Cruise Report

California Current Ecosystem LTER Program
CCE-P1408, Process Cruise #6
R/V MELVILLE, 6 August – 4 September 2014

Compiled and submitted by: Michael R. Landry, Chief Scientist
Scripps Institution of Oceanography, Univ. California, San Diego

Cruise ID: CCE-P1408, aka MV1406
Depart: 6 August 2014 at 0800 (PST)
Return: 4 September 2014 at 0800
Vessel: R/V MELVILLE
Operator: Scripps Institution of Oceanography
Master: Captain Christopher Curl
Chief Scientist: Michael R. Landry
Marine Technicians: Keith Shadle, Rob Palomares, Carl Mattson, Bud Hale

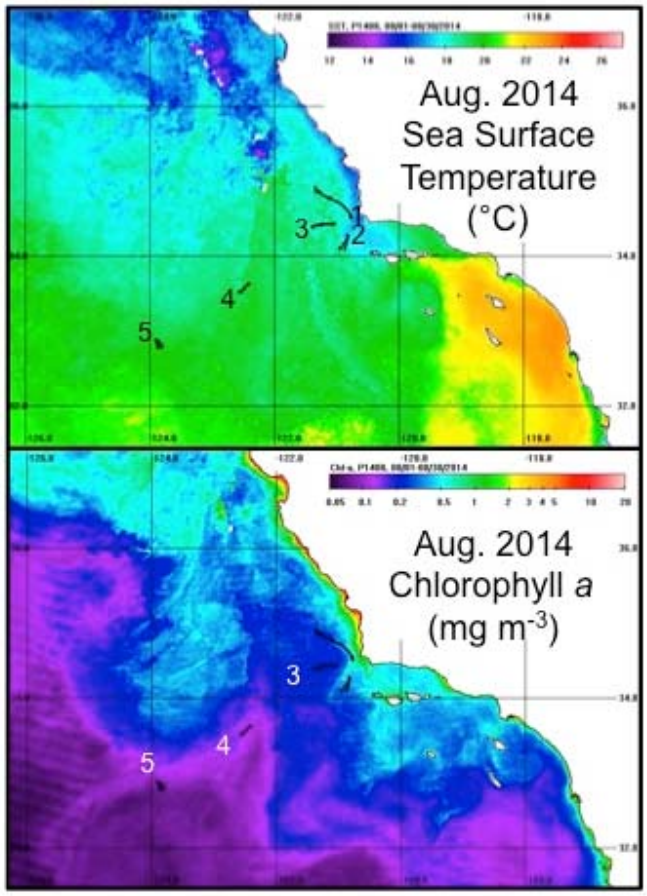


Fig. 1. Locations (drifter trajectories) of experimental Cycles 1-5 during P1408 superimposed on satellite images of sea surface temperature (SST) and surface chlorophyll *a*. Images are averaged for the month of August 2014 (1-30 Aug.), but over-represent the later cruise due to early cloud cover. Cycle numbers are positioned at the starting side of drifter experiments, and lines show distances and directions of drift over ~3 days. Images courtesy of M. Kahru.

Contents

CCE-P1408: CRUISE PERSONNEL

1.	Michael Landry	mlandry@ucsd.edu	Chief Scientist, SIO
2.	Mark Ohman	mohman@ucsd.edu	Project PI, SIO
3.	Katherine Barbeau	kbarbeau@ucsd.edu	Project co-PI, SIO
4.	Ralf Goericke	rgoericke@ucsd.edu	Project co-PI, SIO
5.	Michael Stukel	mstukel@umces.edu	Scientist, Florida State
6.	Alan Giraldo Lopez	alan.giraldo@correounivalle.edu.co	Scientist, Columbia
7.	Fanny Chenillat	fchenillat@ucsd.edu	Post-doc, SIO
8.	Peter C. Davison	pdavison@ucsd.edu	Post-doc, Farallon Inst.
9.	Andrés Gutiérrez	gutierrez@sb-roscoff.fr	Post-doc, France
10.	Andrew Taylor	agtaylor@ucsd.edu	Post-doc, SIO
11.	Rasmus Swalethorpe	rsw@aqua.dtu.dk	Post-doc, Denmark
12.	Carmina Ramirez	chramirez@cusdk12.org	Educator, K-12
13.	Marc Picheral	marc.picheral@obs-vlfr.fr	Engineer, France
14.	Mark Hafez	markhafez@hotmail.com	Technician, LDEO
15.	Megan Roadman	mroadman@ucsd.edu	Technician, SIO
16.	David Jensen	dwjensen@ucsd.edu	Programmer, volunteer
17.	Tristan Biard	tbiard@sb-roscoff.fr	Grad Student, France
18.	Jennifer Brandon	jennibenni@mac.com	Grad Student, SIO
19.	Tyler Coale	tcoale@ucsd.edu	Grad Student, SIO
20.	Alain De Verneil	adeverneil@gmail.com	Grad Student, SIO
21.	Alexandra Freibott	afreibott@ucsd.edu	Grad Student, SIO
22.	Irina Köster	ikoester@mail.ucsd.edu	Grad Student, Germany
23.	Lauren Manck	lmanck@ucsd.edu	Grad Student, SIO
24.	Amanda Netburn	anetburn@ucsd.edu	Grad Student, SIO
25.	Catherine Nickels	cnickels@ucsd.edu	Grad Student, SIO
25.	Angel Ruacho	aruacho@ucsd.edu	Grad Student, SIO
27.	Brandon Stephens	bmstephe@ucsd.edu	Grad Student, SIO
28.	Bellineth Valencia	bellival@ucsd.edu	Grad Student, SIO
29.	Ben Whitmore	bmwhitmo@ucsd.edu	Grad Student, SIO
30.	Jamie Chang	jwc018@ucsd.edu	Undergrad Student, UCSD
31.	Maya Land	majibula@gmail.com	REU Student, UCSD
32.	Kyra Rashid	krashid@ucsd.edu	REU Student, UCSD
33.	Jasmine Tan	jasminehtan.94@gmail.com	REU Student, UCSD

SCIENCE OBJECTIVES

This was the sixth Process Cruise of the CCE LTER (California Current Ecosystem, Long-Term Ecological Research) Program, which has the long-term goals of understanding the coupling of physical, chemical and biological dynamics in the California Current ecosystem and, ultimately, the system responses to long-term climate variability. As the last cruise of CCE-LTER Phase 2, we aimed initially to continue Phase 2 investigations of altered nutrient transport, primary production, plankton community structure, predator-prey interactions, and export along ocean frontal gradients, along the lines of our previous two process cruises. However, gear circumstances and anomalous ocean conditions encountered during the early phase of the cruise caused us to abandon that aim and adapt to the more compelling science opportunities at hand. As described further below, the SeaSoar was lost during the second day of its initial deployment along with the LOPC (Laser Optical Plankton Counter) controller for the Moving Vessel Profiler (MVP), which was installed on the SeaSoar. This loss of underway profiling capability was compounded by the lack of satellite imagery (cloud cover) and US naval restrictions on our areas of operation, essentially eliminating the possibility of long exploratory excursions to find and investigate fronts. At the same time, our initial observations as well as those from CalCOFI and MELVILLE (MV1405) cruises during the previous month showed that ocean conditions from southern California to Oregon were highly anomalous in the CCE coastal region -- with severely reduced winds and upwelling, surface water warming by several degrees (**Fig. 2**), reduced chlorophyll and abundant gelatinous zooplankton. Such conditions are consistent with El Niño-like conditions, but at the time of our cruise the ENSO indicators at the equator were equivocal to mild, suggesting a surprisingly strong regional response to an as-yet-unclear forcing mechanism. We thus revised our science plan *to document and investigate process rates and relationships – essentially the standing stocks, production and fate of pelagic biota – associated with anomalous ocean conditions of summer 2014*. Our experimental studies focused on the typically dynamic upwelling region off of Points Conception and Arguello, and they extended to adjacent offshore waters as coastal conditions remained largely unchanged over the first two weeks of our observations. Our early thought that we might capture the resurgence of normal upwelling conditions later in the cruise were not realized, although we laid the groundwork for that possibility had we experienced an extended period of strong favorable winds.

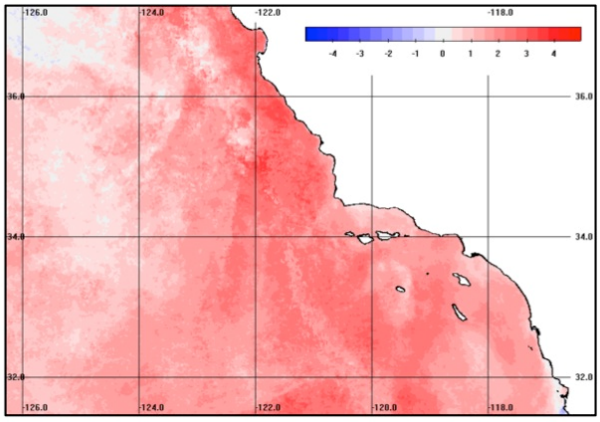


Fig. 2. Regional distribution of SST anomalies for August 2014 based on satellite imagery relative to mean August climatology. Courtesy of M. Kahru

OVERVIEW OF THE SCIENCE PLAN

As described above, our science plan evolved from an initial focus on frontal dynamics to experimental studies during conditions of weak wind forcing of process rates and relationships in representative water parcels from coastal to offshore areas. For both, our interest centered on the unusual warm water and low-upwelling conditions around Point Conception. Our first efforts to document these conditions involved an MVP spatial survey (#1) consisting of 8 connected in-out transect lines from deeper to shallow water around the point (**Fig. 3**). A SeaSoar survey, occupying about one square degree of latitude-longitude, was then laid out to extend the 3-D mapped area further offshore of the point and to reveal frontal systems, if any, that were appropriate for experimental study. SeaSoar was lost without warning on the 5th outbound leg of the survey under calm sea conditions (over deep water and not during a turn). The snatch block that was especially purchased for the SeaSoar operation inexplicably opened. The wire fell and was observed to rest briefly on the life-line cable on the fantail, and it ultimately broke at that point. Loss of the SeaSoar also removed the MVP from operation because the LOPC controller for the MVP was installed on SeaSoar to measure particle size distributions on the grid pattern. That latter loss was remedied by arranging for the manufacturer to ship us a loaner LOPC, which we picked up in a port stop in Santa Barbara several days later. Instrument delivery was coordinated by LTER colleague Dan Reed from the SBC LTER site. In the meantime, we identified a nearshore area from the original MVP survey for experimental study, did a bowtie survey of surface parameters (ALF)

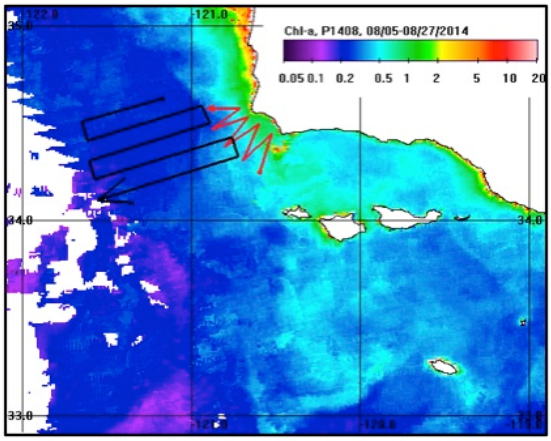


Fig. 3. Initial MVP (red lines) and SeaSoar (black lines) survey transects in the Pt. Conception and Pt. Arguello region. SeaSoar radiator grid shows only the lines completed before the instrument loss. Satellite surface Chl *a* image is the mean for dates 5-27 August. Courtesy of M. Kahru.

and ADCP currents to pick an initial station site with homogeneous water properties, and conducted our first process experiment (Cycle 1).

