Research With Autonomous Underwater Vehicles Informs Educational Resource About Harmful Algal Blooms

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ABSTRACT

Process studies employing autonomous underwater vehicles (AUVs) off central California have advanced the scientific understanding of harmful algal blooms (HABs), as well as the educational resources to explain them. These process studies gathered multidisciplinary observations from AUVs, moorings, ships, aircraft, and satellites. Moored systems included autonomous robotic biochemistry systems for in situ detection of HAB species and toxins. Integrating the knowledge gained from a series of process studies, we developed a visualization of processes that influence bloom ecology in Monterey Bay, California. This visualization, rendered to static and dynamic content, emphasizes how HAB ecology is profoundly influenced by processes that originate at the boundaries of coastal marine ecosystems. In its dynamic form, the illustration is presented in language that is accessible to resource managers and the general public.

AUVs IN OCEAN OBSERVING SYSTEMS

Ocean observing systems (OOS) are changing the way oceanography is conducted (Figure 1), and AUVs are key OOS technologies. These robotic vehicles contribute design-dependent capabilities – cost effective observation, persistent observing presence, detailed multidisciplinary measurements, and onboard intelligence to optimize sampling and observation.

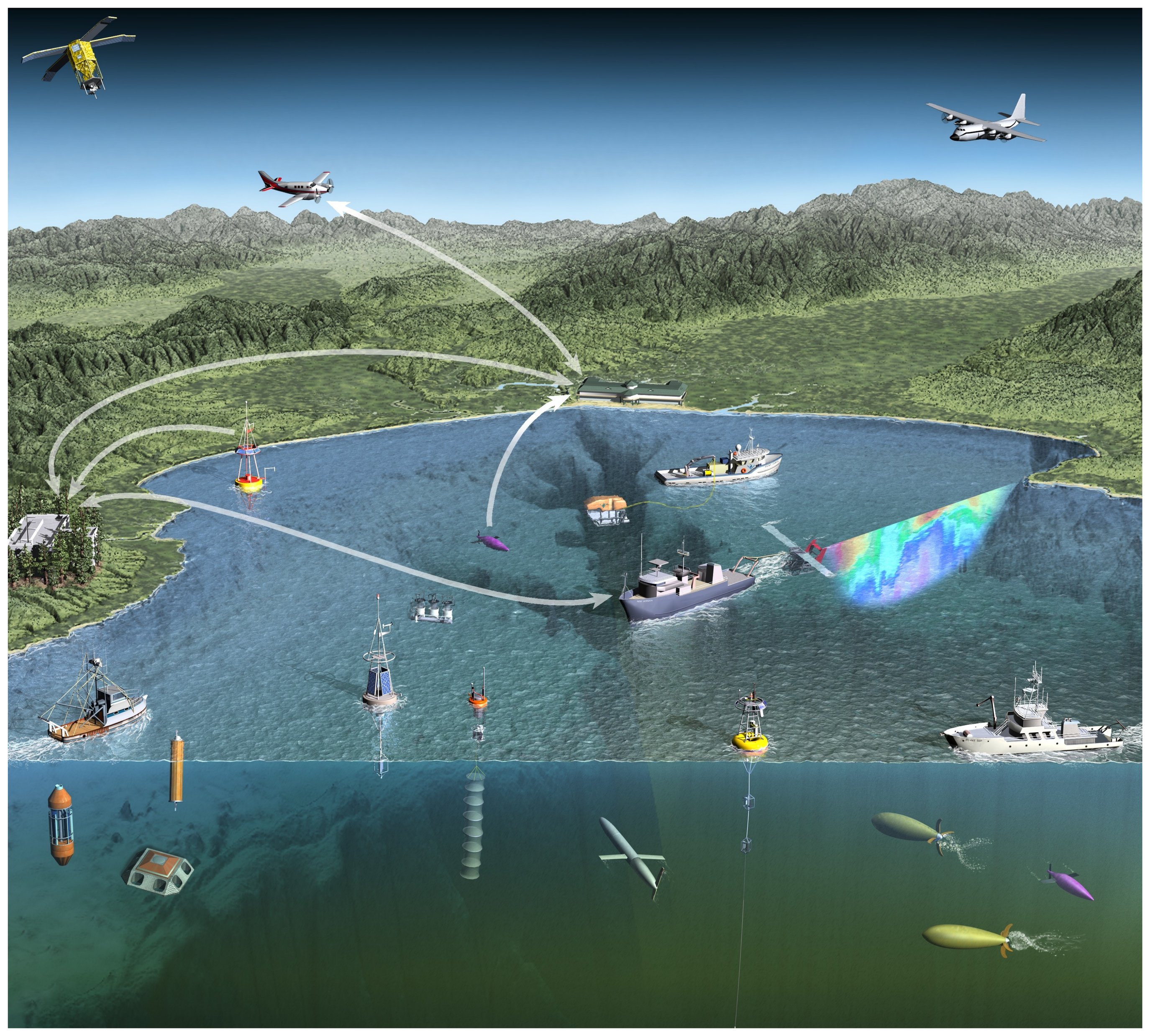

***Figure 1**. Multi-scale OOS are supporting better observations of coastal environments and understanding of HAB ecology. Since this illustration was produced (David Fierstein, © 2001 MBARI), the Central and Northern California Ocean Observing System (CeNCOOS) has been established to expand coastal observing capabilities, connect observing nodes along the California coast, and provide data to decision makers and the public. CeNCOOS maintains active involvement in HAB research and education.*

RESEARCH

The study region – Monterey Bay, California – is a highly dynamic and productive coastal upwelling environment in the central California Current System (CCS). Wind-driven upwelling of deep waters in the CCS enhances nutrient supply to the euphotic zone and thus primary productivity. In the relatively warm, sheltered conditions that develop in the northern bay, phytoplankton thrive on episodic nutrient inputs (Figure 2). Hosting a variety of phytoplankton species that may cause HABs, this region provides a natural laboratory for advancing understanding of HAB ecology in coastal upwelling ecosystems.

