CANON / ECOHAB Spring 2013 Experiment Plan

Spring Experiment Context

The spring 2013 experiment is the first of two planned collaborations between MBARI's CANON Initiative and the NOAA ECOHAB project entitled, *A Regional Comparison of Upwelling and Coastal Land Use Patterns on the Development of HAB Hotspots Along the California Coast*. Institutions participating in the ECOHAB project are UCSC (lead R. Kudela), MBARI, MLML, CeNCOOS, USC, SCCWRP, JPL, and NOAA. This first experiment will take place in the San Pedro Bay region during March – April; the second experiment will take place in the Monterey Bay region during September – October (Figure 1). While sharing some large-scale variability, and perhaps some local environmental characteristics associated with 'upwelling shadow' dynamics, the two regions have significant differences in atmospheric and oceanic forcing, as well as human-impact channels (agricultural runoff, sewage). The contrasting oceanographic settings and anthropogenic influences form the basis of a comparative study to understand the environmental factors controlling the initiation, evolution, and toxicity of HABs – focusing primarily on *Pseudo-nitzschia* spp. that can cause domoic acid (DA) poisoning, and secondarily on *Alexandrium catenella* that can cause paralytic shellfish poisoning.

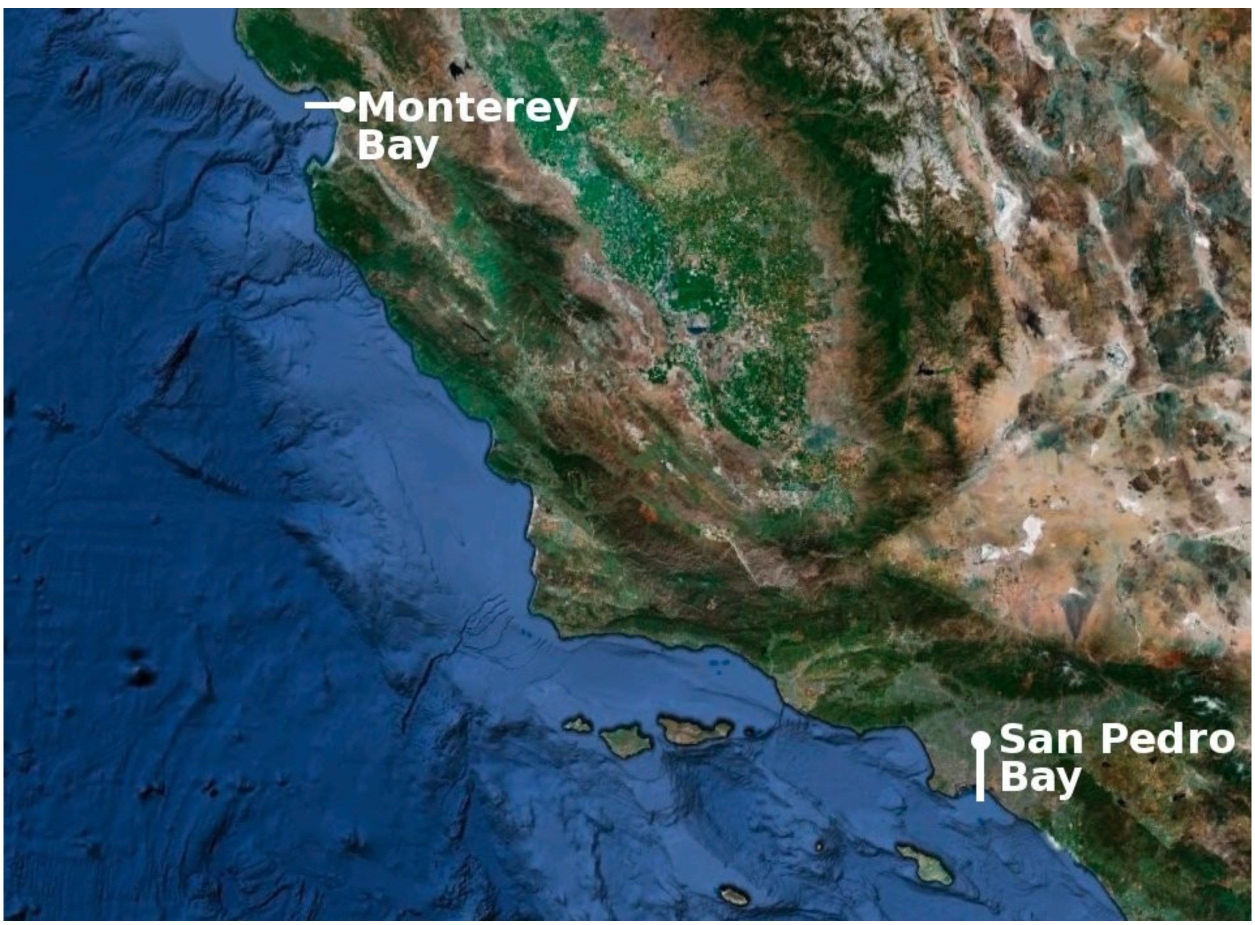

Figure 1. The two regions for 2013 CANON / ECOHAB studies.