Beginning with Cycle 1 and continuing after the LOPC was replaced, our science design followed the experimental cycle approach more typical of CCE Phase 1 Process cruises. We completed 5 experimental cycles. Each followed the temporal evolution of a water parcel marked with a satellite-tracked surface drifter (mixed-layer drogue centered at 15 m) for a period of 3 days while various measurements were made on community composition and process rates (**Fig. 1**). The first three experiments were initiated in more coastal waters, and followed drift trajectories north (Cycle 1), south (Cycle 2) and east (Cycle 3) relative to Point Conception. With the winds continuing to be unfavorable for driving strong coastal upwelling, we moved the last two cycles progressively further offshore to compare system dynamics over the spatial scale

investigated on previous cruises. Cycle 4 began in the vicinity of CCE mooring #1 along CalCOFI Line 80 in the core of the California Current proper. Cycle 5 began at the offshore end of Line 80.

Each quasi-Lagrangian cycle experiment involved a coordinated series of sampling and *in situ* and shipboard experimental activities to measure changes in hydrography and the plankton community in the tracked water parcel, to determine process rates (production, growth, grazing and export), and to evaluate nutrient and trace metal limitation of the phytoplankton community. Export was assessed by the 234-Thorium method and by measured fluxes into sediment traps deployed below the euphotic zone on a second drifter array (deployed at the start of the cycle and recovered at the end). Process experiments were conducted at 6 depths daily using water collected on a pre-dawn hydrocasts from the top to the bottom of the euphotic zone. Measured variables included: temperature, conductivity, density, nutrients (dissolved inorganic N, P, Si), total organic carbon and nitrogen (TOC, TON), particulate carbon and nitrogen (POC, PON), stable isotopes of C and N, particulate biogenic silica (bSi), thorium-uranium disequilibrium, fluorometric Chl*a* and HPLC accessory pigments, microscopical and flow cytometric assessments of microplankton community composition, and samples for molecular analyses. *In situ* bottle incubations were conducted with water from the same hydrocast to measure ^{14}C-primary production, new production (^{15}N-nitrate uptake), and phytoplankton growth and microzooplankton grazing rates (dilution). These incubations were conducted for 24 hours in net bags attached on a line below the drift array (therefore incubated under in situ conditions of temperature and light).

Using the drift array as a moving frame of reference, additional CTD sampling was conducted at mid-day for shipboard assessments of primary production, bacterial production and organic matter composition, and typically in the evening for shipboard experimental studies of phytoplankton growth and microzooplankton grazing (full dilution experiments), mesozooplankton reproduction and feeding, and radiolarian composition and ecology. The latter two were accompanied by short net tows to collect live organisms. As on several previous CCE cruises, an Underwater Vision Profiling system (UVP5), operated by guest researcher Marc Picheral (Villefranche-sur-Mer), was integrated into the CTD package for depth profiles of zooplankton, radiolarians and aggregate distributions to 700 m on most casts.

The Trace Metal (TM) rosette was used to collect water samples for iron (Fe) profiles, organic matter degradation experiments, and incubations relating to iron limitation and 24-h ^{15}N-nitrate uptake experiments (an index of Fe limitation), the latter incubated on the drifter line. Mesozooplankton were collected for size-fractionated assessments of biomass and gut pigments before noon and midnight, using a 202-µm mesh, 0.71-cm diameter bongo net. MOCNESS net tows (202-µm) were taken at mid-day and mid-night to determine the depth structure and day-night variability of the mesozooplankton community. Sampling of mesopelagic fishes and invertebrates was conducted with the large (6 m^2) mid-water trawl (Oozeki, aka MOHT) to collect specimens for physiological assessment of oxygen stress and to document the twilight ascent of actively migrating mid-water animals into surface waters. Periodic activities also included bow-tie surveys with the MVP. These were done prior to the start of cycle experiments to determine variability in water-column characteristics and to select the most homogeneous area to initiate the experiment.

On the return transit from offshore (Cycle 5) to San Diego, an MVP transect was conducted along CalCOFI Line 90 to acquire preliminary data on the effects of hypothesized enhanced mixing over shallow bathymetry of the Santa Rosa-Cortes Ridge. This survey included underway profiles of hydrographic and biological (fluorescence, LOPC) variables to 200 m, three iron profiles (TM rosette), and surface measurements of iron (pole), fluorescence properties (ALF) and extracted Chl *a*.

GROUP REPORTS

Hydrography, Primary Production – Goericke Group (Ralf Goericke, Megan Roadman and Fanny Chenillat)

Hydrography: CTD casts were conducted every 8 to 12 hours in the vicinity of the drifter during process experiments. The package had instruments for temperature, salinity, oxygen, chlorophyll fluorescence, light attenuation by particles, photosynthetically active radiation (PAR), and nitrate (ISUS). Samples were collected from the CTD at about 8 depths per cast for concentrations of plant nutrients (nitrate, nitrite, silicic acid, phosphate and ammonia), salinity, concentrations of Chl *a* (determined fluorometrically aboard the ship), concentrations of particulate organic carbon and nitrogen, and concentrations of taxon-specific pigments. Results from these observations are summarized in **Table 1** as averages for the surface layer of individual experimental cycles.

Table 1. Cycle averages of hydrographic properties of mixed-layer waters.

Cycle	Date	Depth (m)	Temp (°C)	Sal (psu)	Sigma (kg/m^3)	Oxygen (µM)	Oxygen (% Sat)	ISUS (µM NO_3)	Fluor (Volt)	UVP_Num (per liter)
1	08-12-14	11.46	16.31	33.46	24.50	252	103	3	0.06	302
2	08-18-14	11.22	16.88	33.41	24.33	245	101	3	0.08	135
3	08-23-14	11.45	18.26	33.32	23.92	233	99	3	0.04	52
4	08-27-14	11.23	19.08	33.02	23.49	227	98	2	0.01	26
5	08-30-14	11.42	19.65	33.08	23.39	223	97	3	0.01	19

Temperature-salinity diagrams allow the identification of water masses and the tracking of changes of water masses between stations. The average TS diagrams for all P1408 cycles (**Fig. 4**) show that these cycles fall into two categories, coastal (Cyc 1 & 2) and offshore (Cyc 3 to 5). The influence of California Current waters in the offshore profiles is evident from the cool and fresh waters. The offshore cycles differ in the degree of warming in the surface layer. Cycle 3 water masses suggest that some mixing occurred between coastal and offshore waters. The TS diagrams of all casts for the individual cycles (**Fig. 4**) illustrate the variability of the water masses encountered during the cycles or the absence of such variability.

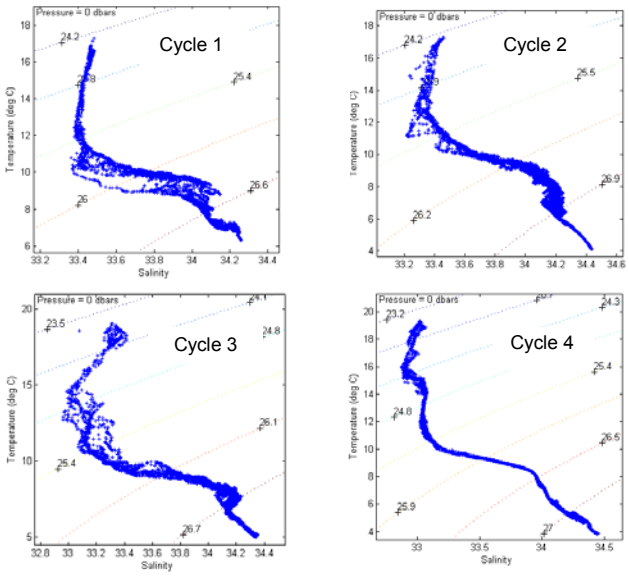


Fig. 4. TS diagrams for all casts of individual cycles, illustrating water mass variability, or absence thereof, during the cycles.

***Phytoplankton community pigments*:** Concentrations of taxon-specific pigments, chlorophylls and carotenoids, were sampled from early morning and mid-day CTD hydrocasts to determine relative contributions of different taxonomic groups to total phytoplankton pigment-biomass. These samples will be analyzed ashore for concentrations of pigments, and phytoplankton community structure will be determined from those samples. We also size-fractioned Chl *a* in selected samples from the mixed layer or the deep chlorophyll maximum (DCM) in order to assess variability in the distribution of phytoplankton biomass over different size categories. Results from these experiments are shown in **Table 2**. The size distribution for the surface layer is shown in **Fig. 5** for the five cycles, illustrating the relative scarcity of large phytoplankton in the oceanic regions.

Primary Production: Rates of primary production were determined from the incorporation of 14C into particulate carbon and dissolved organic carbon. Such rates constrain how much carbon is available for higher trophic levels. Samples will be analyzed ashore.

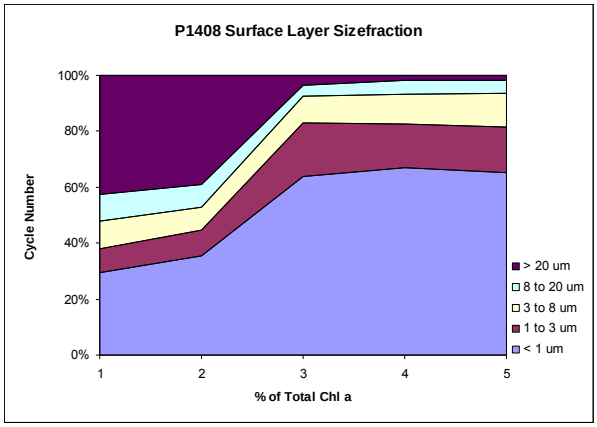


Fig. 5. Average Chl a size distributions for the 5 Cycles (N.B. Labels on the ordinate and abscissa are reversed.)

Table 2. Results of chlorophyll size fractionation with water from the 2 am CTD casts from the mixed layer (ML) and the noon CTD from the Deep Chl Maximum (DCM). Shown are the number of experiments (n), Chl a concentration for the sample (TChl*a*) and the % of TChl in the <1 µm, 1-3 µm, 3-8 µm, 8-20 µm and >20 µm size fractions.