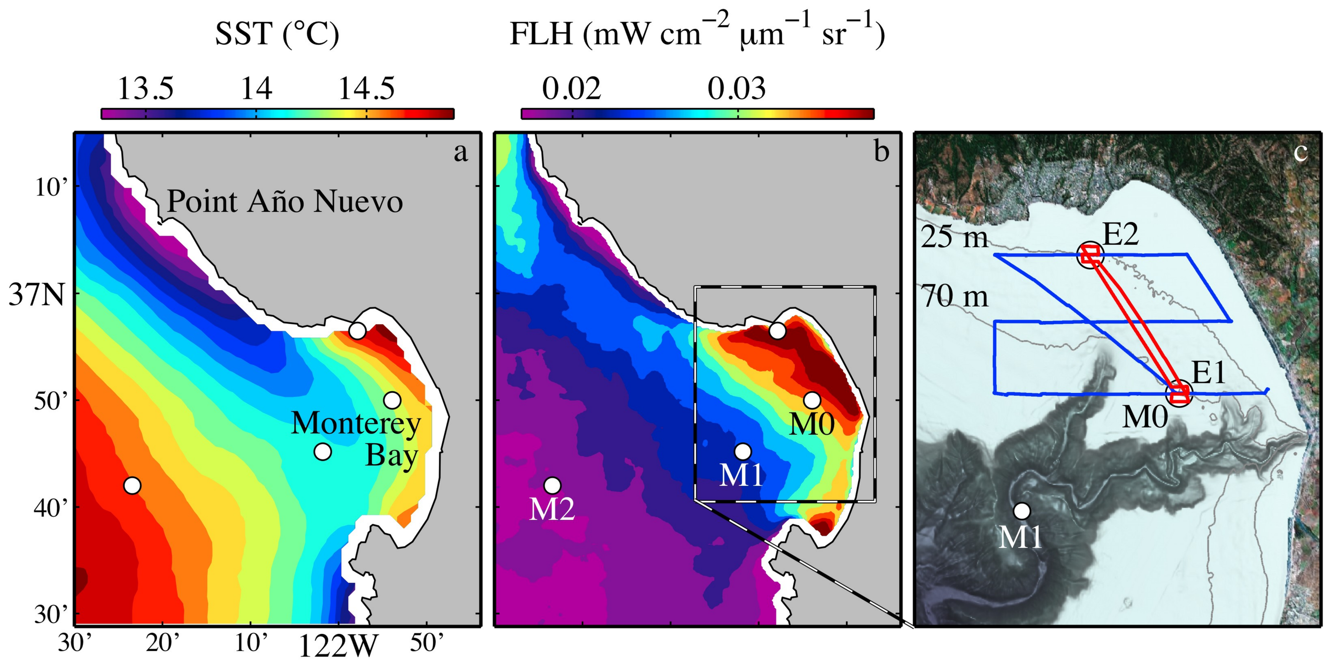

***Figure 2**. Satellite observations and bathymetry data used to plan experiments that integrate autonomous molecular detection of HAB species and toxins (at E1, E2) with AUV observations (red and blue tracks in panel c).*

HAB ecology research requires understanding physical, chemical, and biological factors that interact in dynamic coastal environments. The AUVs employed in our studies address these challenges by carrying a multidisciplinary sensor suite, and by employing rapid survey methods that capture accurate 'snapshots' of rapidly evolving conditions. High-resolution, multidisciplinary observations acquired by the *Dorado* AUV during a HAB study illustrate the complexity of bloom ecology (Figure 3).

