Red Tide in Berkeley Marina Raises Concern for Toxic Blooms in Central Bay

Brian Cole, USGS and Andy Cohen, SFEI

The development of a red tide in parts of Central San Francisco Bay during August 1997 suggests that the bay may be susceptible to the harmful algal blooms that have been reported with increasing frequency in estuarine and coastal waters throughout the world. "Red tide" generally refers to a bloom of microscopic floating organisms that may result in conditions ranging from simple discoloration of the water to the buildup of noxious (foul smelling) or toxic substances. These substances can contaminate mussels and other bivalves, kill fish and other animals, and even be toxic to humans.

Many phytoplankton, including diatoms and blue-green algae, can form noxious or toxic blooms, although red tides are usually caused by dinoflagellates. These microscopic organisms generally have been classified as plants, although recent research suggests that they would more appropriately be classified as protists (which have characteristics of both plants and animals).

Researchers have reported a dramatic worldwide increase in the incidence of red tides since the late 1960s, with such blooms occurring more frequently and in regions where they were not previously reported (Smayda 1990; Cullota 1992; Hallegraeff 1993; Milot 1997). These blooms have caused temporary closures of shellfisheries, sometimes with substantial monetary losses; illness in people who ate contaminated shellfish or, in a few cases, simply breathed the sea air; and some fatalities.

At least part of the increase in red tides is believed to be due to increased nutrient levels in estuarine and coastal waters from sewage effluent, agricultural runoff, or other anthropogenic sources; some recent red tides may have resulted from introduced exotic dinoflagellates arriving via ballast water exchanges.

In early August, Cliff Marchetti, waterfront manager for the city of Berkeley, and patrons of the Berkeley Marina noticed the presence of "reddish water" throughout the marina, located on the east shore of Central Bay. Initially, the red water appeared with high tides and disappeared during low tides, but after a few days water in the marina remained continuously discolored. Noxious odors developed and organisms that had been growing on the sides of the floats and pilings sloughed off.

These observations raised concerns about potential impacts on fish and other organisms, and on people who worked in contact with the water or were exposed to the noxious odors. Reddish water was also reported in Oakland's Outer Harbor, and boat operators reported streaks of red water in the open waters of Central Bay.

On August 22, about two weeks after red water had first been observed in the Berkeley Marina, we measured water conditions and collected water samples at the marina and at Estuary Park in Oakland's Inner Harbor. Throughout the Berkeley Marina, the water color was a deep reddish brown and the phytoplankton community was almost entirely composed of the dinoflagellate *Gymnodinium sanguineum* (=*splendens*), a species known from tropical and subtropical coastal waters around the world.

Cell densities of *G. sanguineum* were approximately 2,600 per mL at the water's surface and 140 per mL at the bottom. Similarly, chlorophyll concentrations were much higher near the surface (70 - 140 μg/L) than near the bottom (10 μg/L at 6 meters depth), possibly due to dinoflagellates swimming towards the light. An observed gradient in midday dissolved oxygen concentrations (10.6 mg/L at the surface and 5.3 mg/L at the bottom) was probably due to higher levels of photosynthesis near the surface. The salinity was 29 psu and the water temperature was 22.2°C. This high water temperature in the marina coincided with the highest water temperatures we have recorded in Central Bay in 28 years, a local result of the 1997 El Niño event. On the Peruvian coast, *G. sanguineum* blooms are associated with temperatures of 17-23°C and salinities of 35 psu (Rojas de Mendiola 1979).

We found no evidence of a red tide at Oakland's Estuary Park. Chlorophyll levels (3 - 4 μg/L) were normal

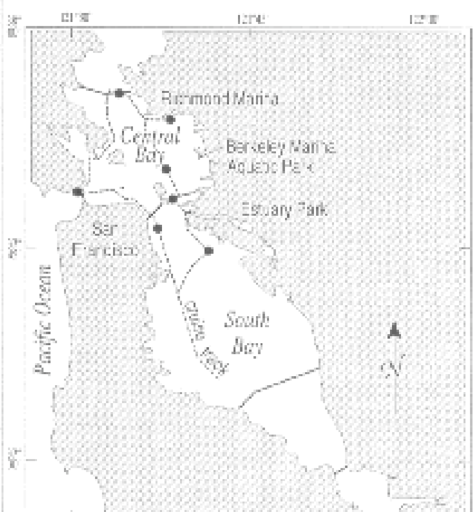

Figure 1
The cruise on August 25, 1997, circled the perimeter of Central Bay. Red colored water was only seen at the entrance to the Richmond Marina, although *Gymnodinium sanguineum* was found at every site where a preserved sample was collected. • Preserved sample collection site.

for Central Bay in the summer, and we did not see any *G. sanguineum*. Observations at Arrowhead Marsh in San Leandro Bay on August 24 found no sign of discolored water and no dinoflagellates in water samples.