Cycle	Location	Depth (m)	n	TChl*a* (µg/L)	<1 µm (% TChl*a*)	1-3 µm (% TChl*a*)	3-8 µm (% TChl*a*)	8-20 µm (% TChl*a*)	>20 µm (% TChl*a*)
1	ML	9	7	0.63 ± 0.16	29 ± 5	9 ± 3	10 ± 5	9 ± 6	43 ± 5
2	ML	8	4	0.72 ± 0.12	35 ± 4	9 ± 3	8 ± 2	8 ± 2	39 ± 7
2	DCM	34	3	0.95 ± 0.22	29 ± 7	18 ± 5	10 ± 1	9 ± 1	34 ± 6
3	ML	8	4	0.19 ± 0.09	64 ± 2	19 ± 1	10 ± 2	4 ± 1	3 ± 1
3	DCM	41	3	0.75 ± 0.02	44 ± 4	33 ± 3	16 ± 2	5 ± 1	2 ± 1
4	ML	11	4	0.10 ± 0.05	67 ± 6	16 ± 6	11 ± 1	5 ± 1	2 ± 0.4
4	DCM	66	3	0.40 ± 0.01	59 ± 2	27 ± 2	8 ± 2	4 ± 1	2 ± 0.4

Advanced Laser Fluorometry – LDGO (Mark Hafez and Alexander Chekalyuk)

Two custom-built ALF (Advanced Laser Fluorometer) instruments were used for underway fluorescence and discrete sample analysis during the P1408 experimental cycles and in support of underway SeaSoar and MVP surveys. The ALF is a portable bench top instrument that combines high-resolution spectrally and temporally resolved flow-through measurements of laser-stimulated emission from seawater, allowing for real-time spectral deconvolution of the signals associated with Chl *a*, phycobiliprotein pigments associated with different types of *Synechococcus*, chromophoric dissolved organic matter (CDOM), and variable fluorescence, Fv/Fm indicative of phytoplankton photochemical efficiency and photophysiological status. For underway measurements, the instruments were connected to the ship's uncontaminated seawater system which provided a steady flow of water. In addition to the underway measurements that were taken along SeaSoar and MVP surveys (**Fig. 6**), the ALF was used prior to Cycle 1 to conduct a bow-tie survey to map the target area of interest during the time when MVP was not operational. During the experimental cycles, one ALF instrument was used for discrete sample analysis. Samples were taken from every noon CTD cast. A total of 16 casts were sampled with 118 samples measured. Both instruments imported MET and GPS data from the ship to provide additional data to relate ALF data to. Additional analysis will be conducted at later time on shore of data in relation to other sampling, such as HPLC and Chl *a* measurements, to calibrate and validate ALF measurements from the cruise.

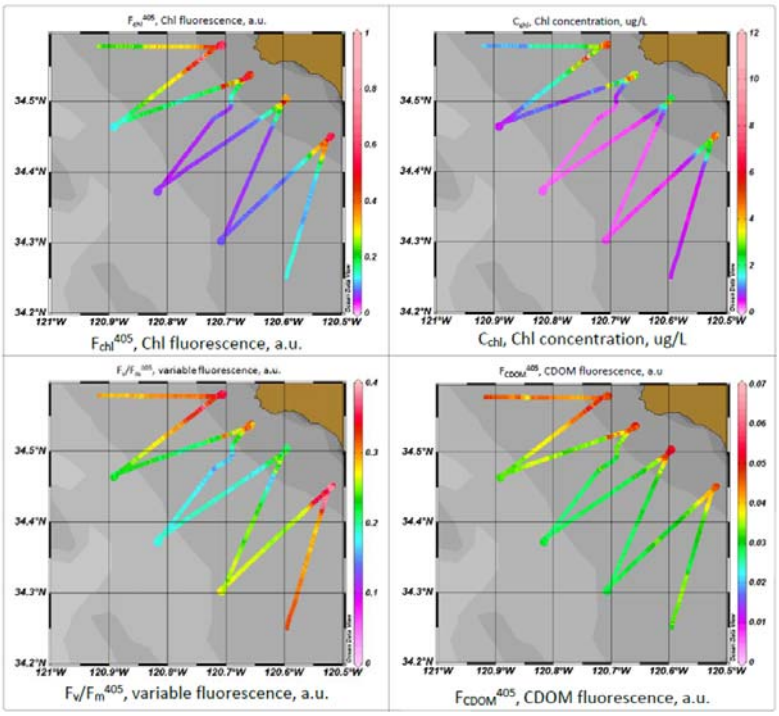


Fig. 6. ALF variables measured during MVP survey #1 off of Pt. Conception. Clockwise: Underway Chl *a* fluorescence, Chl *a* concentration, CDOM fluorescence, and Fv/Fm (variable fluorescence), all at 405 nm excitation.

Trace Metal Studies – **Barbeau Group** (Kathy Barbeau, Angel Ruacho, Lauren Manck and Tyler Coale)

The trace metal group completed 38 sampling casts with the trace metal rosette, including 14 profiles at 7-12 depths for dissolved and dissolvable iron distributions. The other casts were used for obtaining trace metal clean water for various incubations and experiments, for both our group and Brandon Stephens of the Aluwihare lab. In addition, 12 surface pole samples for total dissolvable iron were taken during the line 90 transect at the end of the cruise.

A new feature of our activities this year was to participate in on-array incubations, facilitated by the Landry group and utilizing paired ship CTD-Trace Metal rosette casts to begin each cycle day. In total, the trace metal group carried out 30 separate on-array incubations (5 during Cycle 1; 5 during Cycle 2; 7 during Cycle 3; 7 during Cycle 4; and 6 during Cycle 5). On-array studies consisted of iron addition incubations with $^{15}NO_3$ additions, and also Fe and Fe-chelator amendments with sampling for DNA/RNA. We also carried out on-deck experiments: 3 photochemical experiments to look at the impact of sunlight irradiation on copper speciation; and 3 5-day dark incubations to study the effect of Fe supply and Fe limitation on DOC/POC dynamics and the composition of the microbial community.

DOM Characterization and Decomposition – **Aluwihare Group (**Brandon Stephens)

My goals on this cruise studies were to characterize the surface organic matter and demonstrate potential remineralization of dissolved and suspended particulate organic matter over the course of the observed cycles. During each mid-day CTD cast, I collected samples from 6 depths for [TOC], [DOC], [DON], [POC], [PON], carbohydrates, primary amines, fluorescent and chromophoric DOM, and stable carbon and nitrogen isotopes of particulate organic matter. I occasionally collected samples for nitrate $\delta^{15}N$ and $\delta^{18}O$, which Patrick Rafter has offered to analyze by the denitrifier method.

In addition to CTD sample collections, I conducted incubation experiments on four cycles to demonstrate the modification and remineralization of dissolved organic matter by bacteria. To perform these incubations, large volume samples (60 L) were taken from the deep chlorophyll max using Kathy Barbeau's Trace Metal rosette, and 40 L were split into four replicate grazer dilution (using 10% whole water) experiments. I did not amend the water with nutrients, but kept the treatments the same in order to better account for potential natural variability and minimize contamination. The samples were incubated at in situ temperatures in the dark in a Percival incubator. To estimate bacterial remineralization of OM, during each day of incubation, I collected samples for [TOC], bacterial counts and bacterial production (^{3}H-leucine incorporation, done by Jasmine Tan). With the other 20 L of the collected volume, I used a PPL resin to isolate DOM at the initial and final time points of the incubation, and this material will then be analyzed by elemental analysis, high resolution GC/MS and NMR. Samples were taken from unpreserved sediment trap tubes for chemical characterization of the sinking POM. The sinking organic material will be compared to the suspended and dissolved phases to demonstrate the potential contributions to the signals between such pools.

Microbial Community Biomass, Growth and Grazing – Landry Group

(Mike Landry, Andrew Taylor, Alan Giraldo, Ali Freibott, Belli Valencia, Alain De Verneil, Kyra Rashid, Maya Land)

Our group was responsible for coordinating the drifter experiments, including estimates of phytoplankton growth and microzooplankton grazing rates by the dilution method, initial and final measurements of abundances and biomass of bacteria and picophytoplankton by flow cytometry (FCM), initial and final assessments of the composition, biomass and size structure of auto- and heterotrophic protists by epifluorescence (EPI) and inverted microscopy, and sampling of particulate biogenic silica (bSi). New for this cruise, we also analyzed chitobiase decay in the sampled seawater to assess spatial differences in production rates by crustacean zooplankton. During all cycle experiments, sampling (4 profiles/cycle) and rate (3 profiles/cycle) measurements were made at 6 depths using seawater collected from the early morning (typically 0200-0300) CTD cast. During the initial MVP survey and the partial SeaSoar run, surface seawater samples were taken from the ship's uncontaminated seawater line for analyses of microbial community biomass and composition (FCM, EPI microscopy). Also new for this cruise, we collected mesozooplankton from the field and conducted experimental studies of gut clearance/degradation in order to evaluate the selective role of digestive processing in the transfer of phytoplankton DNA from surface waters to sediment traps (export).

***Community composition and biomass*:** Samples (2 mL) for FCM analysis of phototrophic bacteria (*Prochlorococcus* and *Synechococcus*) and heterotrophic bacteria were preserved with 0.5% paraformaldehyde (final concentration) and flash frozen in liquid nitrogen. On shore, the samples will be stained with Hoechst 34442 prior to analysis. For epifluorescence microscopy, seawater samples (500 mL) were preserved and cleared with sequential additions of 260 µL of alkaline Lugols solution, 10 mL of buffered Formalin and 500 µL of sodium thiosulfate, followed by staining with 1 mL of proflavin (0.33% w/v) and 1 mL of DAPI (0.01 mg mL^{-1}). Aliquots of 50 mL were filtered onto 25-mm, 0.8-µm pore black polycarbonate filters to determine concentrations of nanoplankton, and the remaining 450-mL samples were filtered onto black 8.0-µm polycarbonate filters to determine concentrations of larger cells (microplankton). Filters were mounted onto glass slides and frozen at -85°C for later digital imaging in Z-stack mode at 630X (nanoplankton) and 200X (microplankton) using an automated Zeiss Axiovert 200M inverted compound microscope.

Samples (300 mL) for molecular analyses for the microbial assemblages were also collected at 6 depths per cast, and from each final natural and diluted treatment from shipboard and in situ incubated dilution experiments to assess taxon-specific contributions to community composition and growth an grazing rates. These samples were concentrated onto 0.2-µm Supor filters, packed into cryovials and frozen in LN2.

Samples for analyses of delicate heterotrophic protists, notably ciliates, were collected in 125-mL volumes, preserved with 5% acid Lugols fixative. In the laboratory, these samples will be further fixed with formaldehyde, filtered onto 8-µm pore polycarbonate filters, mounted on slides with Cargille Series A immersion oil, and imaged at 200X by light microscopy on a Zeiss Axiovert 200 M inverted compound microscope with a Zeiss AxioCam MRc black and white 8-bit CCD camera.

Samples (1.1-L polycarbonate bottles) for biogenic Si were taken at 8 depths from the 0200 CTD cast during experimental cycles and from 7 depths at the transect stations. Samples were concentrated onto 47 mm 0.6-µm PCTE filters on an all-plastic filter rig, with vigorous FSW rinses of the sample bottle to dislodge diatom cells that may have stuck to the bottle sides. The filters were placed into cryovials and dried at sea in an oven at 65°C. The sealed cryovials were stored at -85°C for later analysis.