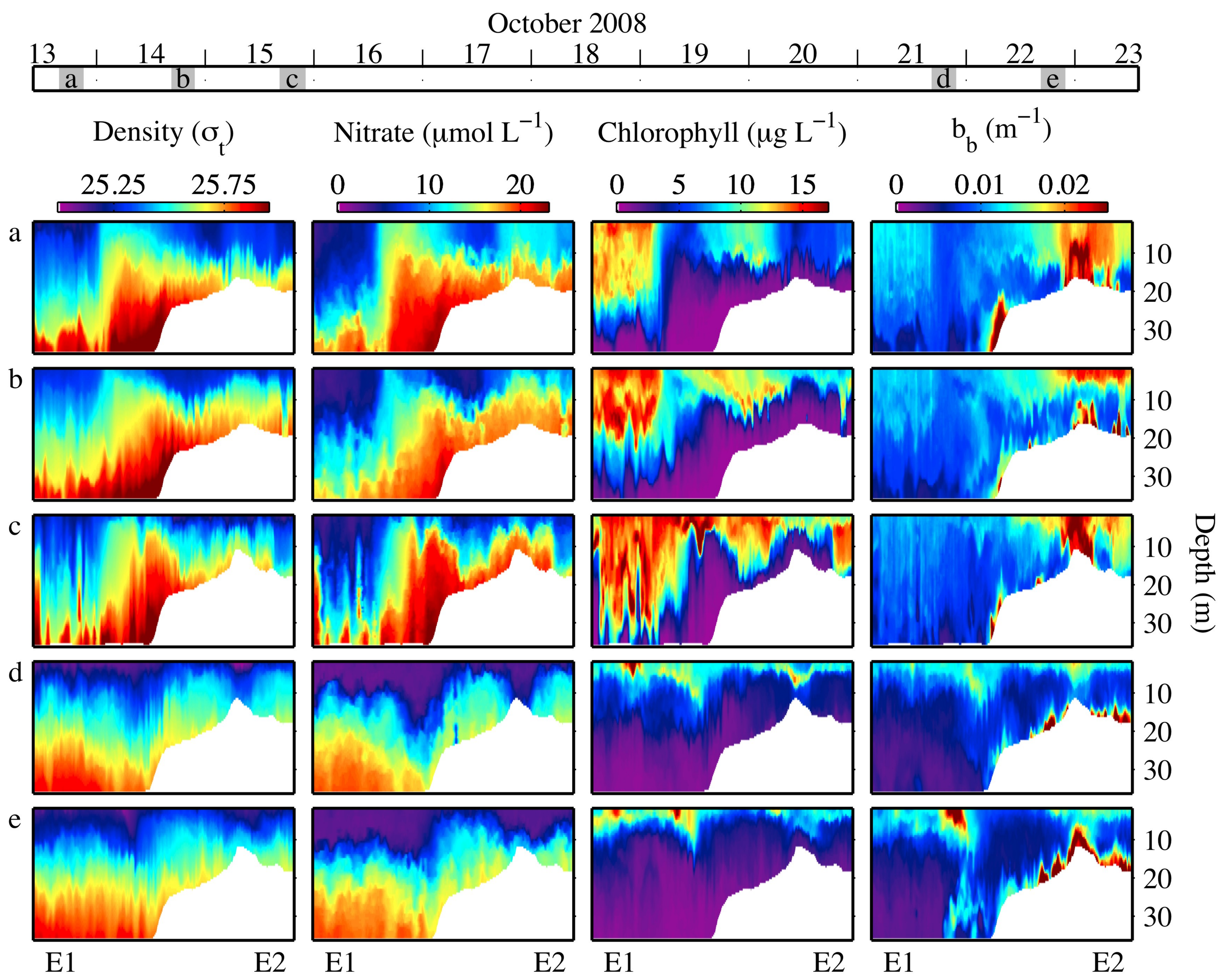

***Figure 3**. Synoptic AUV sections during the (a-c) peak response to upwelling and the (d,e) subsequent warming. Each AUV section was derived from ~240 profiles acquired in 5 hours. The parameter b_b is optical backscattering at 470 nm; it is used to identify resuspended sediments. Toxigenic diatoms bloomed during the upwelling response, and their toxicity and its variability were greater where the phytoplankton encountered resuspended sediments.*

EDUCATION: STATIC TO DYNAMIC VISUALIZATION

Production of the original static illustration (Figure 4) required iterative discussions between scientists, science communicators and illustrators.

