Fact Sheet

# United States Geological Survey

## San Francisco Bay Program:

## Lessons Learned for Managing Coastal Water Resources

*The USGS provides maps, reports, and information to help others meet their needs to manage, develop, and protect America's water, energy, mineral, and land resources. We help find natural resources needed to build tomorrow, and supply scientific understanding needed to help minimize or mitigate the effects of natural hazards and environmental damage caused by human activities. The results of our efforts touch the daily lives of almost every American.*

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Coastal ecosystems, such as bays and estuaries, are among our most disturbed natural environments. These ecosystems also are among our most valuable habitats—estuaries supported U.S. fisheries valued at $19 billion in 1990. Although many human activities cause change in the coastal zone, they occur against a background of natural change. Effective coastal-zone management requires that we identify and understand these separate causes of ecosystem change. With this goal in mind, the United States Geological Survey (USGS) began in 1968 a broad program of scientific study in San Francisco Bay (fig. 1). The program is based on a conviction that sustained, multifaceted investigation of one estuary will produce general lessons to guide the management of natural resources associated with all our coasts.

The USGS San Francisco Bay Program has produced more than 250 reports, including three books and a review of the human modifications of the Bay. These publications are a source of guidance to resource managers as they work to understand how human activities (such as water diversion, commercial trade, and waste inputs) cause change in the coastal zone. The program has been organized around themes. One of the most important themes is the integrated study of nutrients, toxic substances, and living resources at lower levels of the food chain—the phytoplankton and bottom dwelling invertebrates. Close collaboration between chemists and ecologists has helped to explain how plant and animal species of coastal ecosystems are organized into food chains, how nutrients and toxic contaminants are incorporated into these food chains, and how the lessons learned from detailed scientific understanding can be applied to develop effective monitoring programs and rational environmental standards.

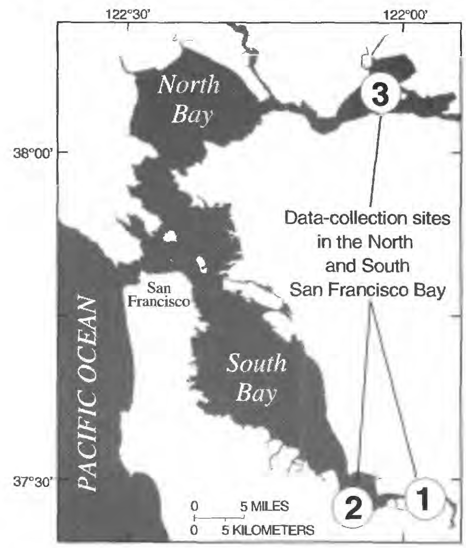


**Figure 1.** San Francisco Bay has been a focus of intensive investigation by the USGS since 1968.

## Nutrient Enrichment

Human settlement around coastal water bodies has led to increased inputs of nutrients such as nitrogen and phosphorus. Many estuaries are now among the most intensively fertilized environments on Earth. Each day, San Francisco Bay receives more than 800 million gallons of municipal wastewater containing 60 tons of nitrogen.

### *Management Questions*

Water-quality managers need to know how nutrient inputs cause changes in water quality, the natural capacity of coastal waters to assimilate added nutrients, the level of waste treatment required to protect living resources from the harmful effects of nutrient enrichment, and if programs of nutrient reduction are having beneficial effects.

### *USGS Contributions*

Since 1968, the continuous study of San Francisco Bay by the USGS has given that agency a unique opportunity to follow ecosystem responses to improved wastewater-treatment methods as mandated by State and Federal legislation. One result of the implementation of these improved methods has been a large reduction in the input of ammonia-nitrogen from some municipal wastewater-treatment facilities (fig. 2).

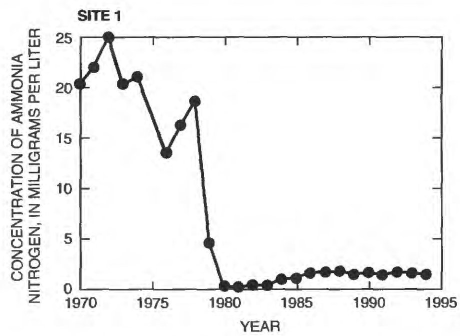


**Figure 2.** Implementation of advanced wastewater treatment in 1979 immediately reduced the input of ammonia- nitrogen to South San Francisco Bay. In prior decades, the South Bay had repeated episodes of oxygen depletion and animal die-offs. USGS measurements have shown a complete cessation of these episodes since 1980. Spawning salmon have recently been observed in South Bay streams for the first time since the early 1900's. See figure 1 for location of site.

USGS studies show that in spite of its nutrient enrichment, San Francisco Bay has not been affected by harmful algal blooms. This seeming paradox is explained partly by the abundant bottom-dwelling invertebrates (small clams, mussels, crustaceans) that filter the water and remove new algae as fast as they are produced. Feeding by these animals is a form of natural waste treatment that helps control the growth of algae in a nutrient-rich environment.

Concepts and measurement techniques from this USGS program are now incorporated into a locally funded and managed Regional Monitoring Program.

### *Lessons Learned*

- The chemical quality of coastal waters can respond almost immediately to waste-treatment improvements.
- Responses of biological communities to these chemical changes can take years or even decades.
- Coastal water bodies have differing sensitivities to waste loading. The most cost-effective national strategy for regulating nutrient inputs will consider these differences among ecosystems.

## Toxic Contaminants

Toxic contaminant inputs from industrial, agricultural, and commercial activities are a high-priority concern in the changing Bay ecosystem. San Francisco Bay receives effluents from 46 publicly owned wastewater-treatment plants, 65 large industrial discharges, and as much as 40,000 tons of at least 65 contaminants each year. Many of these contaminants are toxic to plants or animals or pose threats to human health.

