmly that closer emulation of the SCCWRP governance structure and equal consideration of all scientific and technical information in the discharger-regulator process could result in more rapid and cost-effective solutions.

The Porter-Cologne Act and Clean Water Act have surely had a positive role in bringing about water quality improvements. The ultimate winner in this process was the public, who greatly benefit from the improved water environment brought about by the combined actions of all participants in the POTW, industrial, regulatory, and NGO communities. It is my fervent hope that the passions of all involved will combine to find common ground and give rise to the cost-effective paradigm shifts needed to address future water quality challenge.

Jim Stahl worked for the Sanitation Districts of Los Angeles County for 38 years, retiring as the District's Chief Engineer and General Manager in 2007. Stahl is presently a Vice President of MWH Americas, where he advises municipal and industrial clients across the US. He also formerly served as Chairman of the Water Environment Research Foundation Board of Directors, and President of the California Association of Sanitation Agencies and Southern California Alliance of POTWs.

Runoff Management Perspective

Richard Boon

Sweeping from butchers stalls, dung, guts and blood,
Drowned puppies, stinking sprats, all drenched in mud,
Dead cats, turnip tops, come tumbling down the flood
– A Description of a City Shower, Jonathan Swift, 1710

Over the course of the Clean Water Act's anniversary milestones, commentators have generally portrayed the Act as the Nation's most successful environmental statute, based on reestablishment of recreational opportunities and wildlife to many previously contaminated water bodies. Nonetheless, observers of surface water conditions in sprawling urban areas, such as southern California, might be concerned about the ongoing resonance of Jonathan Swift's observations on urban runoff in 18th century London.

Looking back, positive achievements in reducing metal and other chemical outputs from traditional point source discharges are real and significant. There has also been significant progress in reducing bacterial contamination at southern California beaches. However, this progress is less a direct positive impact of the Act and more a consequence of broad societal recognition of a problem and the ability to implement pragmatic cost-effective solutions, such as dry weather runoff diversions and stream discharge disinfection.

In southern California, the principal threat to recreational water quality and coastal ecology continues to be dry and wet weather urban runoff, despite such discharges having been subject to regulation under the Act for the last two decades. This lack of progress in addressing urban runoff quality issues like fecal pollution, excessive fertilization, and pesticide toxicity was highlighted by the National Research Council's 2008 assessment of the national stormwater permit program. The assessment concluded the "current approach is not likely to produce an accurate picture of the extent of the problem, nor is it likely to control the contribution of stormwater to impairing water quality."

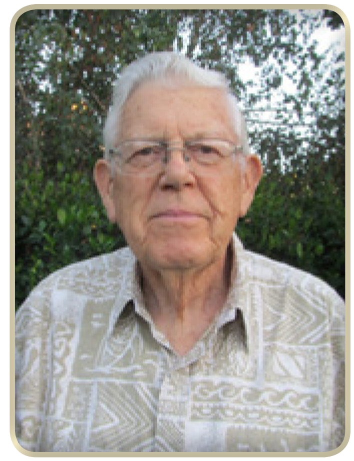
The National Research Council suggested future programs focus less on chemical pollutants and more on "stormwater flow." It also recommended accounting for the cumulative impact of multiple stressors and perhaps most significantly, providing federal financial support to state and local stormwater management efforts. Although this assessment presented a compelling case for fundamentally resetting stormwater regulations, revision of the Act and provision of new federal funding appear remote prospects at present.

In summary, coastal water quality would certainly be much worse in the absence of the Act. However, to achieve significant progress over the next 40 years, wet weather runoff must be more effectively addressed by a regulatory framework that was intended for controlling a limited number of discrete point sources rather than the myriad of pollutant sources across the urban landscape. Ensuring that the current framework effects continued progress will require a more compelling and inclusive common vision of what can be achieved; a way to address the region's major wet weather runoff infrastructure deficit; demonstration of trust, courage, and ingenuity by the region's regulators, regulated entities, and consultants; and recognition of Southern California residents' civic responsibility to ensure only clean water comes tumbling down the flood.

Richard Boon serves as Chief of the Stormwater Program with Orange County Public Works. He serves as Chair of the California Stormwater Quality Association, is a member of the Chartered Institution of Water and Environmental Management, and has worked toward surface water protection in both the United States and United Kingdom for the past 30 years.

Scientific Research Perspective

Donald Reish



Prior to the establishment of the US Environmental Protection Agency in 1970 and the Clean Water Act in 1972, prevalent thinking espoused that the ocean is large and can accommodate an indefinite amount of wastes from human activities. Furthermore, the majority of the population was uninformed and unconcerned about ocean pollution issues. Human and industrial wastes were discharged into marine waters with little or no treatment. Discharges of domestic and industrial wastes, especially in bays and harbors, frequently resulted in little or no dissolved oxygen in the overlying water. The sediment at these localities was often black, possessing a sulfide odor, and absent of benthic invertebrates.