***Growth and grazing rates*:** We used 2-treatment dilution experiments incubated at each depth on the drift array and one full dilution experiment per cycle to determine rates of growth and protozoan grazing for the total phytoplankton community (Chl *a*) and for individual populations. For the drift array, we prepared one diluted treatment and one control bottle (2.7-L polycarbonate) per depth, respectively, with 33% whole seawater (diluted with 0.1-µm Suporcap filtered seawater) and 100% seawater collected from Niskin bottles from the CTD-rosette. Initial FCM samples were taken from each bottle prior to deployment, and initial samples for Chl *a* and other variables were taken from the same Niskin bottle as the incubation water. Experiments were incubated for 24 hours (deployment/recovery ~0500 local time). Upon recovery, the incubation bottles were subsampled for FCM, pigments, microscopy and molecular analysis. Multi-bottle experiments at individual depths were also done on the array by Ali Freibott for more detailed assessments by molecular methods, and by Andrés Gutierrez to examine light-level switching responses.

Chlorophyll-based initial results show growth and grazing estimates generally on the order of 0.2-0.4 d^{-1} and not very different between nearshore and offshore cycles (e.g. Cycle 1 vs Cycle 5; **Fig. 7**), which is unusual for the region. Also atypical for the area, nutrients were depleted in surface waters even for the coastal cycles, and a deep Chl *a* max was apparent both on and offshore and in every CTD cast.

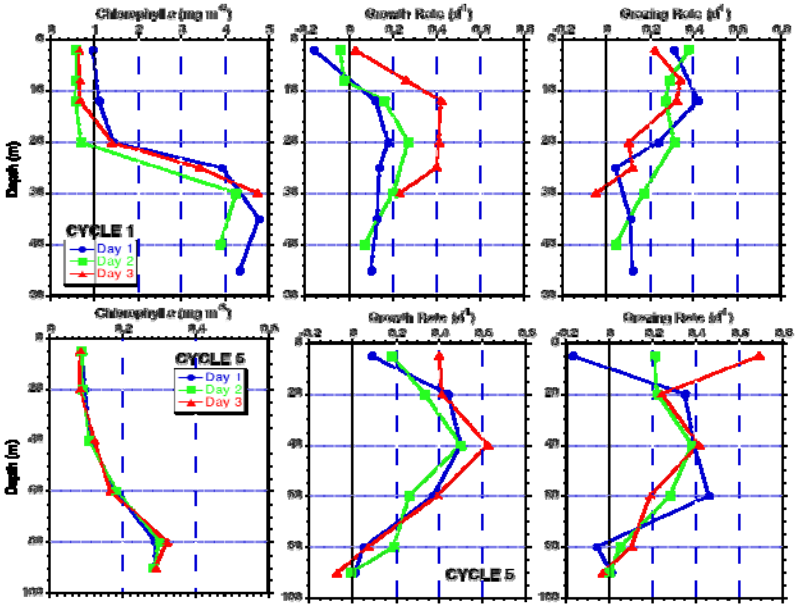


Fig. 7. Depth distributions of phytoplankton biomass, growth and protistan grazing based on shipboard Chl*a*. Low/negative growth estimates at shallow depths may reflect pigment photoacclimation of incubated samples. Cycle 1 (upper row) is the richest coastal water examined; Cycle 5 (lower row) is the most offshore/oligotrophic.

DNA processing by mesozooplankton: Naturally feeding animals were collected with rapid vertical net tows in the upper 50-100 m at night (2130 - 2230) on twelve occasions. For each cycle, fractions of the sample were immediately filtered onto a 200-µm mesh, quick-rinsed with filtered seawater, and immediately frozen at -80°C for molecular analysis of gut contents (specimens to be sorted later). To measure differences in DNA degradation rates at different rates in zooplankton guts, gut evacuation experiments were done with copepods and salps. For the experiment with copepods, females of *Metridia pacifica, Calanus pacificus* or *Pleuromamma* spp. were sorted from the samples depending on their abundance, then were left in filtered seawater for ~12 hours to allow complete evacuation of their guts (initial blank samples) and to collect their fecal pellets. They were then transferred to water with food (typically, chlorophyll maximum water), allowed to feed for ~ 3 hours, and then transferred to filtered seawater, where they were subsampled at periods of 0, 5, 10, 20, 30, 45 and 60 minutes. At each time point, the animals were immediately frozen in liquid nitrogen for molecular analysis of their gut contents. Pellets produced by the copepods during the experiments were also collected. Two gut evacuation experiments were done for *M. pacifica,* three for *C. pacificus* females and CVs¸ and five for different *Pleuromamma* spp. To estimate the rate of pellet production of salps, five experiments were done in which individuals were gently transferred to filtered seawater immediately after collection. At the end of the experiment, the pellets produced as well as the salps were frozen in liquid nitrogen for further molecular analysis. Bulk material and sorted fecal pellets collected by sediment traps in four of the cycles were also frozen in liquid nitrogen for molecular analysis.

Chitobiase activity: REU student Maya Land measured chitobiase-based production rates of crustacean zooplankton communities for each day of the cycle experiments following the protocol developed by Sastri and Dower (2006, 2009). Seawater samples (500 ml) were collected from each of the 0200 CTD casts at 6 depths. The bottles were sampled initially through a 0.1-µm filter, then spiked with copepod homogenate to increase chitobiase levels and achieve a decay curve with time-points at 0, 3, 6, 9, 12 and 24 hours at sea surface temperature (**Fig. 7**). The reaction was prepared with MBF-NAG and measured in a TC-700 Turner Designs fluorometer with appropriate filters. Due to high variability, three replicates and one blank were measured at each time point. Assuming that the copepod community is at steady state (or changing slowly, on average), the rate of chitobiase production should equal the slope of the decay curve. The decay curve for each cycle was achieved by averaging values across all depths per time point, subtracting the average blank value and plotting log [CBA/hour] vs. time. Further analysis is needed to determine bioproductivity rates using chitobiase production estimates and crustacean zooplankton biomass (or total chitin measurements).

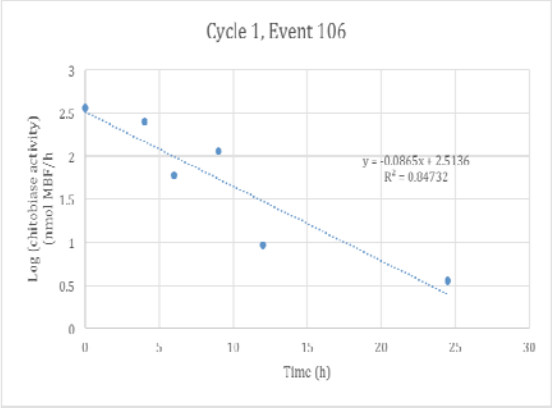


Fig. 8. Example of a chitobiase decay curve from Cycle 1.

Bacterial Biomass and Production – **Azam Group** (Jasmine Tan)

Seawater samples were taken at four depths from each mid-day (1100) CTD cast to measure cell abundance. At each depth, two cryovials were filled each with 3 mL seawater, fixed with 100 µL of 25% glutaraldehyde, and frozen in liquid nitrogen. On shore, the cryovials will be thawed, filtered onto 0.2-µm pore polycarbonate filters, and stained with DAPI. Samples will be examined microscopically to measure bacterial cell abundance.

Samples from the 1100 CTD casts were also taken to estimate rates of bacterial protein synthesis using the leucine incorporation method. In addition, samples from the POM/DOC experiments were taken to estimate rates of bacterial protein synthesis (as well as cell abundance). For each sample, 1.8-mL seawater samples were incubated with 4 µL of 140 mM ^{3}H-leucine for one hour at 12^{o}C in quadruplicate with duplicate 5% TCA killed controls. After the incubation was complete, samples were stored in a -12^{o}C freezer. On shore, these samples will be processed using the centrifugation method. After obtaining a dried pellet from each tube, scintillation cocktail will be added and the tube assayed in a liquid scintillation counter. Disintegrations per minute are converted to protein synthesis rates.

Underwater Vision Profiler (UVP5) – Marc Picheral and Tristan Biard

The Underwater Vision Profiler 5 (UVP5), an in situ plankton camera from the Observatoire Oceanologique, Villefranche-sur-Mer, France, was mounted inside the CTD-rosette frame, where it collected images during 62 downcasts to 700 m on most deployments, and to a maximum depth of 3000 m on two casts during Cycle 5. The Ocean Data View "baseuvp5_sn003_ccelter _2014_cal_lpm_odv.txt" compatible files include LPM abundances and biovolume spectra binned in 5-m intervals. A total of 142,045 vignettes were pre-sorted on the cruise using a 5 category Learning Set, and then validated into 25 final categories, including copepods, other crustaceans, and various categories of aggregates, radiolarians, and suspension-feeding and predatory gelatinous plankton (salps, appendicularians, pyrosomes, ctenophores, siphonophores, etc.). Examples of the images in selected categories and the relative spatial abundance patterns in the upper 100 m are shown in **Figures 9 - 10**. Additional sorting will allow more precise discrimination of organism/aggregate types and their depth distributions.

Fig. 9. Examples of UVP5 categories and images.

