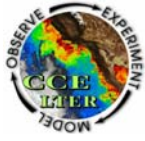# Cruise Report

California Current Ecosystem LTER Program

CCE-P1604, El Niño Response RAPID Cruise

R/V *Sikuliaq*, 19 April – 12 May 2016

Compiled and submitted by: Mark D. Ohman, Chief Scientist

Scripps Institution of Oceanography, University of California, San Diego

Cruise ID: CCE-P1604   (= SQ201605S)

Depart: 19 April 2016 at 0845 (PDT)

Return: 12 May 2016 at 1300

Vessel: R/V *Sikuliaq*

Master: Captain Adam Seamans

Chief Scientist: Mark D. Ohman

Science Technicians: Steven Hartz, Ethan Roth
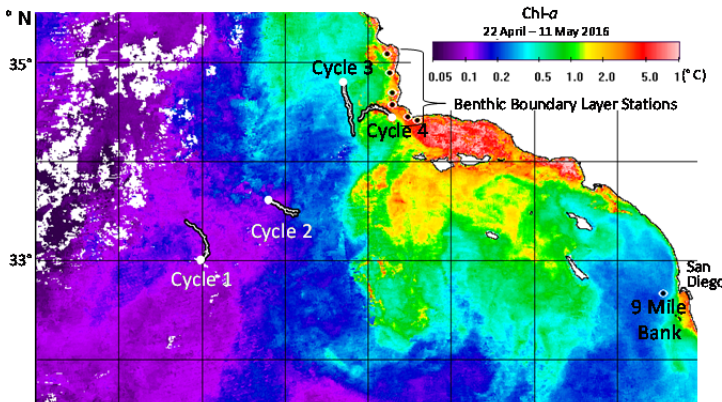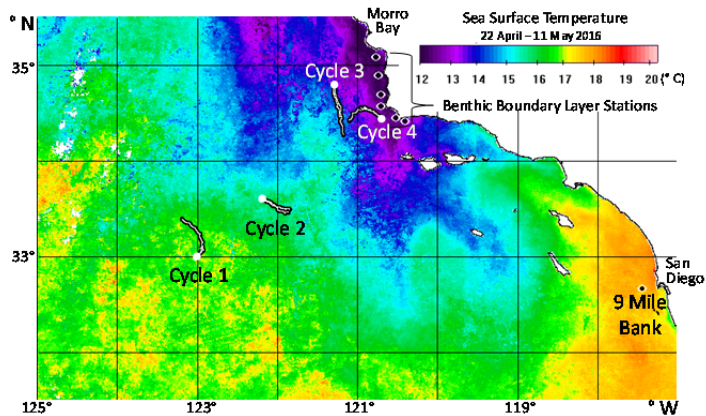
Operator: Univ. of Alaska, Fairbanks

Fig. 1. Locations (drifter trajectories) of experimental Cycles 1-4, Benthic Boundary Layer Stations, and 9 Mile Bank survey during P1604, superimposed on satellite images of sea surface temperature (SST) and chlorophyll *a*. Images are averaged between 22 April -11 May 2016. Dots indicate the starting locations of drifter experiments.

Images courtesy of M. Kahru.

Contents

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SCIENCE OBJECTIVES

This cruise originated as a special RAPID award from NSF to the CCE-LTER site, intended to quantify the effects of the major El Niño of 2015-16 (Fig. 2) on the pelagic ecosystem of the southern California Current System. CCE has recognized El Niño as the dominant element of our ecological disturbance regime since the onset of this LTER site, and this cruise provided an excellent opportunity to directly measure El Niño-related effects on biological and biogeochemical rate processes in the water column. We used a similar Lagrangian design and measurement protocols as used in previous CCE-LTER process cruises, in order to directly compare El Niño effects in spring 2016 with measurements the

CCE-LTER group has made in two El Niño-neutral springs (i.e., 2006 and 2007). Springtime was selected as the focal time period because CalCOFI observations have shown that strong biological signatures of El Niño are often manifest in the spring immediately following the winter peak of El Niño-related physical anomalies. Early spring is the time of onset of upwelling-favorable winds.
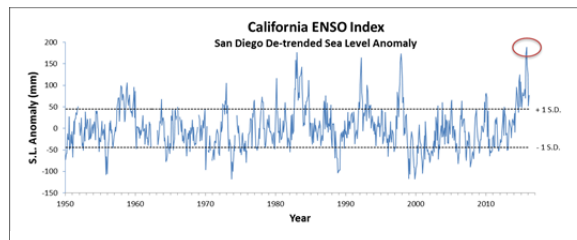
Fig. 2. ENSO index (De-trended San Diego Sea Level Anomaly) for the CCE region

