Autonomous Event Response: Harmful Algal Blooms

MBARI

Food for thought in the engineering strategic discussion…

Acknowledgements

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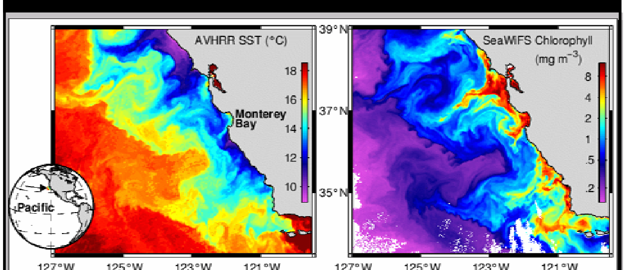
OUTLINE

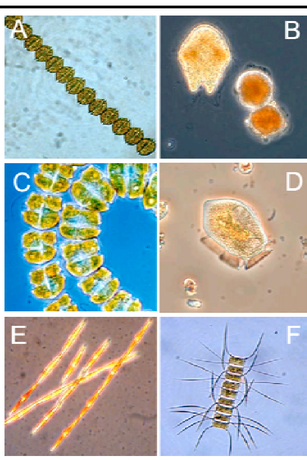
- **Harmful Algal Blooms & Red Tides**
- **Lessons from Monterey Bay studies**
- **ESP ←→ ecosystem measurements**
- **Multi-platform event response**

Harmful Algal Blooms & Red Tides

- Not all HABs are red tides; not all red tides are harmful.
- ~ 50% of red tide species and 75% of HAB species are dinoflagellates.
- Deleterious impacts of HABs occur primarily through:
    - toxins that enter sea life and people through food or aerosols
    - direct physical harm to organisms (e.g. gill damage and skin lesions in fish kill events)
    - development of hypoxic or anoxic conditions
- HABs also have significant economic impacts: fisheries, human health, recreation & tourism, monitoring & management
- Increasing HAB occurrence is evident globally

A highly productive and dynamic system





Key HAB species in upwelling regions

Images from R. Kudela (UCSC)

A. Alexandrium catenella (PSP)
B. Akashiwo sanguinea (yessotoxin poisoning)
C. Gymnodinium catenatum
D. Dinophysis acuta (DSP)
E. Pseudo-nitzschia australis (ASP)
F. Chaetoceros (fish kills)

HABs & Red Tides in Monterey Bay

P. australis

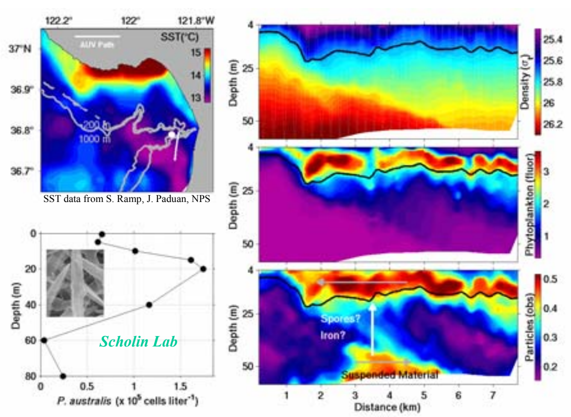
Mortality of sea lions along the central California coast linked to a toxic diatom bloom

Christopher A. Scholin*, Frances Gulland†, Gregory J. Doucette‡, Scott Benson§, Mark Busman‡, Francisco P. Chavez*, Joe Cordaro||, Robert DeLong¶, Andrew De Vogelaere#, James Harvey§, Martin Haulena†, Kathi Lefebvre*, Tom Lipscomb**, Susan Loscutoff††, Linda J. Lowenstine‡‡, Roman Marin III*, Peter E. Miller*, William A. McLellan§§, Peter D. R. Moeller‡, Christine L. Powell‡, Teri Rowles||, Paul Silvagni‡‡, Mary Silver*, Terry Spraker¶¶, Vera Trainer## & Frances M. Van Dolah‡

* *Monterey Bay Aquarium Research Institute, 770 Sandholdt Rd, Moss Landing,*

Nature 403: 80-84.

