

C-MORE 2012: The Hawaii Ocean Experiment (HOE)

SUMMARY: This summer C-MORE will conduct an extended field experiment to observe and interpret temporal (diel to seasonal) variability in microbial processes, and the ecological and biogeochemical consequences thereof. We seek fundamental information on the relationships between and among the physical forcing and the biological response of processes in the North Pacific Subtropical Gyre (NPSG). Special focus will be given to time-space coupling because proper scale sampling of the marine environment is an imperative, but generally neglected aspect of marine microbiology. We propose to conduct a “continuous”, long-term field experiment in the NPSG on a scale and scope that has never previously been achieved. This experiment will be conducted at the Hawaii Ocean Time-series (HOT) Sta. ALOHA, which has an extensive 23-year data archive for many relevant physical, chemical and microbiological parameters. By complementing the approximately monthly HOT observations with much higher frequency measurements and experiments, we can open new windows of opportunity and test numerous hypotheses about microbial life in the sea. Together, this HOT-CMORE research collaboration will comprise the Hawaii Ocean Experiment (HOE; *hoe* is a Hawaiian word meaning: *get to work, keep working, do your share, paddle a canoe*). The initial focus will be on the DYNAMICS of Light And Nutrients, so the 2012 HOE campaign will be termed HOE-DYLAN. We now seek your input, ideas, discussion and especially, your participation.

BACKGROUND: The ocean is an ephemeral and dynamic habitat, and its microbial inhabitants are poised for the ecological opportunity presented by this habitat variability. Physical and microbial processes vary on time and space scales ranging more than 9 orders of magnitude in each dimension (minute to century time scales, and millimeter to ocean basin space scale). Most previous investigations have adopted observational windows of convenience, rather than a sampling program based on the scales of variability that matter for the ecological and biogeochemical processes under investigation. This is due, in part, to the overlapping nature of relevant time and space scales and to the overwhelming magnitude and complexity of an ideal sampling and analysis program. The goal of HOE is to design and conduct a multi-scale, multi-discipline experiment at unprecedented temporal frequency and duration at an oligotrophic station in the NPSG. The fusion of complementary data will improve understanding and enhance modeling of the fundamental questions regarding controls on microbial productivity, diversity and function in the sea.

Most ecological processes are ultimately linked to physical forcing including climate variability. However, no universally applicable predictive theory currently exists. For example, both enhanced turbulent mixing and enhanced stratification can lead to increased rates of primary production, but for fundamentally different reasons and by different microorganisms. A current unresolved controversy is the concept of a ‘net heterotrophic’ surface ocean. Short-term experimental measurements (lasting 12-24 hrs) of most oligotrophic ecosystems conclude that they consume more organic carbon and oxygen than they supply via contemporaneous primary production. Nevertheless, in the longer term (weeks to months) they produce excess oxygen and export organic carbon to the deep sea, documenting that they are net autotrophic. These contradictory observations can be reconciled if the system operates as a non steady-state system, with short lived bursts of oxygen and organic carbon production superimposed on a background state of net heterotrophy, as now seems to be the case. This type of feast or famine existence requires either intense predator-prey cycles (top-down control) or the aperiodic delivery of nutrients (bottom-up control), or both. The production and consumption of oxygen and organic matter are arguably the most fundamental processes in any ecosystem, yet we are largely ignorant of how these fluxes are regulated in the open ocean. The greater the number of time periods and space scales that are involved, the greater the required measurement intensity to achieve even a basic understanding of who is there and what they are doing. As oceanographer Henry Stommel cautioned many years ago, “Where so

much is known, we dare not proceed blindly – the risk of obtaining insignificant results is too great.” Undersampling is, unfortunately, a sobering fact of life in microbial oceanography.

A revolution is underway in microbial oceanography, ignited in part by the application of novel molecular-based techniques. These approaches have led to the discovery of new organisms, genes and metabolic pathways that have altered our basic paradigms of the structure and function of marine ecosystems. Proper scale sampling of the marine environment is an imperative but generally neglected aspect of marine microbial ecology. Generally, sampling is achieved on relatively short-term (a few weeks, at most) ‘expeditions’ that are planned well in advance of deployment and mostly inflexible in their scheduling. We cannot simply adopt the observational ‘window’ of greatest convenience, but rather we must design our studies to match the scales that matter to the microbes. In most oceanographic field studies the number of samples that are collected is regrettably small and usually inadequate for the intended purpose.

Major technological advances for unattended, remote ocean observations are rapidly changing our views of the scales of variability in marine ecosystems. However, remote data collection using satellites, floats or gliders is still limited to only a few parameters, and there is no sample recovery. Recent progress with the Scholin-ESP and the Taylor-SID, both deployed on the recent C-MORE BioLINCS expedition, are starting to alter the way we can and eventually will sample the sea. Because microorganisms have the ability to respond rapidly to environmental changes we need to be able to understand high frequency variability (daily), and to incorporate short-lived microbial processes into our conceptual and numerical models of the mean ocean state. Furthermore, we also need to resolve individual subpopulations of the diverse microbial assemblage, perhaps even at the scale of single cells, to determine how populations and communities are structured and how they interact. Several of the most basic ecological processes in the NPSG, including solar energy capture, net ecosystem metabolism, supply of deep water nutrients, production and turnover of dissolved organic matter (DOM) and control of particulate matter export and carbon sequestration are under-sampled even by the intensive monthly occupation of Sta. ALOHA.

