

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 red-dish 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 profedje@renc.igs.net.