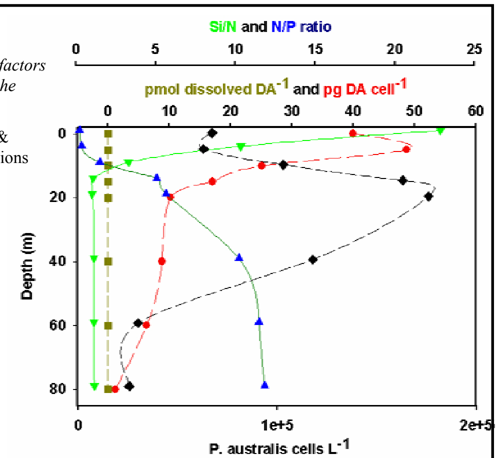
Benthic-pelagic coupling during a *P. australis* bloom in 2000



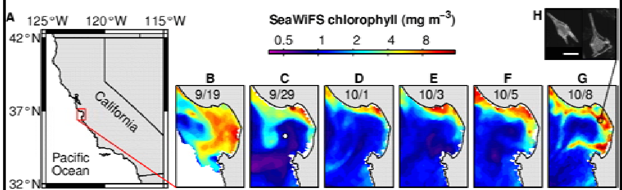
Ryan et al. (2005) Marine Ecology Progress Series 287: 23-32.

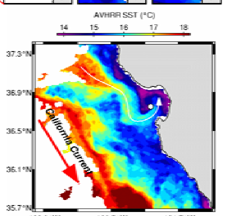
Trophic transfer factors near the core of the food web:

- phytoplankton & grazer concentrations
- per-cell toxin concentrations



Physical forcing of a red tide (2002)

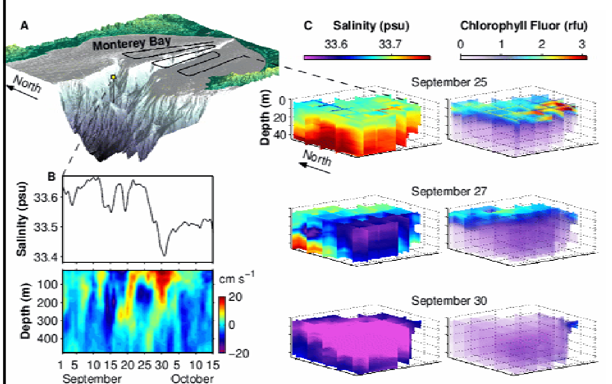




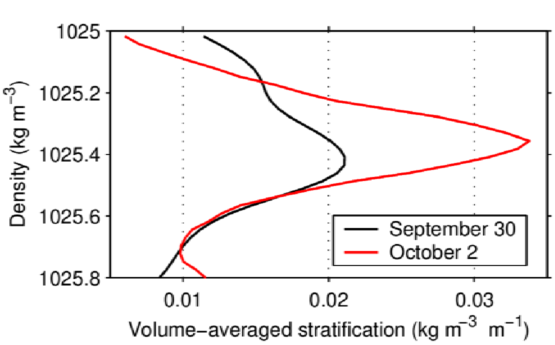
Bay flushing and red-tide rebound.

Bloom advection indicated.

