SECTION NEWS

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Heat Wave Brings an Unprecedented Red Tide to San Francisco Bay

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An exceptional red tide in San Francisco Bay was observed on 8 September 2004. The red tide had chlorophyll concentrations approaching 200 mg/m^3 (Figure 1) in red/purple surface streaks containing high abundances of the dinoflagellate *Akashiwo sanguinea*. Red tides and harmful algal blooms (HABs) are common features of coastal ecosystems, and their growing frequency is a suspected outcome of coastal eutrophication.

However, the authors have never observed a dinoflagellate bloom of this scale during 28 years of sampling in the nutrient-rich San Francisco Bay. Phytoplankton biomass along this transect is typically < 5 mg Chl*a*/m^3, and has never exceeded 21 mg Chl*a*/m^3 during summer-autumn (historic data are available online at http://sfbay.wr.usgs.gov/access/wqdata).

The apparent resilience of San Francisco Bay to the occurrence of HABs and other eutrophication impairments is derived, in part, from strong tidal currents that stir the water column and prevent persistent density stratification [*Cloern*, 2001]. This anomalous bloom occurred during a coincidence of unusually weak neap tides, calm winds, and four consecutive days of record high air temperature. The combination of large heat flux with reduced inputs of turbulent kinetic energy from winds and tides created a shallow (< 3 m) surface layer above a thermocline that persisted long enough for this motile algal species to proliferate. Surface water temperatures on 8 September were the highest ever measured (22.6°C maximum) in this region of south and central San Francisco Bay.

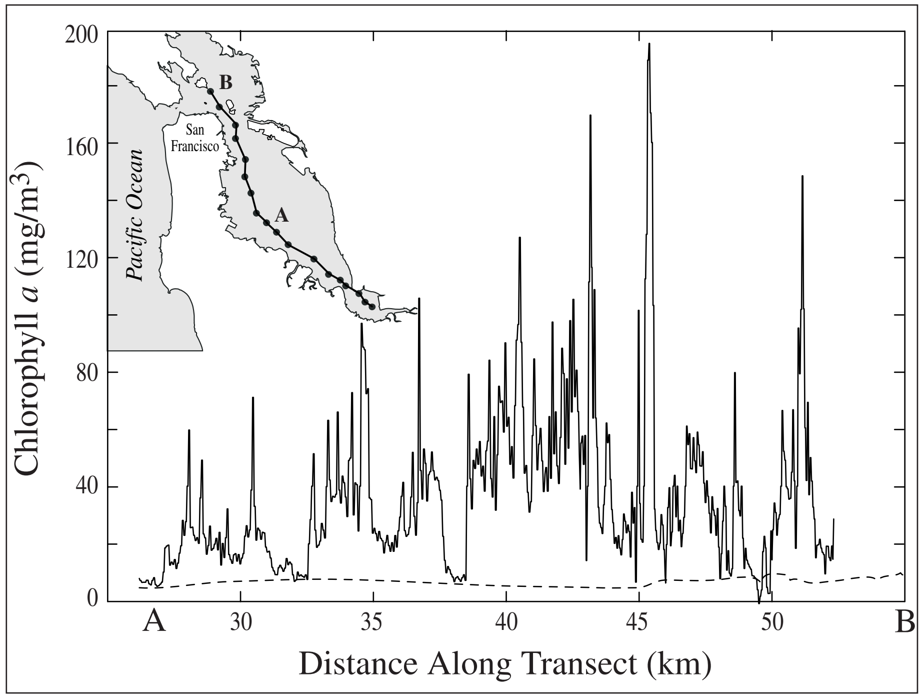

Fig. 1. Phytoplankton biomass (chlorophyll a *measured continuously by in vivo fluorescence) in near-surface waters of San Francisco Bay during a red tide on 8 September 2004 (solid curve). Phytoplankton biomass returned to typical seasonal levels on 14 September (dashed curve). Inset map shows location of the sampling transect A-B.*

Dinoflagellate blooms develop under low-turbulence conditions when density stratification damps mixing between the upper photic zone and deeper, nutrient-rich waters. Motility is the key because these algal forms (unlike diatoms) can migrate downward to assimilate nutrients at night and upward to photosynthesize during the day.

No impairments of water quality or mortalities of fish or shellfish were reported during this red tide, perhaps because the algal bloom dissipated within a week (Figure 1) after winds returned to normal and the subsequent spring tide mixed the water column. However, a devastating bloom of this same species (*Akashiwo sanguinea = Gymnodinium sanguineum*) led to anoxia, fish kills, and port closure in Paracas Bay, Peru, during April 2004 [*Kahru et al.*, 2004].

Sustained ocean observing systems capture anomalous events that can be exploited as natural experiments. This natural experiment provides one answer to the question: What happens when turbulence is damped in nutrient-rich tidal ecosystems like San Francisco Bay? The rapid development of a massive bloom indicates that the bay's resilience to eutrophication can be weakened when its physical dynamics are altered by climatic events.

What will happen in the future if global warming alters the balance between heat input (which serves to stabilize the water column) and wind-tidal stresses that mix the water column? Could one scenario be more frequent episodes of thermal stratification followed by large blooms? Complete assessments of global warming will consider how it will alter physical dynamics of the ocean, including stratification of shallow coastal waters that receive growing inputs of land-derived nutrients as population growth parallels trends of climate change.

References

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