In both regions, a key hypothesis is that subsurface layers, "hidden" from near-surface observing strategies, are critical to HAB population dynamics and bloom development. Also in both regions, episodic upwelling is key to HAB ecology. In Monterey Bay, persistent "thin layers", hosting dense populations of toxigenic *Pseudo-nitzschia*, have been documented (McManus et al., 2008). However, the prevalence and seasonality of such layers is unknown, and their ecology is poorly understood. On the San Pedro shelf, previous studies including one that employed two Environmental Sample Processors (ESPs) in spring 2010, indicate that subsurface layers of *Pseudo-nitzschia* from the off-shelf deep chlorophyll maximum (DCM) seed bloom events on the shelf during upwelling events (Caron et al., 2011; Seegers et al., 2011). However, such seeding has never been directly observed, and the species composition and dynamics of the DCM on and off the shelf are not well understood.

Domain

Pseudo-nitzschia populations that bloom in San Pedro Bay are thought to come from along-coast transport from the NW. Although this aspect is important to understanding regional HAB ecology, its spatial domain is too large to cover adequately with the experiment observing assets. To effectively study HAB ecology in San Pedro Bay, we will concentrate efforts largely within waters on and near the southern San Pedro Shelf — where *Pseudo-nitzschia* blooms have been observed during spring, previous HAB ecological experiments have been conducted, and risks from shipping traffic are relatively low (Figure 2). Real-time data may motivate excursions toward the hypothesized source region of *Pseudo-nitzschia* populations further to the NW, but this focus will be secondary to operations on/near the southern San Pedro shelf.