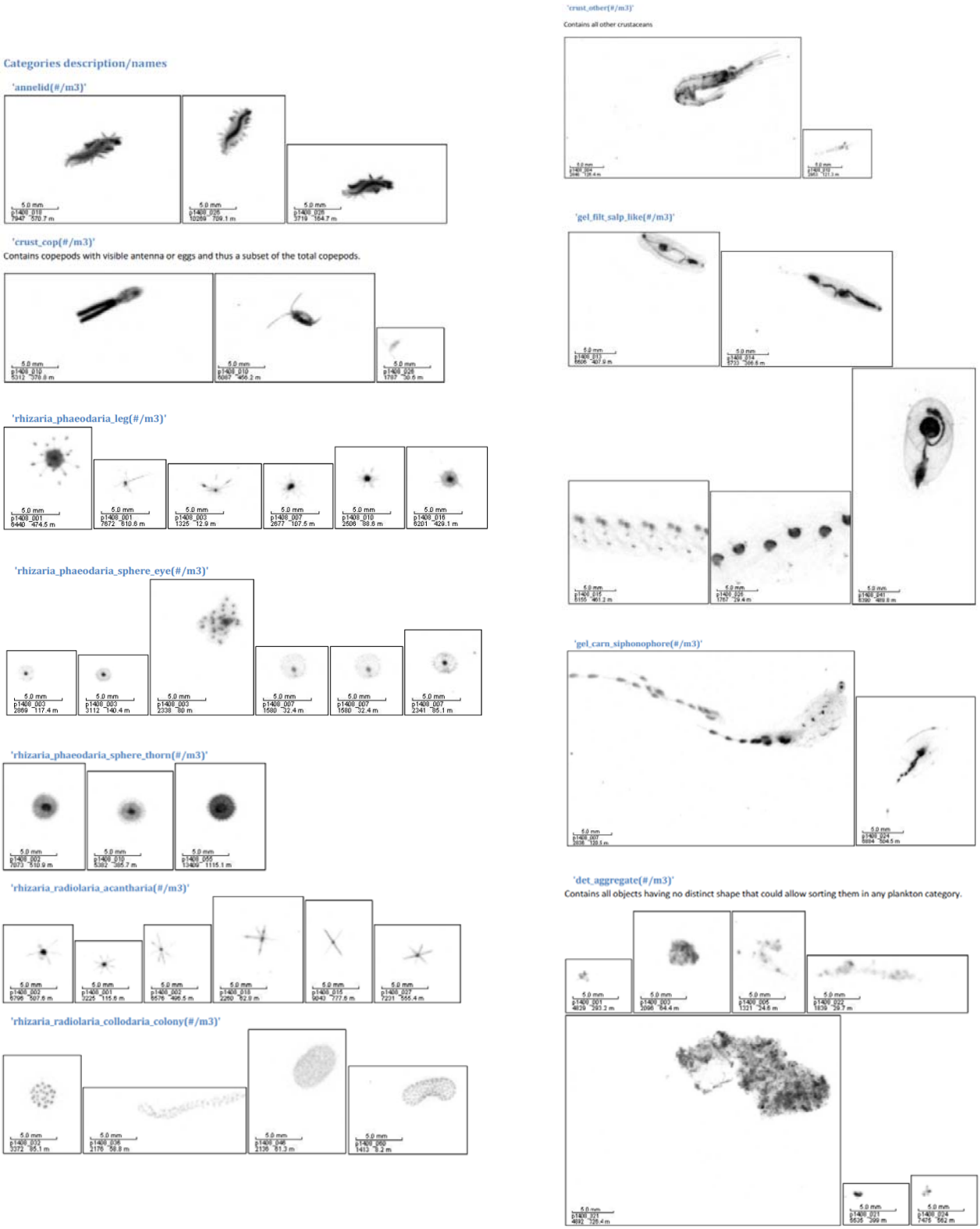
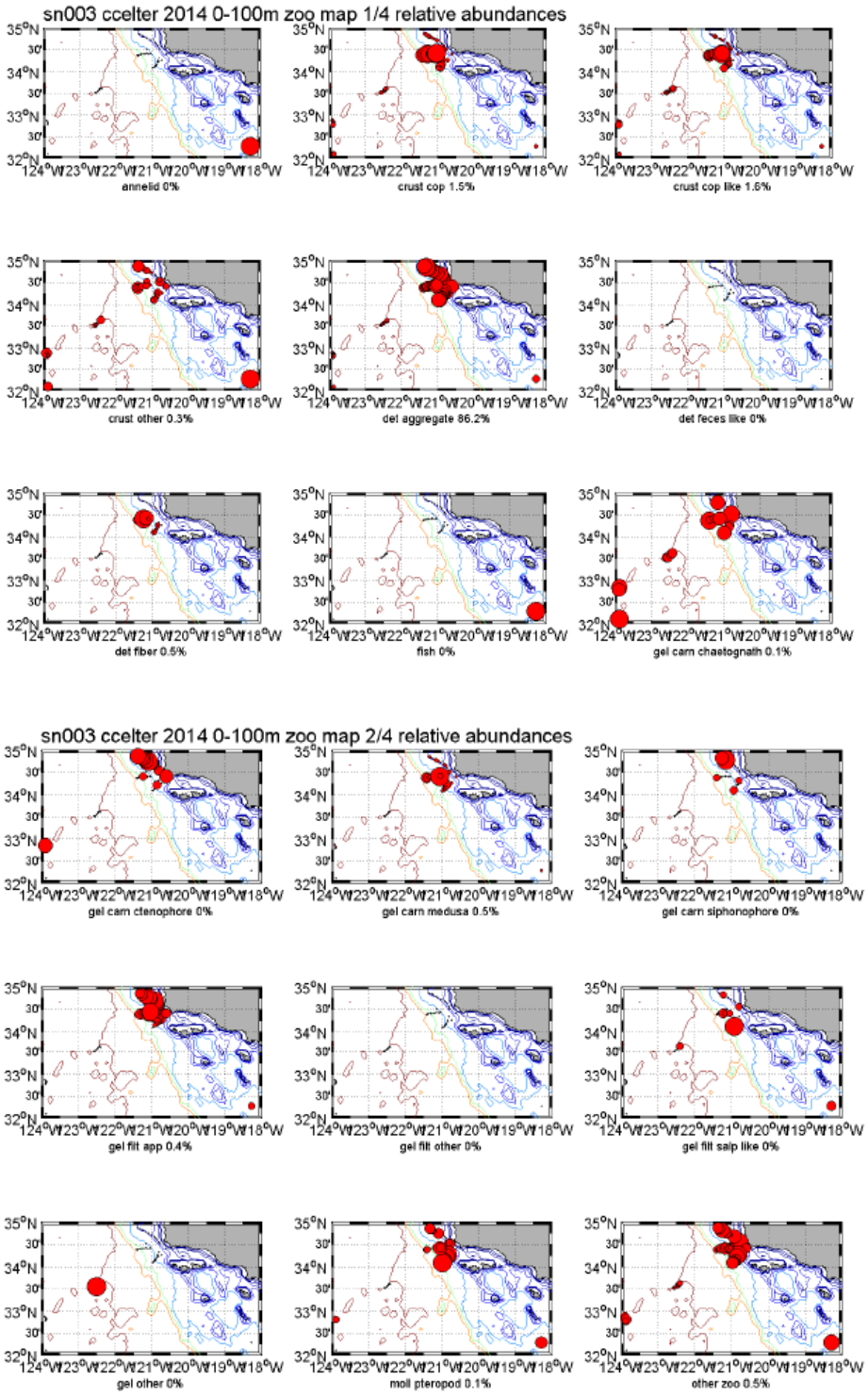
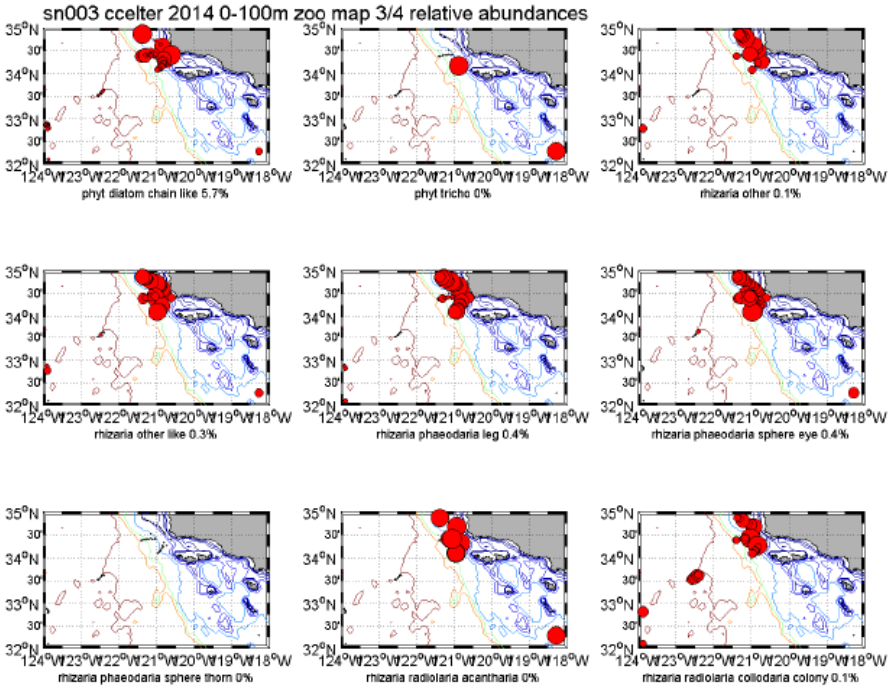


Fig. 10. Relative abundance distributions (mean upper 100 m) of organism and aggregate categories from UVP5 images on all cruise CTDs (continued to next page).





Radiolarian Research – SB Roscoff Group (Andrés Gutierrez and Tristan Biard)

Our cruise research focused on the distribution and community structure of phaeodarian, radiolarian, and free-living symbiotic microalgae species across the different water masses (coastal-to-offshore) of the CCE system, their vertical structure in the water column and their contribution to vertical export. We have adopted a morpho-molecular approach that combines molecular and image analytical tools. We took samples for metabarcoding analysis of the DNA community composition using 18S rRNA. We took samples for fluorescence in situ hybridization (FISH) analysis specific to a number of free-living symbiotic microalgae species (known to be symbionts of Radiolaria) for which we have designed fluorescence molecular probes. We also sorted out single cells in ethanol for single-cell image and molecular identification and preserved samples in ethanol for later molecular analysis in the lab. Phaeodarians and radiolarians encompass organisms with size that spans more than 3 orders of magnitude, with Acantharia ranging from 50-1000 µm diameter, larger phaeodarian cells in the millimeter range, and larger colonies of centimeter length. We combined different sampling approaches including net tows and CTD Niskin bottles in order to cover this wide range of sizes and concentrations in the water.

CTD sampling: We used late evening CTD casts to sample at 6 depths. We did two CTD's during Cycles 1,2 and 3; and one CTD during cycles 4 and 5. We collected the following samples for each depth: a) one entire Niskin bottle (10 L) was concentrated into 250 mL using a 5-µm mesh net, filtered onto a 8-µm Supor membrane filter and flash frozen for DNA community analysis (n = 48 samples); b) a 3 L sample was filtered onto 0.8-µm Supor filter for DNA community analysis of the nano- size fraction (n = 48); c) a 1-L sample was filtered onto a 0.2-µm Supor filter for DNA community analysis of the pico- size fraction (n = 480); a 250-mL sample was filtered onto a 3-µm polycarbonate filter for FISH analysis of free-living symbiotic microalgae

(only one CTD per Cycle, n = 30 samples); d) a 300-mL sample was filtered on a 3-µm polycarbonate filter for scanning microscopy analysis to analyze the thickness and calcification state of the coccolithophorids across oxygen gradients (only one CTD per Cycle, n = 30 samples); and e) 15-25 L were concentrated into 250 mL using phytoplankton 5-µm mesh net, with 50 mL preserved in ethanol for molecular analysis, and the other 200 mL fixed with formalin and $SrCl_2$ for microscopical analysis (n = 48 ethanol and 48 formalin + $SrCl_2$ samples). We also used opportunistic deep casts to sample the community of radiolarians that has been reported to inhabit deep waters (700-3000 m), but about which we know very little. We focused on the DNA community larger than 5 µm by filtering 20-40 L of water from 700 m in Cycles 3 and 4 (previous concentration with >5-µm net) and 20 L at 1000, 2000 and 3000 m during Cycle 5.