G. sanguineum remained abundant in samples collected at the Berkeley Marina on August 24. Examination of the dock fouling biota in the marina at that time showed that some of the common invertebrates attached to the sides of the docks were dying and exuded an odor of decay. This community was dominated by the bay mussel *Mytilus* sp. (consisting of the native mussel *M. trossulus* and the introduced Mediterranean mussel *M. galloprovincialis*). In several samples taken, 20 to 60 percent of the *Mytilus* were dead or dying, many with empty valves.

Another common species, the Atlantic tunicate *Molgula manhattensis*, was also in poor condition, in many cases apparently disintegrating into slime. These species (along with other species growing on them) were easily detached from the pilings and floats, another sign of morbidity. Typically these organisms grow well in the bay during summer and fall. Since routine monitoring of the dock fouling community began in 1993 (by A. Cohen), we have observed such die-offs only in response to sustained freshwater flows, such as occurs during wet winters and springs.

On August 26 the USGS conducted a special cruise throughout Central Bay to characterize the spatial extent of the red tide. Chlorophyll levels in Central Bay during an August 5 cruise had been typical for the season—about 2 μg/L. However, chlorophyll concentrations on August 26 were about four times higher throughout most of Central Bay. Red water was not visible except in Richmond Inner Harbor, at the entrance to the Richmond Marina, where the chlorophyll concentration was 17 μg/L and the water was a deep reddish color. Chlorophyll levels west of the Golden Gate Bridge were also slightly higher (about 10 μg/L) than those within the Bay, but there was no visible discoloration of the water.

Microscopic examination of preserved samples confirmed the presence of *G. sanguineum* at all sites where preserved water samples were collected (Figure 1), but at lower densities than had been seen in the Berkeley Marina. On the next USGS cruise of September 9, chlorophyll concentrations along the central channel of Central Bay were at 4.5 μg/L, only slightly above typical summer levels. Red water disappeared from the Berkeley Marina around September 1, however red water was seen in nearby Aquatic Park (a brackish-water lagoon connected to the Bay through culverts and tide gates) for about a week in early September. On September 6, City employees removed a large number of dead fish from the lagoon, including 50-60 striped bass up to 3 feet long, halibut, and some smaller fish (Cliff Marchetti, Brad Gross, pers. comm.). In a survey of dock fouling communities in late October, we found healthy organisms in abundance at all sites in Central Bay, including Berkeley and Richmond marinas and Aquatic Park.

Outside of San Francisco Bay, red tides were observed during the summer at Ocean Beach in San Francisco (Francis Parchaso, pers. comm.) and near Santa Cruz, with *G. sanguineum* identified as the organism causing the latter (David Garrison, pers. comm.).

G. sanguineum has been associated with oyster (Nightingale 1936) and fish kills and is questionably toxic (Tomas 1996). It may be that the observed morbidity of near-surface invertebrates in the Berkeley Marina and the fish kill in Aquatic Park were due to direct toxic effects from the red tide, or that the fish kill resulted from low oxygen levels due to decay of the bloom (Rojas de Mendiola 1979), or to night-time respiration by the dense dinoflagellate concentrations.

Although the Berkeley red tide did not cause any apparent long-term harm, it raised a number of issues regarding our preparedness for dealing with potentially toxic blooms in the future. Dinoflagellate blooms can be catastrophic, as demonstrated by the recent *Pfiestria piscicida* outbreak in North Carolina (Milot 1997) and the illnesses and fatalities resulting from red tides in other parts of the world. Yet the public who work and recreate in and around the bay are generally unaware of the potential consequences of such blooms, nor do they know whom to contact with observations of red tides.

Many important questions remain unanswered: Do warmer waters resulting from El Niño increase the likelihood of toxic blooms? Could ballast water discharges release new species of toxic bloom-forming organisms into the Estuary? And what effect might such blooms have on the ecological functioning of the Estuary?

Rodgers *et al* (1996) reported on the occurrence of phytoplankton species in San Francisco Bay that have caused noxious or toxic blooms in other systems. They noted that although no toxic red tides had yet been documented in the Bay, conditions in this nutrient-rich system could support such blooms. Last summer's red tide shows that their warning was timely. It also suggests the need for routine surveillance of phytoplankton in the Bay, both to alert Bay-area residents and agencies when harmful blooms are imminent or in progress and to determine whether San Francisco Bay (like other nutrient enriched estuaries) is experiencing shifts in phytoplankton composition towards noxious/toxic species. Surprisingly, no monitoring program is currently in place to detect or document events such as the toxic red tide of last August.