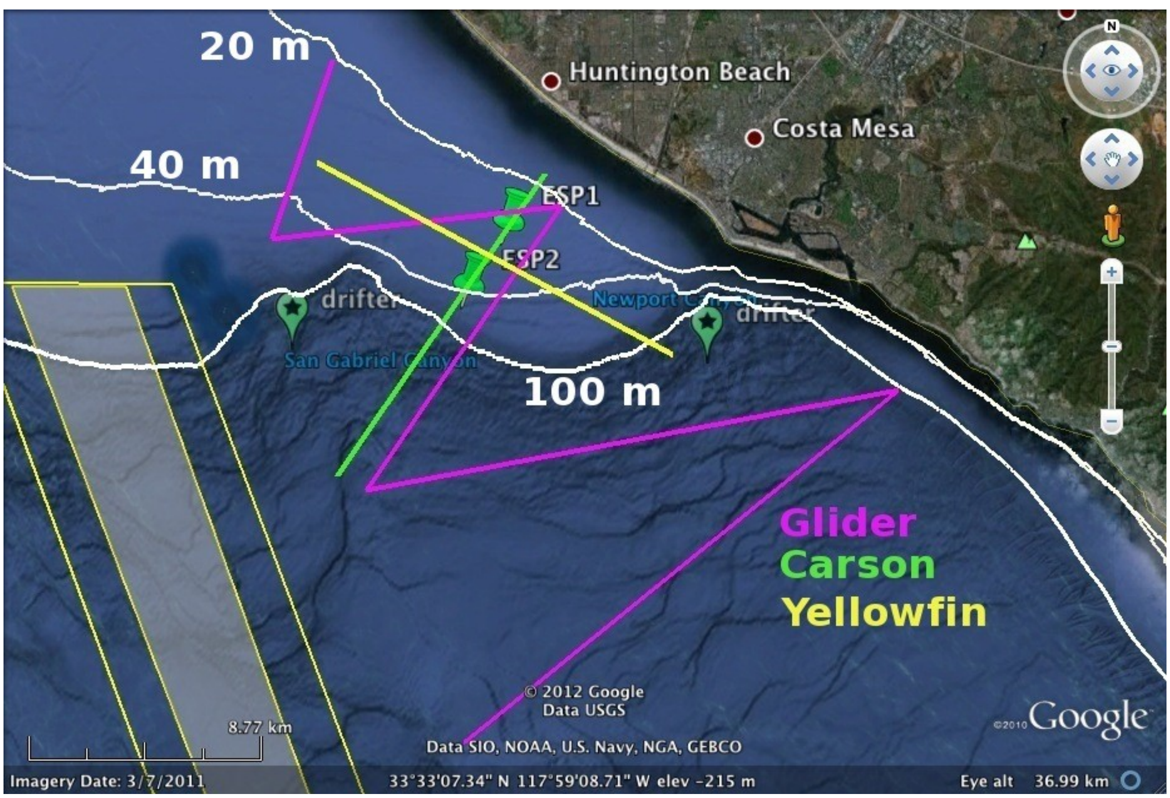

Figure 2. Focal experiment domain and straw plan for deployment of some observing assets.

Shown in Figure 2 is a straw plan for the deployment strategy. Details follow this section, however a brief explanation is noted here. The ESP locations and "standard" USC glider track are those used in the 2010 experiment. Because these ESP locations were effective in the spring 2010 study, they represent the approximate locations planned for the 2013 experiment. The R/V Rachel Carson section parallel to the ESP array (and to a glider section) represents one of the two modes of Carson operations; the other mode is Lagrangian observation of DCM populations. LRAUV (Tethys, Daphne) operations will include high-resolution mapping centered on ESP moorings, and possibly patch-tracking in collaboration with Dorado AUV operations. The R/V Yellowfin will conduct a survey of the Carson cross-shelf section prior to the intensive. During the intensive, on days when the Carson occupies the cross-shelf section, we propose that the Yellowfin conduct a complementary along-shelf section (distance offshore to be informed by near-real-time data), or targeted sampling based on near-real-time observations. On days when the Carson conducts Lagrangian DCM tracking and observation, we propose that the Yellowfin occupy the cross-shelf section.

Deployment schedule

The planned deployment schedule for MBARI assets is shown in Figure 3. The intensive phase of the experiment is defined as the period during which the R/V Rachel Carson will serve as a hub for collaborative (MBARI, UCSC, USC) day-cruise operations: March 19-21 and March 24-26 . The Dorado AUV and drifters will be applied only during this period. The month-long deployment of the two ESPs, intended to be approximately centered on the intensive phase, will be ~ March 8 to April 5. Prior to the intensive, USC gliders, ESPs, LRAUVs, Wirewalkers, the R/V Yellowfin, and the ROMS model will be applied for ecosystem characterization. During the intensive, informed by near-real-time data, we will apply alternate strategies using the R/V Carson and Dorado AUV. These strategies are essentially Eulerian and Lagrangian approaches to studying HAB ecology; they are sketched below. If available, the Waveglider will ideally not only support the San Pedro Bay experiment, but also provide data from a transit between Monterey Bay (depart March 1) and San Pedro Bay. The schedule for DCM-drifter operations will depend on ecosystem conditions and coordination with USC operations. Considerations for scheduling of USC / UCSC / Scripps platforms (gliders, Wirewalkers, small boats) include potential collocation of Wirewalkers with ESPs, timing of reconnaissance to inform the intensive, coordination of Carson and Yellowfin operations during the intensive (e.g. for along- and cross-shelf coverage, Figure 2), use of the glider-deployment boat for drifter chasing, etc.