We actively collaborated with Marc Picheral during this cruise to investigate the distribution of rhizarian morphotypes (mainly phaeodarians and collodarians) across the different water masses using the UVP. For each CTD profile, we sorted the different rhizarian and were able to infer their abundances as well as their contributions to the overall zooplankton community >1 mm size. From previous CCE cruises, a category of organisms was associated with the phaeodarian. This category showed high abundances and biomasses (especially between 125-150 m), sometime locally higher than copepods. To assess the validity of our identification as a phaeodarian, we isolated a set of different rhizarian organisms and calibrated the UVP on board. The UVP was removed from the CTD rosette, placed into a seawater container, and the different organisms dropped one by one into the imaged volume. Optical microscopic observations were then compared to the "*in-situ*" images provided by the UVP. We therefore confirmed that these highly abundant organisms previously observed, belong to the phaeodarian. Molecular single-cell barcoding and morphological ID should later provide names to these organisms.

Net sampling: We took a $1/8^{th}$ subsample of the daytime bongo net tow daily for molecular analysis of radiolarian community. Of that, a half split ($1/16^{th}$ of total) was filtered on a 100-µm polycarbonate filter and flash frozen in LN2, and the other half was fixed with pure ethanol.

We also took one ring net tow (330-µm mesh) per cycle to sort single specimens of interest. We imaged them for morphologic identification and preserved them in ethanol for single-cell molecular ID and scanning microscopy of skeleton-bearing individuals. The ring net further aimed at collecting enough live radiolarians to use in in situ incubations on the drift array. During Cycles 1-3, we focused on phaeodarians and collodarians (radiolarian group forming large symbiotic colonies or large solitary forms). We sorted several phaeodarians morphotypes including those most frequently associated with the thick layer of Radiolaria found below the euphotic zone on previous CCE cruises. Molecular ID of these specimens will be done in the lab. Partly due to the abundance of gelatinous organisms (salps mainly), no specimens were recovered in good enough condition to use in incubations. During Cycles 4 and 5, however, we found a very different community in our ring net tows, which (free of salp tyranny) allowed us to sort specimens for two types of incubation experiments. In one, we assessed the concentration of dimethyl sulfur compounds in symbiotic radiolarians incubated across 4 depths in the water column. The objective of these experiments was to test the putative antioxidant role of these compounds in phytoplankton and

symbiotic species in particular. We hypothesized that DMSP concentration would decrease under higher irradiance conditions of shallower incubations due to its capacity to scavenge hydroxyl radicals and form DMSO. For the other type of in situ incubation, we measured per cell ^{14}C- and ^{15}N-uptake rates at surface and deep chlorophyll maximum depths in collaboration with R. Goericke's group and M. Stukel. We also measured chlorophyll per colony biovolume, which gave measurable and surprisingly high values for some species. For instance, one solitary symbiotic collodarian specimen, yielded similar chlorophyll values to approximately 50 mL of DCM water at the same station. We performed a total of 3 DMSP and 4 productivity experiments (with colonies and solitary collodarians).

Sediment trap sampling: To assess the contribution of phaeodarians and radiolarians living in the first 100-150 m of the water column to vertical fluxes, we plugged into the sediment trap deployments led by M. Stukel. Following the same morpho-molecular approach as for the water column, we collected samples from two tubes at each depth of trap deployment in each of the cycles. One of the tubes fixed with formalin while the other was deployed without preservatives to facilitate the DNA extraction and follow-up analyses. This will offer an interesting methodological comparison to assess the influence of degradation or consumption on the community composition recovered after 3 days of deployment. We quantitatively split the contents of each of the tubes into different filters (0.2, 0.8, 8-µm pore sizes) and preserved with formalin + $SrCl_2$ fixation and ethanol preservation for molecular and microscopy analysis, respectively. We also took samples for HPLC pigment analysis at each depth from both the formalin preserved and non-preserved tubes.

Mini-dilution experiments: Lastly, we conducted daily mini dilution experiments on the drift array. These experiments belong for the most part to a different topic and objectives to those related to radiolarians, although part of them are linked. They are designed to assess the response of phytoplankton growth and grazing mortality under different in situ irradiance conditions. Water was collected from a single depth below the mixed layer where photosynthesis was expected to be light-limited. Six replicated mini dilution experiments were prepared and incubated across the 6 depths of the array. Two additional mini dilution experiments were systematically prepared; one incubated in the dark at the shallowest depth, and one extra experiment incubated at the depth of water collection to improve the accuracy of the rate estimates at original depth of collection and to get a sense of the reproducibility of the experiments. This design encompassed a total of 8 experiments per array. Samples for flow cytometry were taken for every experiment. Samples for DNA (0.45-µm filter pore) were taken on the first two days of each cycle for qPCR analysis of specific groups of picophytoplankton (e.g. picocyanobacterial clades), while samples for FISH analysis were taken on the third day to assess the growth and grazing mortality rates of free-living symbionts of Radiolaria like *Phaeocystis* sp. (Prymnesiophyceae, symbiont of Acantharia) and *Brandtodinium* (Dinophyceae, symbiont of polycystines radiolarians).

Mesozooplankton Research – Ohman Group (Mark Ohman, David Jensen, Catherine Nickels, Jennifer Brandon, Ben Whitmore, Rasmus Swalethorpe and Irina Köster)

***Moving Vessel Profiler (MVP)*:** A free-fall Moving Vessel Profiler (MVP) was used to characterize the suppressed upwelling conditions associated with the nearshore region off Pt. Conception, to guide site selection for experimental cycles, to make high-resolution vertical profiles for later estimates of vertical mixing coefficients, and to analyze the effects of topographically-related mixing along line 90. The MVP sensors included a Laser Optical Particle Counter (LOPC), Chl-*a* fluorometer, AML Micro fast response CTD, and an Acousonde hydrophone for recording marine mammal vocalizations. A total of 327 MVP casts was completed, excluding the final line 90 sampling. Because the LOPC was also used on the SeaSoar, when the SeaSoar was lost on 10 Aug., the LOPC was lost with it. We promptly arranged shipment of a rental LOPC from ODIM-Rolls Royce in Canada, permitting us to use the MVP for the remainder of the cruise. The MVP performed well on all deployments.

***Vertically stratified MOCNESS sampling*:** Vertically stratified plankton sampling was carried out with a 1 m^2 MOCNESS with 202-µm mesh nets, deployed at each of the five experimental Cycles. The MOCNESS was equipped with sensors for temperature, salinity, O_2, beam attenuation coefficient, Chl-*a* fluorescence, and dissolved oxygen. Sampling was conducted to assess changes in mesozooplankton vertical distributions and diel vertical migration behavior across different hydrographic conditions. In addition, comparisons were made of the catch efficiency for euphausiids of a MOCNESS with an array of strobed LED's in relation to unstrobed samples. For this purpose, the ship followed a circular path (typically a diameter of 0.9 km) in order to remain in the same krill patch. A sequence of nets was triggered with the strobes on, the net frame was recovered to the surface and the lighting turned off, then the frame was lowered to re-sample the same patch again. Six comparisons (3 day, 3 night) were carried out. All strobed comparison samples were fixed in 5% sodium tetraborate-buffered Formalin. All other MOCNESS samples were split at sea with a Folsom splitter, with half fixed in 5% sodium tetraborate-buffered Formalin and half in 95% non-denatured ethanol. Ethanol-fixed samples were drained within 24 h of initial fixation and the ethanol replaced. Ethanol-fixed samples will be used to analyze zooplankton molecular genetics, including for planktonic radiolaria, and shell calcification of selected species of calcareous zooplankton. A total of 22 MOCNESS tows were completed, including replicated day and night tows at each experimental Cycle and the strobe on/off comparisons.

***Mesozooplankton biomass and grazing rates*:** Bongo tows were made with a 71-cm diameter, 202-µm mesh bongo net, for determination of mesozooplankton biomass and grazing rates, the latter by gut fluorescence. Samples were taken to a depth of 210 m at each experimental cycle, with one net sample fixed in 5% buffered Formalin for taxonomic analyses and the other anaesthetized immediately in soda water, then size-fractionated into 5 size categories (0.2, 0.5, 1.0, 2, 5 mm) and frozen in liquid N_2. The latter sample was divided such that 3/8ths will be used for biomass determination, 3/8ths for mesozooplankton gut fluorescence, and1/4th for other studies, including molecular characterization of radiolarians and analysis of zooplankton feeding.

Thirty oblique bongo tows were completed, representing 3 replicate day and night series at each experimental Cycle.

***Copepod egg production experiments*:** Incubation experiments were performed with three of the numerically dominant calanoid copepods in our study region (*Calanus pacificus, Metridia pacifica,* and *Eucalanus californicus),* to assess mesozooplankton reproductive responses in relation to suppressed upwelling conditions. These results also provide an index of secondary production by mesozooplankton. Live copepods were collected in the upper 200-250 m in the daytime and incubated in water from the depth of the chlorophyll maximum. Egg production was recorded at 12 and 24 h, and egg hatching success was recorded after a time corresponding to 1.5X the embryonic duration. Fifteen such experiments were conducted, three at each of the five experimental cycles.

Ingestion of microplastics by gelatinous suspension-feeders: Because of the ubiquity of salps across the study region, surface samples were taken at Cycles 4 and 5 to assess ingestion of plastic micro- and nano-particles by surface-dwelling salps. At least five species of salps were present. Individual salp zooids or colonies were dip-netted from surface waters at Cycle 4 and were collected with a surface bongo tow at Cycle 5 (where the sea state was not conducive to dip-netting). Upon recovery, animals were immediately anaesthetized with soda water to arrest feeding. Gut content analysis will be performed in the shore-based laboratory. In addition, numerous samples from the stratified MOCNESS and the bongo series are available for this purpose.

Seabird and Marine Mammal Observations – Pete Davison

Bird and marine mammal observations were negatively impacted by the loss of the SeaSoar (and associated survey time) and thus were limited to daylight transits and MVP bowtie surveys. Nonetheless, qualitative patterns were observed in abundance and community. In general, abundance of birds was greatest inshore and least offshore. On the continental shelf, we observed an expected nearshore community with many gulls, terns, pelicans, cormorants, murres, and some auklets. At the shelf break, the bird community was dominated by pink-footed shearwaters and Leach's storm petrels. At Cycle 4 ("CA Current"), Buller's shearwaters replaced the pink-footed shearwaters. Few birds (~1/hr) were observed near Cycle 5. Three boobies were seen outside of formal observation periods, including an adult brown-booby sitting on the A-frame, an unusual number of this tropical bird. Baleen whales were only observed near the Channel Islands (by crew, off of formal observation periods) and near Cycle 4. Many odontocetes were observed near the shelf-break and Channel Is., but few offshore. Sea lions were present in low numbers everywhere.

Export Flux and New Production - Mike Stukel

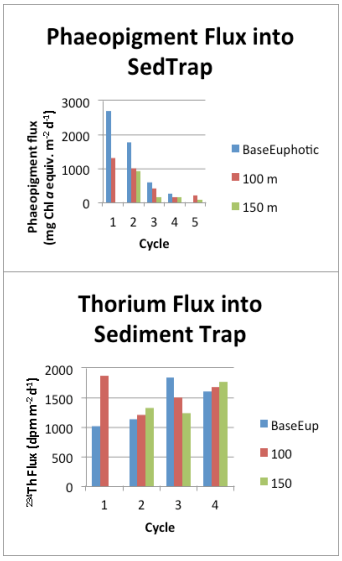


Fig. 11. Thorium flux into sediment traps.