### *Management Questions*

Water-quality managers expect from the scientific community reliable answers to questions about the origins of toxic substances, how toxic substances cause change in aquatic ecosystems, how these changes can be remedied, and if the $70 billion national investment in wastewater-treatment facilities is justified.

### *USGS Contributions*

Comprehensive study of toxic trace metals by the USGS has shown that contamination levels in San Francisco Bay accelerated during the 1950's. Some Bay locations are among the most highly polluted coastal sites in the United States. Contamination by silver, cadmium, lead, and selenium is especially high. These metals are of particular concern because they can impair the growth or reproduction of fish, birds, and mammals.

In response to these concerns, the USGS developed a biological monitoring procedure that has been used continuously since 1977 near a waste-treatment facility. Monitoring continued as wastewater-treatment technologies improved. This is the longest continuous record of contaminant concentrations in a natural environment of the United States (fig. 3). The transfer of monitoring procedures developed by the USGS to local agencies and businesses serves as a model of cooperation between research and regulatory agencies.

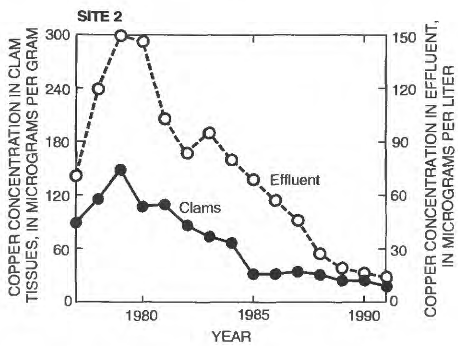


**Figure 3.** Steps of improved wastewater treatment have gradually reduced the inputs of toxic metals to San Francisco Bay. USGS monitoring has shown that these investments to remove contaminants have resulted in improvements in some indicators of biological health, such as metal concentrations in clams living near a wastewater discharge. See figure 1 for location of site.

In 1990, the USGS began a special series of investigations to describe the origins and effects of toxic contaminants in San Francisco Bay. Early results have shown that pesticides (such as diazinon) applied in the Central Valley of California are carried by rivers into the Bay at levels exceeding national guidelines. Biological tests have shown river waters to contain high levels of pesticides soon after they are applied to fields.

The multifaceted USGS program has given local managers an objective scientific basis for identifying the most critical contaminant issues, and for establishing priorities. On the basis of high-quality data from the USGS, Bay area inhabitants are now concerned with the effects of toxic contaminants rather than nutrient enrichment.

### *Lessons Learned*

- Public concern about the effects of toxic contaminants on coastal organisms is justified. Trace metals and pesticides are periodically found in San Francisco Bay at levels that can cause toxicity or impairment of ecosystem health.
- Sustained biological monitoring indicates that reduced discharge of toxic substances into coastal waters yields ecosystem benefits.
- Some ecosystem responses to reductions in contaminant loading are gradual and continue for many years after the reductions have begun. Management strategies for assessing the benefits of waste treatment need to include long-term monitoring of results once actions are taken to reduce pollution.
- The protection of coastal ecosystems requires a strategy for prioritizing pollutant concerns followed by strategies for reducing inputs on the basis of these priorities. Integrated assessments by teams of chemists and biologists are effective for identifying and prioritizing human activities that threaten the integrity of coastal ecosystems.

## Biological Contamination

One unexpected result of commerce can be the movement of plants and animals to new environments. Biological contamination by exotic species is a particular problem in coastal environments where organisms are redistributed by commercial shipping. More than 130 introduced species of plants, invertebrates, and fish live in San Francisco Bay. Many of these have displaced native species.

### *Management Questions*

As regulators search for strategies to protect living resources, they ask how habitat loss and biological contamination can change coastal ecosystems, if these disturbances permanently change fish or bird populations, how these changes compare to those caused by chemical contamination, and if current regulation of biological contamination is adequate or necessary.

### *USGS Contributions*

Continuous long-term investigation of San Francisco Bay has given the USGS a rare opportunity to measure ecosystem changes following invasion by a highly successful exotic species. The Asiatic clam, *Potamocorbula,* was introduced to the Bay in 1986, probably by a cargo ship. A cascading sequence of ecological changes followed (fig. 4), similar to

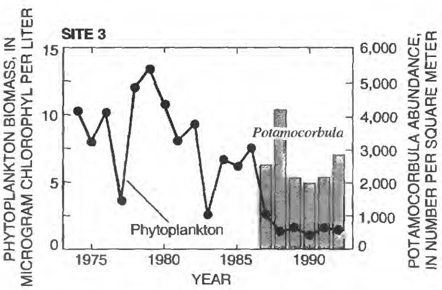


**Figure 4.** USGS studies have documented the remarkable invasion of San Francisco Bay by the Asiatic clam, *Potamocorbula.* Colonization by this filter-feeding clam has led to depletions of phytoplankton in the North Bay. Phytoplankton are a food source for small zooplankton animals that, in turn, are a critical food resource for young fish. Zooplankton abundance has dropped since the 1986 *Potamocorbula* invasion, and most fish populations also have declined in the North Bay. See figure 1 for location of site.

changes in the Great Lakes after their invasion by the zebra mussel. These fundamental ecological changes have likely contributed to the population declines of almost every fish species living in the North Bay.

### *Lessons Learned*

- The complex ecological consequences of biological contamination can be revealed only through consistent measurement programs that are sustained before and after introductions of new species.
- Biological contamination can cause ecosystem changes just as powerful as those caused by chemical contamination.
- Protection of living resources requires an ecosystem view that considers the multiple effects of all sources of human disturbance, including biological introductions.

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Additional earth science information can be found by accessing the USGS "Home Page" on the World Wide Web at "http://www.usgs.gov".

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