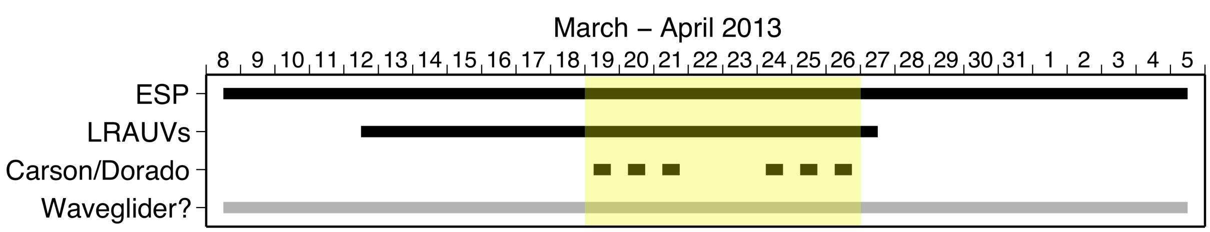

Figure 3. Deployment schedule for MBARI assets. The intensive phase is highlighted.

ESP deployment Locations and Depths

Providing periodic molecular detection of HAB species and DA, the ESP moorings establish an organizational footprint for other moored and mobile observing assets (Figure 2). The deployment locations chosen for the spring 2010 experiment proved effective, even though the glider time-series indicates that the ESPs only caught the early phase of the bloom response. Potential modifications to location and sampling depth are considered in light of 2010 results.

Outer-shelf 'Sentinel' ESP

In the spring 2010 experiment, the outer-shelf ESP (Figure 2) effectively captured the rise of *Pseudo-nitzschia* populations during ~April 21-25, associated with an upwelling response. Therefore, this location is proposed as the primary 'sentinel site' for the early upwelling response in the spring 2013 experiment. The geographic location and ESP sampling depth may be adjusted slightly based on operational and scientific results from 2010. During a portion of the 2010 experiment, this ESP mooring was tilted to such an extent that sample processing failed. This tilting may have been caused by unusually strong currents and/or unobserved entanglement. If unusually strong currents are known to develop near the shelfbreak, perhaps associated with the influence of San Gabriel Canyon, then moving this ESP slightly onshore may be prudent. The ESP was located at ~17 m depth where water column depth was ~55 m. Although the ESP detected clear signal from *Pseudo-nitzschia* populations, glider data suggested that the maximum DCM signal was deeper. We need glider data to quantify this, but in the absence of data, we still propose a slightly deeper ESP at this location based on a rough estimate from glider volume survey plots (~ 25 m, requiring a cable of ~30 m length).

Mid-shelf ESP

In the spring 2010 experiment, the mid-shelf ESP (Figure 2) also detected increased signal from *Pseudo-nitzschia* populations at the end of its deployment. Physical signal of upwelling was evident ~ 1 day earlier at this location, however sustained *Pseudo-nitzschia* signal occurred ~ 5 days later and coincided with intermediate temperatures (Seegers et al., 2011). Both ESPs were sampling at the same depth (~17 m), and the mid-shelf site was ~ 5 km shoreward of the outer shelf site. The glider sections suggest a general pattern of high chlorophyll concentrations residing shallower toward the coast, thus it is possible that the relatively weak signal of *Pseudo-nitzschia* at the mid-shelf ESP was due to populations being concentrated above the ESP. Again, glider data can inform this evaluation, but it is possible that while this geographic location is appropriate for the mid-shelf mooring, we will benefit from placing the ESP at a shallower depth (~ 10 m). This site will not require a new cable.

R/V Rachel Carson / Dorado surveys

During the intensive (Figure 3), Carson operations will be conducted in two modes: (1) Eulerian-framework observations along the central cross-shelf section (Figure 2), and (2) Lagrangian-framework observations of the DCM, based on tracking a drifter drogued in the DCM. During mode 1 surveys, ship and Dorado sampling around and offshore of the ESP array and sampling within/outside the DCM will effectively define relationships between shelf populations of *Pseudo-nitzschia* and the DCM seaward of the shelfbreak (key hypothesis). We propose that the first day of each 3-day survey block (Figure 3) be dedicated to this detailed ship/AUV mapping across the central cross-shelf section. The operational mode for the second and third days of each 3-day block will be determined based on near-real-time results from the greater observing program. For example, if ship / AUV observations define a strong DCM off the shelfbreak near the focal study region, and sampling determines that the DCM contains significant populations of *Pseudo-nitzschia*, then we may tag the DCM with a drifter and employ ship and AUV assets to observe transport of DCM populations, resolve influential processes, etc.