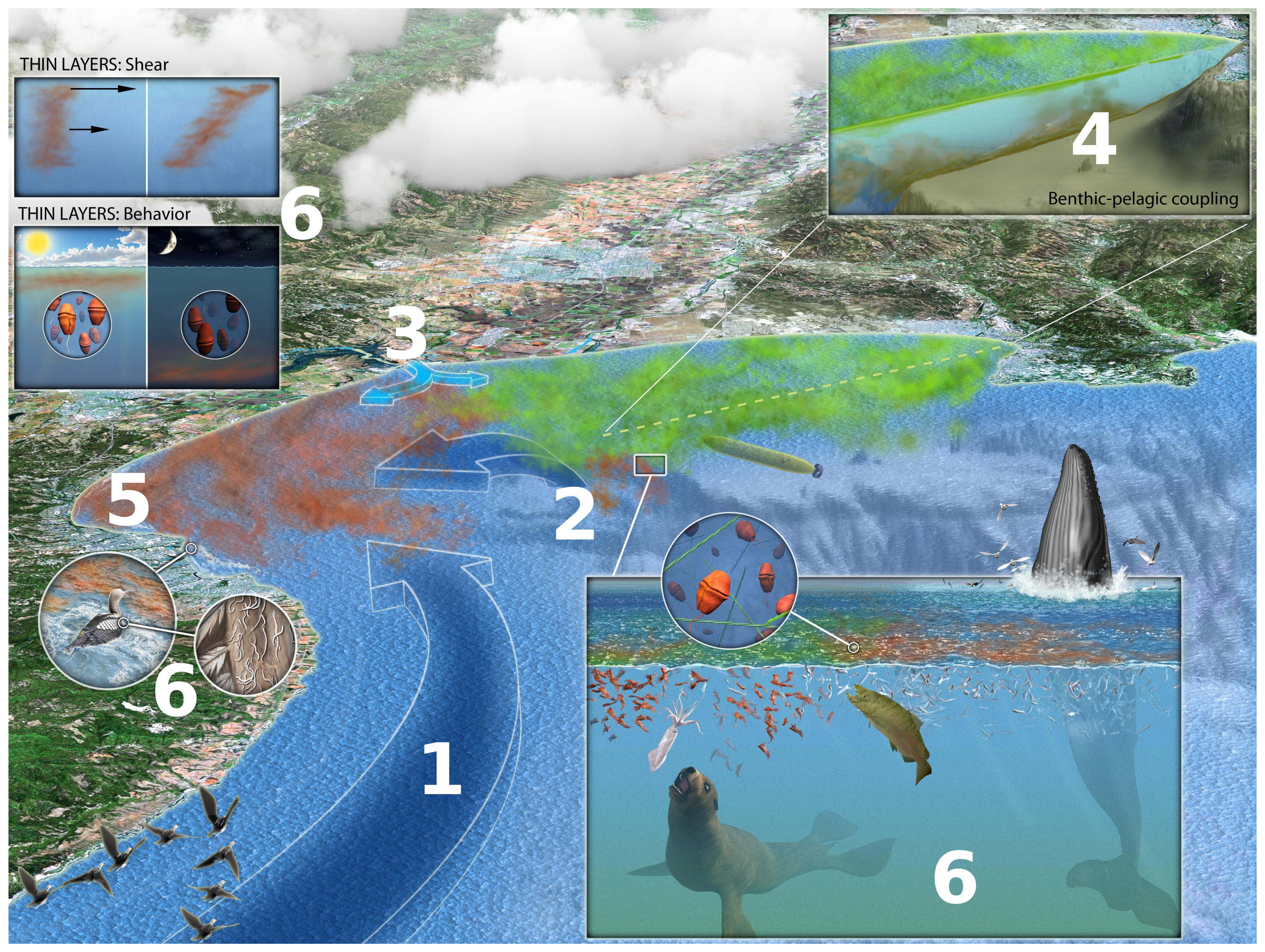

***Figure 4**. The HAB / red-tide ecology illustration that resulted from studies multiple employing AUVs, such as the data shown in Figure 3. (David Fierstein, © 2008 MBARI).*

To make the dense information content of the still image more accessible, we produced a slide show that deconstructs and reconstructs the information content of the image. This process involved (1) preparation of interview questions, (2) audio recording of an interview between the science communicator and scientist, providing a description of all elements in the illustration, (3) editing and arrangement of interview excerpts to create an audio script for the animation, (4) creation of a series of still images, each of which showed only key details appropriate to specific portions of the script (using Adobe Illustrator), and (5) assembly of the still images and audio into a slide show with controls that allow the user to navigate (using Adobe Flash)

The slide show describes interacting environmental processes that influence phytoplankton ecology in Monterey Bay, in the context of boundary influences (numbered elements in Figure 4). Transport of upwelling filaments into the bay (#1), canyon-to-shelf transport (#2), and drainage of terrestrial and estuarine systems (#3) involve fluxes of nutrients, heat, salt, and sediments across the boundaries of the bay's shelf ecosystem. Some of these fluxes also cause changes in stratification. Coupling of the shelf sediments and turbid fluid from the bottom boundary layer to the overlying water column (#4) can introduce chemical and biological influences, including nutrients, trace metals, and resting stages of phytoplankton. Sheltering of phytoplankton populations in coastal-boundary refugia (#5) can influence the initiation, progression, and persistence of bloom events. Interaction between organism behavior and environmental conditions at surface and interior (thermocline) boundaries (#6) also greatly influence HAB ecology.

Translation of years of research into an educational resource was a very positive experience. Once posted on the web, appreciative reviews from resource managers indicated that our goal had been met: to make a very complex topic understandable.

Smartphone users may link to this slide show by scanning the QR code to the right. The link is:
http://www.mbari.org/news/homepage/2009/ryan-blooms/ryan-blooms.html.

Ocean Sciences Meeting 20-24 February 2012 Salt Lake City, Utah Session: 035: Using Data from Autonomous Vehicles and Drifters to Support Education and Outreach Abstract ID: 9437