Our specific objectives were to quantify the effects of El Niño on key processes that control the structure of the pelagic food web and rates of elemental cycling. The processes measured included primary and secondary production, grazing by microzooplankton and mesozooplankton, dissolved iron effects on phytoplankton growth, carbon and nitrogen cycling, and elemental export in both particulate and dissolved forms. Measurements were made in a Lagrangian reference frame while following discrete water parcels for several days at a time. These water parcels were selected to represent key sub-regions of the California Current Ecosystem, in order to test for differential effects of El Niño on different ocean sub-regions. These measurements are intended to facilitate the development of quantitative forecast models that can be used to project ocean responses to future El Niños and perhaps other warming phenomena. Our Broader Impacts objectives also included providing seagoing opportunities and training for numerous graduate students, and communication with the general public about the effects of El Niño on the coastal ocean via development of a public program with the Birch Aquarium at Scripps.

OVERVIEW OF THE SCIENCE PLAN

We conducted a series of rate process measurements on four Lagrangian experimental "Cycles" in water parcels selected to represent four primary subregions of the California Current Ecosystem. These were the offshore stratified region (Cycle 1, Fig. 1), core of the California Current proper (Cycle 2), offshore of the coastal boundary in the wind stress curl upwelling domain (Cycle 3), and the coastal boundary upwelling region (Cycle 4). In each case, satellite-tracked sediment traps and in situ incubation driftarrays were used to follow water parcels over repeated day/night measurement cycles to measure the temporal evolution of rate processes and community composition. Both sediment traps and driftarrays were drogued at a depth of 15 m with a holey sock. All other measurements were made in these same water parcels in close proximity to the driftarray, or centered on the driftarray (in the case of towed nets like the bongo and MOCNESS). Incubation bottles were suspended from the driftarray at six light depths

spanning the euphotic zone in order to determine specific growth rates of phytoplankton and specific grazing rates of microzooplankton (seawater dilution experiments), in situ rates of ^{14}C-based primary production, and in situ New Production from ^{15}NO$_3$ uptake. Additional measurements/samples at the drifter locations included Fe limitation and ligand production incubations; vertical profiles of trace metals sampled with a Trace Metal clean rosette; analysis of stable isotopes of N, C, and O; reactivity of DOC and DON; ^{234}Th:^{238}U disequilibrium; microbial diversity assessed by 16S and 18S ribosomal subunit genes; bacterial production by ^{3}H-leucine incorporation; phytoplankton pigments by HPLC; size-fractionated Chl-*a*; POC and PON; picoplankton samples for flow cytometry; microplankton samples for epifluorescence microscopy; mesozooplankton biomass and grazing (via gut fluorescence) in five size fractions; copepod egg production rates for up to 3 species of calanoid copepods; mesozooplankton vertical distributions via vertically stratified MOCNESS samples; and vertical profiles of macronutrients and standard hydrographic variables. In addition, continuous underway measurements were made on the ship's uncontaminated seawater system, including phytoplankton pigments, variable fluorescence (F$_v$/F$_m$), and CDOM, all measured by an Advanced Laser Fluorometer (ALF; Chekalyuk and Hafez. 2008. LOM: 6:591); O$_2$:Ar ratios as a measure of net community production (S. Wang); continuous pCO$_2$; standard ship-provided measurements of ocean surface properties and meteorological variables; ADCP-derived currents at 75 and 150 kHz; and EK60 acoustic backscatter at five frequencies (18, 38, 70, 120, 200 kHz). In situ plankton images were acquired on all CTD-rosette casts using an Underwater Vision Profiler (UVP5), operated by Tristan Biard visiting from France. Measurements are described in greater detail below.

Ancillary measurements that were not made onboard the R/V *Sikuliaq*, but supported our RAPID cruise site selection and activities, included autonomous measurements from a *Spray* glider equipped with an ISUS nitrate sensor and deployed along line 80; CCE1 and CCE2 moorings along line 80; satellite remote sensing; and CalCOFI cruise 1604SH, which immediately preceded our cruise.