Capabilities of the Dorado AUV that are particularly valuable to experiment goals include its multidisciplinary sensing / imaging, high speed surveying, a sample acquisition system, and well developed control for adaptive navigation and water-sample acquisition. Although it may be possible to conduct Dorado operations overnight (deploy at the end of the day and recover in the morning for turnaround), thereby extending temporal coverage in some sense, this option is not sought, particularly for observations along the central cross-shelf section. The value of Dorado observations to understanding the environment sampled by ship CTD sections is far greater when the observations are concurrent and approximately collocated.

For mode 1 (section) surveys (Figure 2), simple AUV navigational control (MVC) and a well established peak-capture algorithm (Zhang et al., 2010; Ryan et al., in press) will serve very effectively. The goal is to acquire exceptionally synoptic, high-resolution, multidisciplinary description of the environment and plankton community (including plankton imaging), as well as precisely targeted sampling within and outside of the DCM, to complement the ship CTD sampling. Considering the length of the section (Figure 2), a complete AUV survey with acquisition of up to 10 Gulper samples will require ~ 2 – 2.5 hours. Therefore, we propose to conduct two Dorado sections (outbound, inbound) in a single day operation. To speed Dorado turnaround, we will aim for having two complete sets of Gulpers. Ship CTD sampling will follow behind Dorado on both outbound and inbound surveys, and thus acquire the full CTD section in a sequence that meets in the middle. Ship CTD profiles will be as dense as possible, considering the survey time window, station time, transit speed, and Dorado turnaround.

For mode 2 (Lagrangian) surveys, navigational control requirements are greater, and here we will use well established capabilities of T-REX to autonomously map repeated volumes around a drifter. With T-REX, we will have the option of either tracking the drifter directly, or (with a human in the loop) tracking a centroid defined by an LRAUV that tracks drifter position and applies further algorithms for patch-centroid localization (Godin et al., 2012; Ryan et al., in press). The DCM-tracking drifter will be placed according to where there is a strong DCM "upstream" of the ESP array (determined by analysis of data from the greater observing system). We will adapt drogue depth immediately before deployment, after defining DCM center depth from a CTD profile. Ship CTD profiles will be acquired next to the drifter at a periodic interval throughout the day. Considering that the first survey of each 3-day block will be a day operation along the central cross-shelf section, it is probable that drifter-tracking operations with ship CTD and Dorado will likewise be day-operations. This would have the advantage of collocated measurements and 3 full operational days for Dorado in each 3-day block (versus one day and one overnight).

As successfully applied in multiple T-REX patch-tracking missions, we will use the peak-capture algorithm to acquire samples from within and outside the DCM. Additionally, Dorado's "surgical sampling" capabilities may be further augmented by JD, who is beginning to develop an environmental niche model for prediction of *Pseudo-nitzschia* hotspots in San Pedro Bay.

There are many considerations, including availability and attributes of training data (from surface shelf waters only?), availability of derived variables onboard Dorado, and data QC cost versus predictive benefit. If the model is demonstrated to be effective with ship-based data sets in a way that is applicable to a subset of Dorado measurements available in real-time, its operation onboard Dorado may be tested during the experiment.

Long-Range AUV (LRAUV) Operations

LRAUVs Tethys and Daphne will be active during the full intensive as well as ~ 1 week prior (Figure 3). Prior to the intensive, we propose to dedicate their capabilities to high-resolution mapping around each ESP, using repeated perpendicular sections over a horizontal scale of ~ ±2 km from each ESP. This will effectively describe patchiness, DCM dynamics in relation to ESP sampling, and ecologically relevant small-scale dynamics, and it will inform parameterization of adaptive sampling by the ESPs. During the intensive, when observations motivate patch tracking, we may consider directing an LRAUV to coordinated operations with Dorado.