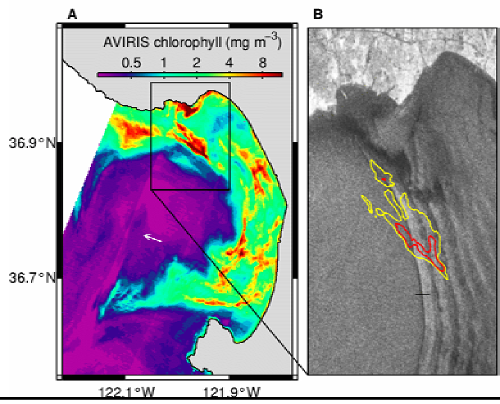
Rapid and extensive ecosystem change…



Enhancement of vertical density stratification immediately preceding the red tide bloom…



Advection and internal waves influenced patchiness at the height of the bloom…



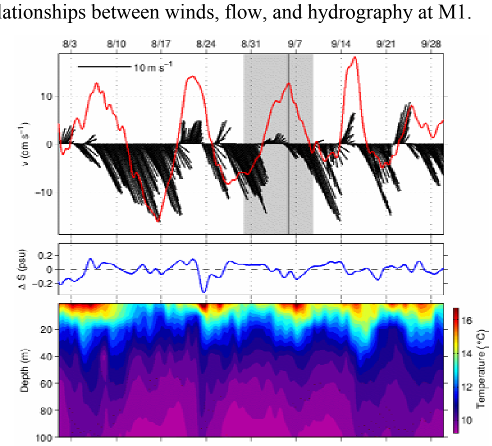
Forcing of bloom genesis and evolution can span a wide range of scales and involve diverse processes and conditions. This case study involved dynamics of an eastern boundary current, bay-wide changes in vertical density stratification, circulation of the bay and adjacent sea (bloom advection), and interaction of motile cells with circulation fields of internal waves.

Despite the tremendous complexity of HAB & red tide physical-biological interactions, physical phenomena are being more clearly linked to variability in important red tide and HAB species, e.g.

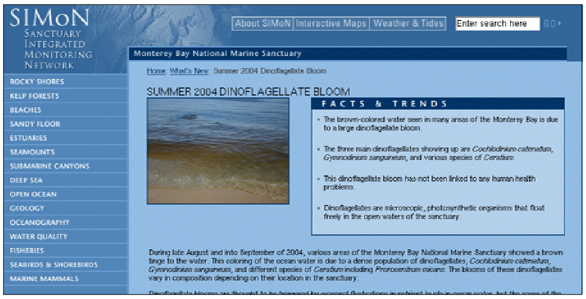
- Wind relaxation and red tide seeding (Africa, Spain)
- Cold eddy "HAB nursery" (Pacific Northwest)

→ Monitoring of key physical phenomena can provide a basis for informed and efficient use of limited, critical observations (e.g. autonomous species identification with ESP, water sampling surveys, synoptic mapping efforts).

Relationships between winds, flow, and hydrography at M1.



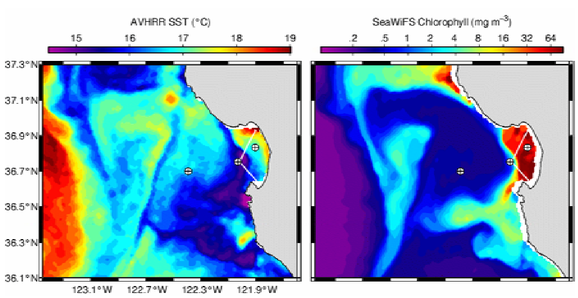
2004 Red Tide: Widespread and Persistent



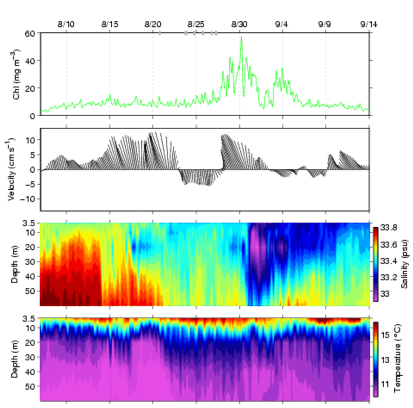
The dinoflagellate bloom included *Cochlodinium catenatum*, a harmful species not previously noted in this region. Mary Silver (UCSC) found that mussels died in response to a bloom of this species off Santa Cruz.