Site selection for water parcels for each of the experimental Cycles began with analysis of current satellite imagery of SST, Chl-*a*, and AVISO sea surface height anomalies. Satellite measurements (Fig. 1) were complemented by in situ subsurface measurements from the ISUS-*Spray* glider (Fig. 3), CalCOFI
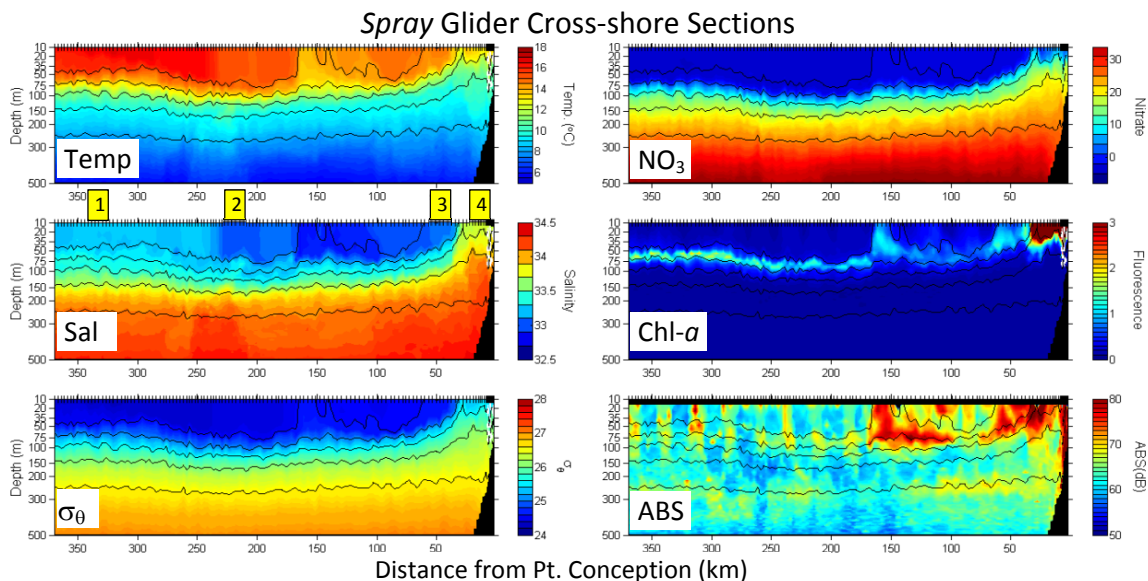

Fig. 3. *Spray* glider sections along CalCOFI Line 80 (22 April – 5 May 2016), with coast (Pt. Conception) to the right. Approx. offshore locations of Cycles 1-4 indicated above salinity section, although Cycles were not located directly on line 80. (Dan Rudnick & Mark Ohman)

cruise measurements, the CCE1 and CCE2 moorings, and shipboard ADCP profiles. A final step in localizing a water parcel of interest was to conduct a preliminary site survey using a series of Moving Vessel Profiler (MVP) profiles to a depth of 200 m. These profiles were typically conducted in a bow tie pattern (Fig. 4), permitting regions of strong frontal gradients to be localized and avoided prior to release of drifters.
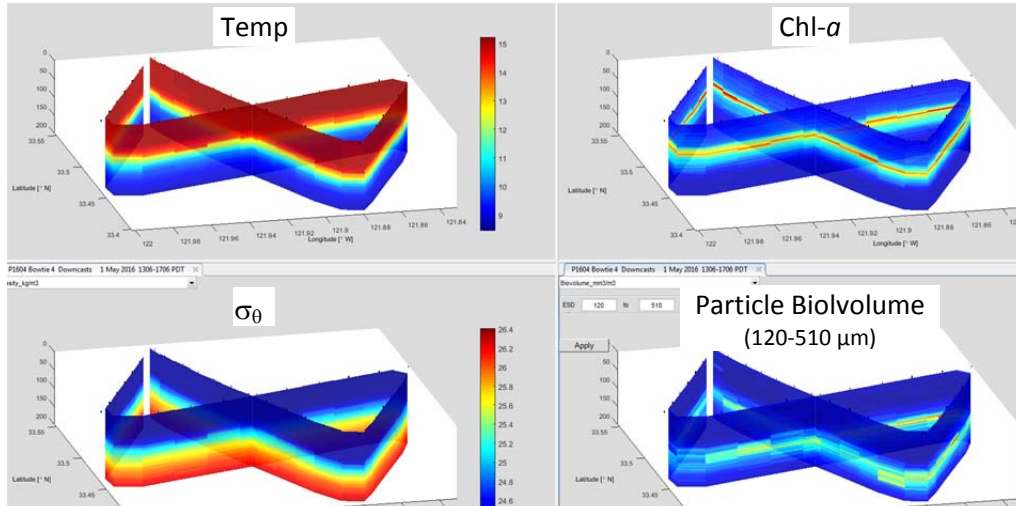

Fig. 4. MVP Bow tie site survey 4, prior to Cycle 2. Small black tics indicate cast locations.