Details

ESP

- We have ESP cables as long as 20 m, allowing ESP to reside at ~ 15 m depth. This is likely not deep enough to most effectively target outer-shelf DCM populations, and we propose to make up a 30 m cable to support ESP deployment at ~ 25 m depth. Glider data may become available to confirm this estimate (made request to Burt and Bridget). The mid-shelf ESP should be readily supported by existing ESP EM cables.
- Checking if 2010 sites (for 2013 repeat) are within cell-phone coverage range.
- Considering no pier ESP deployment, do we want to put the 2nd ESP closer to shore?

R/V Rachel Carson

- LA Harbor was used for previous ESP work, but it would be ~ 15 mi from the focal study region. Orange County Harbors would permit shorter transits and more time for day operations (http://www.boatharborslocator.com/sc_orange.htm). Checking with Chris Grech...
- Get full listing of day-cruise participants.
- Load / stow Kudela Lab gear in Moss Landing before March 8 departure for Brewer / Paull operations?
- Use ship for dockside berthing of MBARI participants?
- Estimate potential CTD station density for central cross-shelf transect, define nominal stations.
- Is there already an underway mapping system on the Carson? If not, install Ryan / CANON system. Can we augment it (ac-s or ac-9, FRRF from Kudela)?
- How can we deploy Kudela's optical profiling package (stand-alone cage swapped with Carson CTD or migrate optical sensors to Carson CTD)?
- What is the duration of a standard day operation on the Carson? (I see 10h and 12h in different places.)
- Near-real-time processing of Dorado sensor data: SSDS / on ship, etc.

Drifters

- Use Stella or Pacific Gyre drifters? (have two Pacific Gyre drifters that need servicing)

- The relatively long drogue tether that is required introduces some concerns about drag and the consequences of vertical shear in horizontal currents, which can dunk the surface float (G. Friederich). These risks can be minimized with relatively minor modifications in the tether material (coated twisted stainless cable suggested), and possibly the drogue (if vertical shear is very strong between the surface and DCM).
- Plan for quickly adapting length according to DCM depth.

Dorado

- Confirmed two complete sets of Gulpers to speed Dorado turnaround during day operations.
- UCSC / USC processing of Gulper samples, student involvement
- Gulper sample analysis on ship / shore for rapid results versus detailed results. What is the quickest way to quantify Pseudo-nitzschia abundance (molecular assay or microscopy)?
- LOPC requires servicing; Doug is determining turnaround time for this.

Risk avoidance

- For AUVs, consider the risk analysis provided by Burt relative to our study domain
- For coordinated ship/AUV sampling in Lagrangian operations.

Pre-experiment data analysis

- ROMS analysis of "preferred" transport pathways between the channel DCM and shelf
- Glider-based analysis of DCM patterns during upwelling and relaxation
- CODAR and ADCP: evaluation of whether surface currents are representative of DCM-depths during upwelling and relaxation; possible evaluation of tides in ROMs (Yi).
- AVHRR image analysis to define "typical" upwelling / relaxation patterns.

ODSS

- Clarify how ODSS will be used on shore / ship, how to best manage discussion of data for near-real-time planning, a complete listing of what data sets will go into / through ODSS, etc.
- Will risk analysis for AUVs and gliders be incorporated into ODSS (Kanna, USC meeting notes)?

Coordination with greater ECOHAB team

- Make Carson and Yellowfin operations most effective / complementary
- Use of glider-tending boat for drifter chasing, if needed?
- Use of Kudela incubators by Caron lab?
- Will USC gliders run the "standard" survey? Are there motivations for a different survey pattern in this experiment? Will USC gliders cover the ESP array (Kanna, USC meeting notes) before arrival of LRAUVs then move on to larger-area surveys (Figure 2)?

Contingency planning

- What if there is no evidence of Pseudo-nitzschia populations in the focal study region by the time the Carson begins operations? Should we stay put with consistent sampling throughout the intensive, or might we extend operations toward the hypothesized source region NW of the shelf? Within day operations, we could likely achieve an effective section across the channel off Pt. Fermin with Dorado and ship CTD.