Public officials were aware of these marine pollution problems but remained concerned about the cost of environmental improvement. In 1949, the State of California established the Water Pollution Control Board and sponsored freshwater and marine studies. Many surveys were initiated in southern California, but no appreciable environmental changes resulted.

With the advent of the Clean Water Act and its associated funding mechanisms, though, environmental conditions in southern California's marine waters began to improve. Areas in Los Angeles Harbor, which was previously devoid of dissolved oxygen, responded quickly to the elimination of industrial discharges. Fish, harbor seals, and benthic invertebrates were seen again within months following implementation of industrial pollution abatement measures. Sewage treatment plants, which discharged their wastes offshore, also began to improve their effluent quality, first via primary and then secondary treatment. These changes likewise resulted in improvement of benthic environment in the vicinity of the discharge. The benthic environment transformed from impoverished to a more diverse population. These changes paved the way for in an increase in fish diversity, which benefited marine birds, fishermen, and the environment as a whole.

Knowledge and awareness of ocean health issues also experienced a major about-face. Public hearings became commonplace to inform the public about any proposed changes in waste discharges. For example, the City of Seal Beach held a hearing regarding the proposed construction of five sewage treatment plants along the San Gabriel River, which would discharge effluents into the river and eventually the ocean. As scientists, managers, and the public gained knowledge about the marine environment and the effect of human activities, research began to delve into the causes and biological effects of metals and organic compounds on wildlife, leading to the more intricate environmental studies used to inform today's ecosystem management measures.

The Clean Water Act has not only improved the marine waters of the nation, but the Act has influenced officials in foreign countries to take notice of their own marine water conditions and make use of its measures to improve water quality in their countries.

Dr. Donald J. Reish is a professor emeritus at California State University, Long Beach. A participant in the first marine benthic studies conducted in southern California (and the US) in 1951-52, his later research was first to show the beneficial effects of pollution abatement on the marine environment (Los Angeles Harbor). Notably, Dr. Reish developed standard toxicological test procedures that were widely adopted for national and international application.

Nongovernmental Perspective

Linda Sheehan

In a familiar scenario for the times, my childhood saw local streams deadened by upstream discharges (tanneries, in my case), and doctor visits after swims in a sewage-spiked ocean. The Clean Water Act approached such gross pollution insults with large-scale responses. Its support for new sewage treatment facilities, controls on end-of-pipe discharges, and citizen suits resulted in significant pollutant reductions with associated benefits.

The Act has considerably improved the overall quality of the nation's waterways, including southern California's coastal ocean, and we have benefitted from it tremendously. However, the pace of improvements has stalled. We have addressed the "low-hanging fruit", but our waterways are still not healthy. Moreover, the Act cannot advance significant new improvements as written. We must evolve the law to meet rising challenges, while retaining what has worked to date.

At a minimum, the Act should be amended to close gaps, such as those for irrigated agricultural discharges and water diversions, which can have far-reaching impacts. For example, excessive water diversions from the Bay-Delta Estuary threaten both the Estuary as well as marine and anadromous species. While the diversions provide water to southern California communities, they do so at the cost of impacts elsewhere. Our laws should consider and avoid such broader impacts. They also should incorporate the precautionary principle to prevent further damage, and focus on achieving healthy waterways overall, rather than slowing the pace of degradation.

Such focused reforms can buy time, but more is needed in light of broad, escalating threats, such as those associated with greenhouse gas emissions, mercury bioaccumulation, and emerging contaminants. We must think past narrow reforms and take swift, comprehensive action to incorporate the environment more broadly into our governance systems. Environmental statutes alone cannot hold back the inexorable pressure of overarching legal and economic systems that financially reward environmental destruction and discourage preservation and restoration.

To start, we should step back and reexamine the assumptions that led us here. One key assumption is the Act's unquestioning acceptance of humans' role as "manager" of servile water systems. In fact, science demonstrates that we are inextricably bound up with the natural world, indicating instead a partnership relationship. We must correct this imbalance in our overarching laws to self-govern our behavior appropriately. For example, if human water diversions are permitted through water rights, then waterways similarly must be allocated rights to the (clean) water they need to flourish. For the well-being of people and planet, we must reshape our overall governance systems to recognize and respect the inherent rights of people and the natural world, including southern California's coastal ocean ecosystem, to exist, thrive and evolve.

Linda Sheehan is Executive Director of the Earth Law Center in Fremont, CA. She previously served as Director of the Pacific Region Office of the Ocean Conservancy and the California Coastkeeper Alliance. With over 20 years of environmental law and policy experience, Sheehan has successfully advocated a number of federal and state water policies and initiatives.

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