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Comprehensive Monitoring and Research for CALFED

Randall Brown, DWR

Over the past few months there has been considerable activity directed towards CALFED's monitoring and research component. At the November 24, 1997, meeting of the CALFED Policy Group, representatives of the IEP and the San Francisco Estuary Institute proposed that these two organizations take the lead in working with CALFED staff and others to develop a comprehensive monitoring and research program. The proposal consisted of two phases - the first three months to prepare a recommended program scope and the second to develop the detailed program within the scope approved by the Policy Group at the end of the Phase One. The proposal was to complete both phases in nine months. The Policy Group approved the proposal with the stipulation that IEP assumed responsibility for completing the work.

At about the same time the Secretary of the Interior directed the U.S. Geological Survey to tell him by January 1, 1998, how the Survey could provide scientific support to CALFED. The Secretary also directed the Survey to prepare a second report by September 30, 1998, containing an ecosystem monitoring program. By December 19, a small team of scientists from the USGS's Water Resources and Biological Resources divisions completed a draft of the January 1 report.

On December 20, 1997, the Policy Group met again with one of the agenda items devoted to reconciling the IEP/SFEI and USGS monitoring and research proposals. After considerable discussion, the Policy Group reaffirmed its approval of the IEP/SFEI proposal and directed the USGS to work with the IEP to prepare a scope of work for the detailed monitoring and research program.

The CALFED, IEP, SFEI, and USGS representatives recognize that developing a comprehensive monitoring and research program is an inclusive effort and will involve a host of Bay/Delta and Central Valley groups. We have created an steering committee and DWR has assigned Zach Hymanson to staff this full time - at least for the next few months. In Phase one we will be working closely with CALFED's Indicators Group being coordinated by Bellory Fong to help ensure that any recommended monitoring program is responsive to ecological indicators developed by this group.

A representative of the steering committee will be updating the CALFED Policy Group in late February on Phase One progress. It is likely that many of you may be called on to help develop the monitoring and research program which will be recommended to CALFED this fall.

Zebra Mussel and Aquatic Nuisance Species

On March 16-19, 1998, the California Sea Grant Program and several cosponsors will be holding the 8th International Zebra Mussel and Aquatic Nuisance Species Conference in Sacramento. On Wednesday morning, March 18, several speakers are presenting papers about such West Coast invasive species as cordgrass, green and chinese mitten crabs, and *Potamocorbula*. Additional information can be obtained at 1-800-868-8776 or by email at profedge@renc.igs.net.

Interagency Ecological Program for the Sacramento-San Joaquin Estuary

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For information on the Interagency Ecological Program, visit our home page on the World Wide Web (www.iep.water.ca.gov).

Readers are encouraged to submit brief articles or ideas for articles. Correspondence, including requests for changes in the mailing list, should be addressed to Randall Brown, California Department of Water Resources, 3251 S Street, Sacramento, CA 95816-7017.

Interagency Program Quarterly Highlights

1997 Fall Dissolved Oxygen Conditions in the Stockton Ship Channel

Stephen P. Hayes and Jeannie S. Lee

Dissolved oxygen concentrations in the Stockton Ship Channel are closely monitored by staff of DWR's Bay-Delta Monitoring and Analysis Section during the late summer and early fall each year. Monitoring is conducted because D.O. levels can drop below 5.0 mg/L in the eastern channel due to low stream inflows, warm water temperatures, high biological oxygen demand, reduced tidal circulation, and intermittent reverse flow conditions in the San Joaquin River past Stockton. These low dissolved oxygen levels can cause physiological stress to fish and block upstream migration of salmon. A barrier is usually installed at the head of Old River during periods of projected low fall outflow to increase net flows down the San Joaquin River past Stockton. The barrier was not installed in fall 1997, a wet year, because of high fall flows in the San Joaquin River.

Surface and bottom D.O. levels in the Stockton Ship Channel were obtained on eight monitoring runs conducted from August 4, 1997, to November 17, 1997. Monitoring from August through October 1997 showed a distinct surface and bottom dissolved oxygen sag in the eastern end of the ship channel with the lowest values (5.0 mg/L or less) in and immediately west of the Rough and Ready Island area. High water temperatures and low flow conditions appear to have contributed to the low D.O. conditions in the eastern channel. Water temperatures ranged from 25-27°C in August, 23-26°C in September, and 16-24°C in October. Average daily flows in the San Joaquin River past Stockton ranged from -466 cfs to +198 cfs in August, -329 cfs to +117 cfs in September, and -233 cfs to +439 cfs in October.

Dissolved oxygen conditions gradu-

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