PROSPECTUS: Our logistical plan is to conduct several high frequency (hourly), long duration (several months) experiments to resolve key ecosystem processes on the scales that matter both to the microbes and to the large scale biogeochemical cycles. This comprehensive field experiment, HOE-DYLAN, will begin on 21 May 2012 with a short cruise to deploy a bottom-moored sediment trap array, two Seagliders and possibly other remote instrumentation (NOTE: If there is interest and demand to justify the expense, we could deploy the HALE ALOHA full ocean depth mooring). Then from June to October there will be ample opportunity to collect samples, conduct experiments, deploy instruments and then some on a series of C-MORE, HOT and “other” cruises that will be operating at or near Sta. ALOHA. We “control” the C-MORE cruises, but berths and wire time aboard HOT and other will be on an opportunity available basis. The fact that the R/V *Kilo Moana* will be near Sta. ALOHA for such an extended period of time may be a “once in a scientific lifetime” opportunity. The schedule cruises are: 15-19 May (HOT), 21-25 May (C-MORE), 28 May – 7 June (Other), 12-21 June (C-MORE), 23-27 June (HOT), 29 June – 7 July (Other), 8-28 July (C-MORE), 30 July – 3 Aug (HOT), 9-18 Aug (C-MORE), 20-24 Aug (HOT), 26 Aug – 15 Sept (C-MORE), 22-26 Sept (HOT), 28 Sept – 1 Oct (C-MORE), 19-23 Oct (HOT). While not all research activities or target sampling can be (or needs to be) done on all cruises, this is certainly a possibility but obviously needs to be carefully planned and executed.

Due to the recent uncertainties surrounding the R/V *Kilo Moana*, it was impossible to begin detailed planning for HOE-DYLAN. However, the U.S. Coast Guard approved the vessel for service a few weeks ago and she is now en route to a shipyard in Portland, OR to effect the necessary repairs to the hull. While the dates given above may slip by a few days, they are for the most part solid – so now is

the time to plan the C-MORE sponsored legs of the 2012 expedition. I tried, unsuccessfully, to identify a C-MORE scientist who could serve as the CEO of HOE for 2012. While some volunteered to assist in planning and execution, no one was in a position to take on full expedition leadership so I have agreed to do so, but only with your collective help! I believe that the best way to move forward is to establish a small committee of interested parties; I will chair the planning committee. So with this “all hands” document I am asking for volunteers who might wish to serve as either Chief Scientist or Junior Chief Scientist for one of the C-MORE legs, or otherwise contribute your talents and efforts serving on the committee. Whether you are able to help in a leadership capacity or not, I hope you may be interested in participation – so now is the time to speak out. Thanks.

Science Plan: This will be developed by all of you, through a series of teleconferences that will commence soon after I get a sense of the level of interest across the Center. However in a general sense we will characterize the abundance and diversity of organisms that catalyze major biogeochemical pathways, using traditional and modern high throughput approaches, to determine the dynamics of populations over a broad range of time scales never before observed in the open sea. While the initial focus will be on light and nutrients as primary controls on microbial activity, these are very broad and inclusive themes that can cover most of the research currently conducted in C-MORE. Among our top priorities is to capture episodic blooms that are rarely observed during short cruises, and to study their development and demise in a sustained way. We will be able to relocate the R/V *Kilo Moana*, as needed, to study surface phytoplankton blooms detected by satellites or subsurface blooms detected by Sea Gliders. Both types of blooms have been reported in this region of the NPSG.

Example research questions that might be addressed in fundamentally new ways include: (1) How do physical perturbations like wind, eddies, currents and mixing impact microbial productivity and diversity? (2) How do phytoplankton blooms form and evolve? Are the eukaryote assemblages in them clonal? How and when does sexual reproduction occur in diatom assemblages? (3) How do ‘non-bloomers’ such as *Prochlorococcus* respond during eukaryote-based phytoplankton blooms? How does *Prochlorococcus* restore dominance in the post-bloom ocean? Do specific *Prochlorococcus* ecotypes “bloom?” (4) How do the heterotrophic bacterial populations change as the bloom alters the composition and concentrations of DOM? (5) What is the time scale of change in the phage, micrograzer (protozoa) and macrograzer (zooplankton) communities? (6) Are the cycles of C, N and P coupled in time and space? What is the role of N₂ fixation? and (7) Is light the key habitat variable for ecosystem processes? What is the role of photoperiodism?

To approach these and related questions, our investigations will focus on both single cells and selected target populations to determine who is there and what they are doing. The single cell assays will range from genome analyses, to single cell activity, to elemental composition (C, N, P, S, O) using electron microscopy and X-ray microanalysis. For the first time ever, we will be able to relate taxonomy to elemental composition to metabolism, and determine the population distributions (e.g., normal, skewed, multi-modal) for each property. Population and community measurements will focus on controls of solar energy capture and net community metabolism, as well as emergent ecosystem properties like large scale element cycles and ecological stoichiometry. Ecosystem-scale experiments, including artificial upwelling and phosphate loading, will test model predictions regarding nutrient limitation and carbon sequestration potential. HOE research will also support outreach, and provide a vehicle to educate the general public on contemporary scientific issues of great societal relevance. These are just a few of the many topics that might be studied during HOE-DYLAN.

Overall it should be a thrilling year. Welcome aboard!