We assessed carbon export using two different approaches, ^{238}U:^{234}Th disequilibrum and sediment traps. VERTEX-style sediment traps were deployed at depths of 100 m, 150 m, and also at the base of the euphotic zone (when the euphotic zone was shallower than 100 m) for the duration of each experimental cycle (~3.25 days). Sediment trap tubes were sorted to remove zooplankton swimmers, split, and used for several different analyses including C/N, C:^{234}Th, isotopes, particulate Si, pigments, molecular analyses, and taxonomic enumeration. Preliminary pigment analyses showed significantly higher pigment flux (phaeopigments and Chl *a*) in the cycles that started closer to shore than the cycles in the offshore region. Unlike pigments, the flux of ^{234}Th collected on sinking particles in the sediment trap did not vary significantly across the cycles (**Fig. 11**). This may indicate relatively constant carbon flux across the region (despite highly variable pigment flux), or it may indicate significantly lower C:^{234}Th ratios in the offshore region. The C:^{234}Th ratio will be measured on land after the ^{234}Th has decayed away.

Two different ^{234}Th sampling patterns were employed on the cruise: a surface grid survey of the coastal region and vertical profiles during Lagrangian experimental cycles. During the grid survey of the study region (which coincided with SeaSoar and Moving Vessel Profiler surveys of the physical setting), we took 4-L samples from the ship's uncontaminated flow-through seawater (UFS) system (intake at 3-m depth). The UFS system was cleaned with bleach immediately prior to the start of the grid survey. To ensure that UFS sampling did not bias our samples, we compared triplicate samples from both the UFS system and surface-tripped Niskin bottles before the survey and found no difference between sampling methods. During experimental cycles, we took 4-L Niskin samples at 11 depths spanning the upper 200 m of the water column twice per cycle, as we tracked water parcels with a Lagrangian drift array for durations of 3 days. Preliminary water-column values for ^{234Th} showed similar vertically integrated deficiencies across the first four cycles (**Fig. 12**; results for Cycle 5 are not yet available), which agrees with what we found for ^{234}Th flux into the traps. Vertical profiles, however, show deficiencies in Cycle 4 (in the vicinity of the California Current) to be lower at the surface and higher at depth than those in the nearshore region.

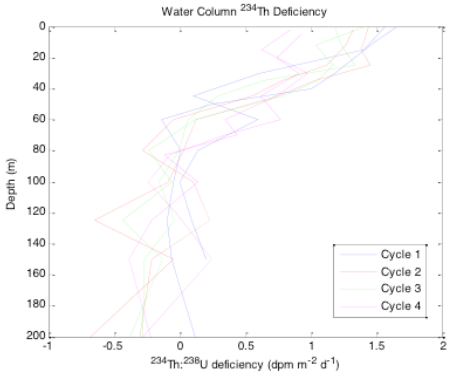


Fig. 12. Preliminary assessments of ^{234}Th deficiency during cycles. Higher values indicate more export.

We also measured $^{15}NO_3$ uptake as an estimate of new production. $^{15}NO_3$uptake was measured *in situ* daily at six depths daily during the cycles. Samples were typically spiked with $^{15}NO_3$ at a concentration of 2-10% of ambient nitrate (as assessed spectrophotometrically) and incubated for 24 hours.

Micronekton – Amanda Netburn and Pete Davison

The abundance, vertical and horizontal distribution, size and species composition of the micronekton were examined acoustically with a pole-mounted Simrad EK-60 multifrequency (38, 70, 120, 200 kHz) system and with direct sampling with a Matsuda-Oozeki-Hu trawl (MOHT) (5-m^2 mouth opening, 1.7-mm mesh, with a TSK flowmeter in the mouth to estimate volume water filtered). These systems were also used experimentally to follow the migration of migrants into surface waters at dusk (Davison) and to test hypotheses relating to metabolic effects of low oxygen waters at mesopelagic depths (Netburn).

Multifrequency acoustic data (38, 70, 120, and 200 kHz) were collected throughout the cruise. Quantitative acoustic data were obtained to 1000 m with the 38 kHz transducer, reducing to 200 m at 200 kHz. The acoustic pole was pulled out of the water in Santa Barbara harbor for inspection after Cycle 1, and was found to be in perfect condition. The pole was inspected hourly, and data backed up daily. The new mounting system, with fared cables secured away from direct contact with the hull, is much improved over previous designs, and no vibration noise was detectable. Aggregations of euphausiids were observed in many places 150-300m in daylight. During the Cycle 2 MVP "bowtie" survey, a school of epipelagic fishes was observed coincident with a large pod of common dolphins and associated seabirds. The EK60 data was used for real-time targeting of scattering layers with the MOHT and strobed-MOCNESS trawls. The data will also be used in association with the trawl data for biomass and target strength estimates.

Ten dusk trawls with MOHT were performed during the diel migration of the deep-scattering layer in order to ground-truth multi-frequency acoustic data collected during the same time period (Fig. 1). The objective was to verify that the rising DSL is dominated by the expected juvenile myctophids (dominant vertically-migratory fishes with gas-filled swimbladders), and to address the question of whether or not these small 2-3 cm fishes allow the gas in their swimbladder to expand/contract with changes in depth, thus altering their acoustic target strength. Target strength is required for abundance estimates, and is poorly known for mesopelagic fishes. Unfortunately, the DSL was poorly resolved in Cycle 1 at the continental shelf, and even when we moved offshore few fishes were captured in the rising scattering layer. This indicates that either fishes do not dominate the rising DSL (unlikely at 38 kHz in the absence of abundant physonect siphonophores) or that enough light remains at dusk for the fishes to visually detect and avoid our net. Deep tows in daylight and shallow tows at night both captured abundant juvenile myctophids. Qualitatively, the rising deep-scattering layer showed no evidence of increasing acoustic strength with decreasing depth, and some evidence of a reduction in resonance between daytime depth and the lower epipelagic (expected due to the depth-dependence of resonance; **Fig. 13**).

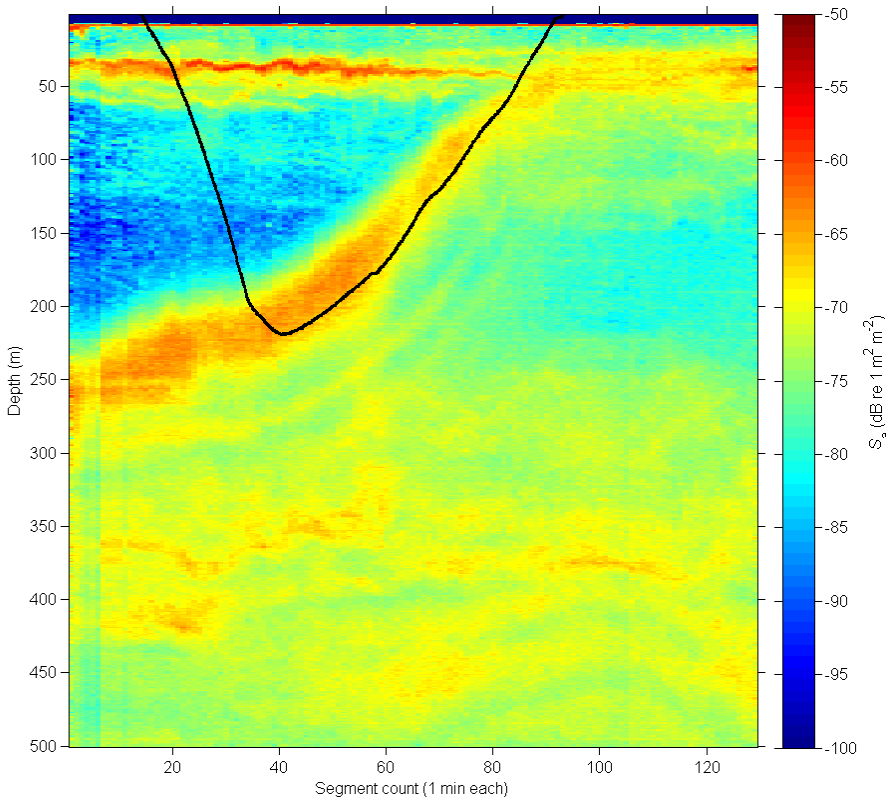


Fig. 13. 38 kHz backscattering for Cycle 3, MOHT tow 5 (began 8/25/14, 19:08 PDT). Path of the net (from time-depth recorder) is shown in black. The shallow non-migratory scattering layer is likely fish larvae from dB-difference analysis (not shown). The shoaling scattering layer is consistent with that from gas-filled swimbladders (dB difference).

Specimens collected on CCE-P1408 will be used to test two questions relating to oxygen limitation in the mesopelagic habitat: (1) What are the environmental limitations on animals that comprise the deep scattering layer? (2) Do fishes increase reliance on anaerobic metabolism in areas with intensified hypoxia and shallower hypoxic boundary depths? Following the cruise, a previously developed algorithm will be applied to EK60 data to detect deep scattering layer depths at locations where there are concurrent CTD casts. Multivariate methods will be used to determine which environmental variables constrain the upper and lower boundaries of the DSL. To test the second question, fishes were collected using oblique net tows with the MOHT trawl. We conducted a total of 11 deep (~700 m) daytime, 1 deep nighttime, and 7 shallow (~150 m) nighttime tows over the course of the cruise. Over 1500 individual fish specimens comprised of about 15 different species of mesopelagic fishes were collected and flash-frozen in liquid nitrogen. These samples will be analyzed in the lab for activity of key enzymes in the aerobic respiratory pathway (malate dehydrogenase and citrate synthase), the anaerobic lactate production pathway (lactate dehydrogenase), and the anaerobic ethanol production pathway (alcohol dehydrogenase).

INFORMATION MANAGEMENT

One of the IM activities is setting up an event logger to provide an authoritative listing of each research activity, with assigned event numbers, date, time and location information. Pre-cruise preparations included incorporation of hardware/software updates on logger laptops, setting up logger stations on the bridge and in the lab, coordination of program decoding with the ship's GPS string, and logger training. A glossary of activity names incorporated as a configuration file serves as a controlled vocabulary list. The event logger functioned very reliably on the present cruise.

Additional IM activities included input of cruise specifics to the information system study list and participant directory as well as uploading of the cruise data CDs to a project shared disk. Since the event log serves as a key mechanism for post-cruise coordination of datasets, event log cleaning was initiated including checking for consistency and missing data.

EDUCATION

Teacher at Sea opportunities provide experience for local K-12 teachers to participate in real-world, interdisciplinary research alongside scientists from the CCE LTER and Scripps Institution of Oceanography. On the present cruise, Carmina Ramirez, a Calexico High School ninth-grade science teacher participated directly in different experimental procedures and sampling techniques. As part of her outreach activities, she posted blogs on the CCE LTER Education Outreach webpage, sharing her experiences and discussing the different types of science taking place on the ship in addition to what life was like at sea. In addition, she was the first on our expeditions to post blogs in Spanish as well as English to better connect with the students and families in her district.