In addition to our core measurements at the four Lagrangian Cycles, we conducted brief El Niño-related studies at (1) 9 Mile Bank and (2) in the Benthic Boundary Layer (BBL) on the continental shelf near Pt. Conception (Fig. 1). After beginning our measurements at the offshore Cycle 1, an urgent medical issue required us to return to San Diego to drop off one member of the science party. We could not then immediately return to Cycle 1 because gale force winds developed offshore. Therefore we conducted a one day study over 9 Mile Bank in support of a graduate student's (Catherine Nickels') PhD research. These measurements (EK60 multi-frequency survey, MVP sections, and bongo tows) are part of her study of whale-krill interactions over abrupt topography. Ms. Nickels had made measurements in this locality on two previous cruises and now has comparable measurements during El Niño for comparison. We also sampled California Undercurrent waters near 9 Mile Bank, then proceeded offshore to recover drifting instruments at Cycle 1. We recovered the sediment traps and also recovered the surface floats and transmitter for the driftarray, however the tether had parted in high seas and the driftarray incubation bottles were lost. Therefore at Cycle 1 we completed one 24-h in situ incubation, including day and night CTD casts, MOCNESS and bongo tows, and other measurements, but these were not replicated. We then proceeded to conduct three 3-day Cycles (2, 3, and 4), progressing from offshore to onshore.

The second ancillary study tested the hypothesis of elevated dissolved iron in the benthic boundary layer (BBL) above continental shelf sediments in the vicinity of Pt. Arguello and Pt. Conception, in particular near the Santa Ynez river. Shelf sediments and the associated BBL may be a major source of Fe for phytoplankton in the southern California region. Co-PI Katherine Barbeau and graduate student

Angel Ruacho are interested in the relationship of Fe supply to El Niño-related river discharge in winter of 2016.

A Scientist-at-Sea live video Skype call was made to the Birch Aquarium at Scripps on 6 May. Four members of the science party (two faculty, two graduate students) participated, answering questions from a middle school class and other aquarium visitors.

Brief chronology of this cruise (see Event Log for details):

19 April 2016 (~0900)	Depart MarFac; anchor in San Diego Bay for EK60 calibration
19 April (~ 2100)	Depart San Diego Bay
20 April (0700-1900)	Equipment tests, then transit to CYCLE 1
21 April (1400)	MVP bow tie survey #1
22 April (0100)	Deploy sediment trap, begin CYCLE 1
23 April (0800)	Steam to San Diego for medical issue
24 April (1300)	Start 9 Mile Bank survey (MVP bow tie #2, EK60, ALF, bongo tows)
25 April (1000)	Return to CYCLE 1
27 April (1500)	Recover Sediment trap, end CYCLE 1
28 April (0800)	MVP bow tie survey #3
29 April (0100)	Deploy sediment trap, begin CYCLE 2
2 May (0600)	Recover sediment trap, end CYCLE 2
2 May (1630)	MVP bow tie survey #4
3 May (0100)	Deploy sediment trap, begin CYCLE 3
6 May (0630)	Recover sediment trap, end CYCLE 3
6 May (1300)	MVP bow tie survey #5
7 May (0100)	Deploy sediment trap, begin CYCLE 4
10 May (0700)	Recover sediment trap, end CYCLE 4
10 May (1300)	Begin Benthic Boundary Layer (BBL) shelf study
11 May (0300)	Deep CTD for Thorium; steam to San Diego
12 May (~1300)	Arrive MarFac

GROUP REPORTS

Hydrography, Primary Production – **Goericke Group** (Ralf Goericke, Megan Roadman)

Hydrography: CTD casts were carried out every 8 to 12 hours while the drifter was in the water. The package (SBE 9Plus) had instruments for temperature (SBE 3), conductivity (SBE 4), oxygen (SBE43, RINKO III), chlorophyll fluorescence (Seapoint), light attenuation by particles (Wetlabs C-Star), and photosynthetically active radiation (Licor PAR sensor). Samples were collected from the CTD at about 8 depths per cast for concentrations of plant nutrients (nitrate, nitrite, silicic acid, phosphate, and ammonium), salinity, concentrations of Chl *a* (determined fluorometrically aboard the ship), particulate organic carbon and nitrogen, and taxon-specific pigments by HPLC. Preliminary results from some of these observations are summarized in Table 1 as averages for the surface layer of individual experimental cycles.