August 27, 2004:

- Approaching maximum chlorophyll concentrations at CIMT mooring
- Strong interactions between Monterey Bay & adjacent sea
- Multiple AUV surveys through the bloom & frontal zone

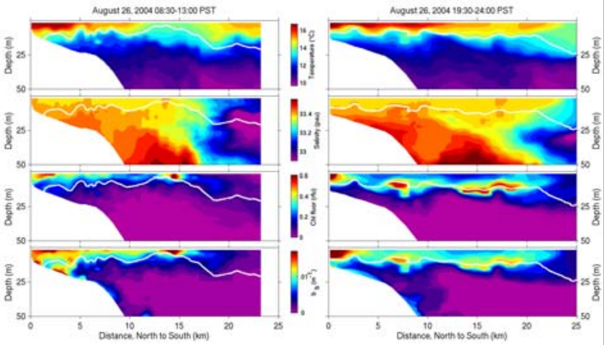


Local chlorophyll maximum coincided with northward flow…

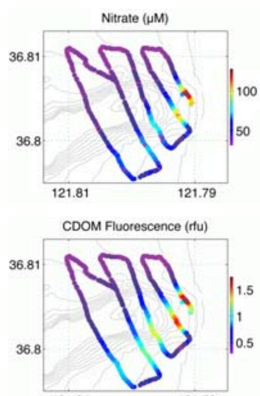


Day-night vertical migration of dinoflagellates? Advection?

→ *Sensor-informed water sampling*



Estuarine exchange in central Monterey Bay influences nearshore plankton ecology through fluxes of nutrients, DOM & phytoplankton.



AUTONOMOUS EVENT RESPONSE: HABs & RED TIDES

Questions:

• Are HAB and red tide seed populations introduced into the bay with intruding water masses / frontal zones? (Barnacle larvae have been identified by ESP during a frontal zone passage.) Are seed populations introduced in shelf sediments transported into the euphotic zone? From the Elkhorn Slough estuary?

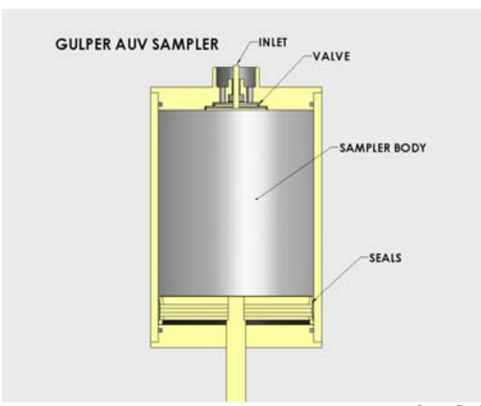
• How do nutrient concentrations and ratios influence toxicity? What are the natural and anthropogenic controls on nutrient influence?

• What combinations of physical, chemical and plankton community conditions create high-impact blooms?

Build on the strengths of existing and emergent observing technologies:

1) Identify presence and quantify abundance of HAB species with ESP. In general, we can't do this with optics alone. Contextual sensors (remote and *in situ*) may be used to trigger ESP, and this is one level of event response.
2) When a HAB event is identified, respond with synoptic mapping of physical and bio-optical property distributions over a region around the moored monitoring station(s), e.g. AUV launched from a dock. This level of event response permits description of bloom distribution and associated oceanographic conditions. However, broad scale phytoplankton ID remains out of reach of sensor readings alone.
3) Apply AUV intelligence for mobile platform event response: adaptive water sample acquisition. This permits intelligent water sampling acquisition, responsive on the scale of local encounter in rapidly changing coastal waters.

AUV water sample acquisition system in development at MBARI



Larry Bird, MBARI

During the 2003 Autonomous Ocean Sampling Network (AOSN) field program, we conducted human-in-the-loop adaptive sampling with the Dorado AUV (movie clip).