For this report, Carmina wrote the following about her experiences: "*My participation as the Teacher at Sea during this CCE-LTER 2014 cruise has been extraordinary. I have learned about state of the art technology used for ocean exploration, research methods, and valuable experiences to share in the near future with my students. I have learned about the processes and procedures of research by enthusiastic scientists who were always willing to explain their work to me. I have seen a comprehensive expedition where the efficiency and professionalism of a vessel crew and the scientific team work together to meet research goals. I understand the importance of long term research as well as some of the California Current features that characterize this area with high biodiversity. Also, I have gained a better understanding of the interconnectedness of species and their role in cycling nutrients. Finally, I have written bilingual blogs (12) for English and Spanish speaking audiences. The Spanish blog will be featured monthly in LA OPINION Newspaper of Los Angeles on-line edition. I have taken 700 plus images and some videos that I will use to incorporate in my lesson plans once I return to my classroom.*"

P1408 also provided valuable research and cruise experience for three UCSD undergraduate students -– Maya Land, Kyra Rashid and Jasmine Tan – as part of the CCE summer REU Program.

CCE-P1408 DAILY ACTIVITY SCHEDULE

6 August – Gear Tests, south of San Clemente Island

0800 Depart San Diego
1830 Trace Metal (TM) rosette
1930 Oozeki trawl – migration
2130 CTD
2230 MOCNESS
0000 Ring net tow, zooplankton experiments

7 August

0100 Submersible pump test
0200 Transit to waypoint 34° 25'N, 120°, 40'W

8 August

0800 **MVP Survey #1**, nearshore Pts. Conception/Arguello
2200 Begin **SeaSoar Survey #1**, Pts. Conception/Arguello area
(SeaSoar lost ~0200, 10 August)

10 August

1500 **Bowtie #1 –** surface measurements (ALF) and ADCP currents only
1930 Oozeki trawl, vertical migration

11 August -- CYCLE 1 (position 34° 29.12'N, 120° 45.35'W)

0000 Sediment trap deployment, begin CYCLE 1
0200 CTD, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Deploy drift array #73
0530 CTD, thorium
0630 TM cast, iron profile
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1200 MOCNESS
1400 Oozeki trawl (500 m – CANCELLED, too shallow)
1600 CTD, radiolarians
2000 CTD, water for zooplankton experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 MOCNESS
2400 Oozeki trawl (shallow)

12 August

0200 CTD, sampling & *in situ* experiments
0300 TM cast, DOC experiment
0500 Recover drift array #73/deploy #74
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics

1200 TM cast, experiments
1300 MOCNESS
1900 CTD, full dilution, zoopl experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 Ring net, zooplankton experiments
2330 MOCNESS

13 August

0200 CTD cast, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Recover #74/deploy drift array #75
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1300 Oozeki trawl
1800 CTD, radiolarians
1930 Oozeki, shallow migration
2130 Ring net, zooplankton experiments
2230 Bongo, zooplankton net tow, gut fluor
2400 Oozeki trawl (shallow)

14 August

0300 CTD, end CYCLE 1 drifter experiments
0500 Recover drift array #75
0730 Recover sediment trap array
0800 Transit to waypoint 34° 25.327'N, 121° 02.029'W
1200 CTD, radiolarians, deep thorium, water zoopl exps
1300 TM cast, DOC experiment
1400 MOCNESS, strobe/nonstrobe catch comparison
1730 Oozeki, deep tow
2030 CTD, 1000-m dissolved organics, experimental water
2130 Ring net, zooplankton live tow
2200 MOCNESS, strobe/nonstrobe catch comparison

15 August

0000 Transit to Santa Barbara
0900 Switch blocks for TM rosette, MOCNESS
1200 Maintenance EK60 pole
1300 Arrival LOPC replacement
1500 Net tow test of new block arrangement
1600 Transit to Waypoint 34° 25.335'N, 120°36.016'W
2230 Ring net tow, zooplankton experiments
2300 CTD, DOM from deep chl max
2400 TM rosette

16 August

0800 Survey area, MVP Bowtie #2
1300 CTD, radiolarians, water for zooplankton exps
1400 Oozeki trawl (deep)

1600 Ring net, radiolarians
1900 Oozeki, vertical migration
2200 MVP survey, Bowtie #3

17 August (34° 14.80'N, 120° 49.88'W)
0000 Sediment trap deployment, begin CYCLE 2
0200 CTD, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Deploy drift array #76
0500 CTD, thorium
0600 TM cast, iron profile
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1600 MOCNESS
1900 CTD, radiolarians, water for zooplankton experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 Oozeki trawl (deep)

18 August
0200 CTD, sampling & *in situ* experiments
0300 TM cast, DOC experiment
0500 Recover drift array #76/deploy #77
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1130 TM cast, experiments
1300 MOCNESS
1800 Ring net, radiolarians
1900 CTD, full dilution, zoopl experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 Ring net, zooplankton experiments

19 August
0200 CTD cast, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Recover #77/deploy drift array #78
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1300 Oozeki trawl
1800 CTD, radiolarians
1930 Oozeki, shallow migration
2100 Ring net, zooplankton experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 MOCNESS

0030 Oozeki trawl (shallow)

20 August

0300 CTD, end CYCLE 2 drifter experiments
0400 TM cast, iron profile
0500 Recover drift array #78
0700 Recover sediment trap array
0900 Ring net, radiolarians
1300 TM cast, experiments
1430 Van Veen bottom grab
1600 Oozeki (deep)
2200 Ring net, zooplankton experiments
2300 MOCNESS

21 August

0200 Transit to waypoint 34° 20.80'N, 121° 21.26'W
0900 Survey area, Bowtie #4
1300 CTD (1000 m), thorium, DOM, rads, water for zooplankton exps
1400 TM cast, DOM degradation exps
1500 Oozeki trawl (deep)
1900 Sediment sample (Van Veen bottom grab, 2000+m)

22 August (approx. position 34° 22.44'N, 121° 21.24'W)

0000 Sediment trap deployment, begin CYCLE 3
0200 CTD, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Deploy drift array #79
0500 CTD, thorium
0600 TM cast, iron profile
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1200 MOCNESS
1430 Oozeki trawl
1800 CTD, radiolarians, zooplankton experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 MOCNESS
2400 Oozeki trawl (shallow)

23 August

0230 CTD, sampling & *in situ* experiments
0330 TM cast, DOC experiment
0500 Recover drift array #79/deploy #80
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics

1200 TM cast, experiments
1330 MOCNESS
1800 Ring net, radiolarians
1900 CTD, full dilution, zoopl experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 Ring net, zooplankton experiments
2330 MOCNESS

24 August

0200 CTD cast, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Recover #81/deploy drift array #82
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1300 Oozeki trawl (deep)
1800 CTD, radiolarians
1930 Oozeki, shallow migration
2130 Ring net, zooplankton experiments
2230 Bongo, zooplankton net tow, gut fluor
2400 Oozeki trawl (shallow)

25 August

0300 CTD, end CYCLE 3 drifter experiments
0400 TM cast, iron profile
0500 Recover drift array #81
0530 SHIP, pump tanks (offsite)
0630 Recover sediment trap array
0800 Sediment sample (Van Veen bottom grab, 1200 m)
1000 Transit to study area (33° 27.8'N, 122° 31.4'W)
1800 MVP – enroute or Bowtie survey #5

26 August

0000 Deploy sediment trap, begin CYCLE 4 (33° 30.6'N, 122° 33.0'W)
0200 CTD, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Deploy drift array #82
0530 CTD, thorium
0630 TM cast, iron profile
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1200 MOCNESS
1500 Oozeki trawl (500 m)
2130 Bongo, zooplankton net tow, gut fluor

2230 Ring net, zooplankton experiments

27 August

0200 CTD (100 m), sampling & *in situ* experiments
0330 TM cast (100 m), Fe/^{15}N and DOC experiments
0500 Recover drift array #82/deploy #83
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD (100 m), 14C-PP, microbiology, dissolved organics
1200 TM cast (100 m), experiments
1800 Ring net, radiolarians
1900 CTD (100 m), full dilution, zoopl experiments
2130 Bongo, zooplankton net tow, gut fluor

28 August

0000 MOCNESS
0200 CTD (700 m), sampling & *in situ* experiments
0330 TM cast, Fe/^{15}N and DOC experiments
0500 Recover drift array #83/deploy #84
0600 TM cast, experiments
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1200 MOCNESS
1500 Oozeki trawl (500 m)
1900 Oozeki – vertical migration
2200 CTD, radiolarians
2230 Bongo, zooplankton net tow, gut fluor
2330 MOCNESS

29 August

0200 Oozeki (shallow)
0400 CTD, end CYCLE 4 drifter experiments
0500 TM cast, iron profile
0530 Recover drift array #84
0600 SHIP, pump tanks (offsite)
0700 Recover sediment trap array
0800 Ring net, radiolarians
0830 Transit to offshore (32° 51.62'N, 123° 56.10'W)
1900 Survey area, MVP Bowtie #6

30 August (approx. position 32° 51.62'N, 123° 56.10'W)

0000 Sediment trap deployment, begin CYCLE 5
0200 CTD, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Deploy drift array #85

0500 CTD, thorium
0600 TM cast, experiments
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1300 MOCNESS
1530 Oozeki trawl (500 m)
2030 Ring net, radiolarians
2000 CTD (3000 m), deep thorium, zoopl experiments
2230 Ring net, zooplankton experiments
2300 Bongo, zooplankton net tow, gut fluor

31 August

0000 MOCNESS
0330 CTD, sampling & *in situ* experiments
0330 TM cast, Fe/^{15}N experiment
0530 Recover drift array #85/deploy #86
0630 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1200 TM cast, experiments
1300 MOCNESS
1600 Ring net, radiolarians
1800 CTD (3000 m), deep thorium full dilution, zoopl experiments
2130 Bongo, zooplankton net tow, gut fluor
2230 Ring net, zooplankton experiments
2330 MOCNESS

1 September

0200 CTD cast, sampling & *in situ* experiments
0300 TM cast, Fe/^{15}N experiment
0500 Recover #86/deploy drift array #87
0730 SHIP, pump tanks (offsite)
0830 Bongo live tows, zooplankton experiments
0930 Bongo, zooplankton net tow, gut fluor
1030 Secchi
1100 CTD, 14C-PP, microbiology, dissolved organics
1200 TM cast, experiments
1300 Oozeki trawl (deep)
1700 Bongo, zooplankton experiments
1800 CTD, radiolarians
1900 Oozeki, shallow migration
2230 Bongo, zooplankton net tow, gut fluor
2400 Oozeki trawl (shallow)

2 September

0300 CTD, end CYCLE 5 drifter experiments
0400 TM cast, iron profile
0500 Recover drift array #87
0530 SHIP, pump tanks (offsite)
0630 Recover sediment trap array
0800 Transit to Waypoint 32° 00.732'N, 120° 50.868'W

3 September

0100 MVP/iron sampling to Waypoint 33° 11.995'N, 118° 20.461'W

4 September

0000 Complete MVP sampling.