Table 1: Cycle averages of surface layer hydrographic properties

Cruise	Cycle	Date	AvgDepth	Temp	Sal	Sigma-t	Oxygen	Oxygen Saturation	FluorVolt
-	-	-	(m)	(º C)	(psu)	(kg/m3)	(µmol/kg)	(%)	(Volt)
CCE-P1604	Cycle1	22-Apr	12	16.6	33.1	24.2	235	97	0.05
CCE-P1604	Cycle2	30-Apr	12	15.2	33.0	24.4	239	96	0.06
CCE-P1604	Cycle3	4-May	11	13.5	33.2	24.9	247	95	0.55
CCE-P1604	Cycle4	7-May	11	13.8	33.7	25.2	267	104	1.64

Temperature-salinity diagrams (Fig. 5) allow the identification of water masses and the tracking of changes of water masses between stations. In terms of hydrography Cyc 1 appeared to be in stratified waters offshore in an cyclonic eddy, Cyc 2 in the core California Current, Cyc 3 in waters influenced by the California Current, while the relatively high surface layer salinity of Cyc 4 suggests that these waters were derived from coastal upwelling. The variability of TS relationships for some cycles and density horizons (e.g. Cyc 4 sigma-t ~ 26) indicates that different water parcels were encountered over the duration of the cycles.
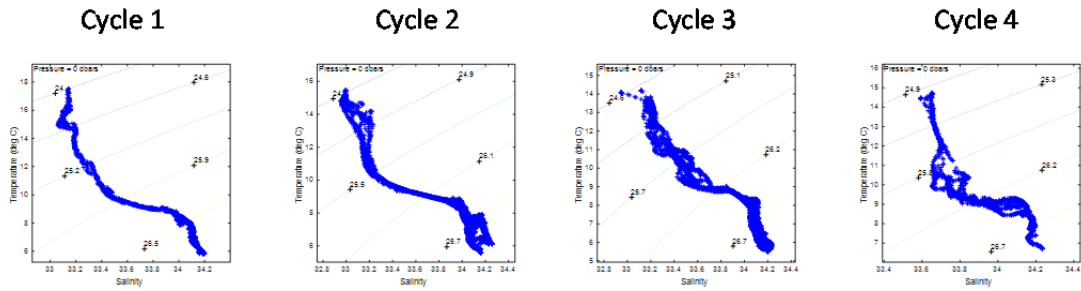

Fig. 5: T-S diagrams for all cast of individual cycles, illustrating the water mass variability or the absence thereof during each cycle.

Averaged ADCP currents at each cycle are shown below in Fig. 6. The reference quiver (blue arrow) represents a current speed of 0.5 m/sec in the direction of 90º.
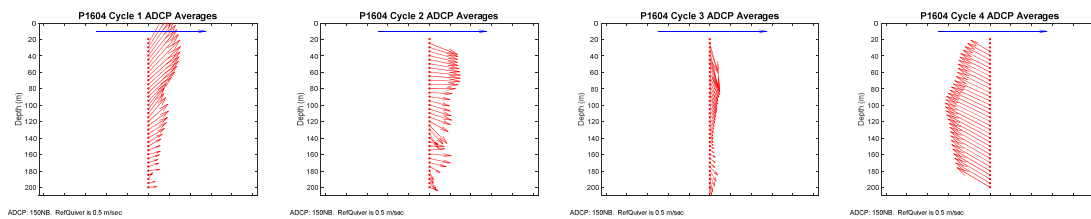

Fig. 6: ADCP currents as a function of depth, averaged over the duration of the four cycles.

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The depth distribution of Chl *a* for the four cycles is shown in Fig. 7. The patterns shown in Cyc 1 and 2 are characteristic of nutrient depleted waters – low values in the surface and a pronounced maximum at depth – whereas the patterns shown in Cyc 3 and 4 are typical for nutrient replete system – maxima of Chl *a* in the surface layer. Mixed layer concentrations during Cyc 4 suggest that we encountered a phytoplankton bloom, which in that location is often dominated by large diatoms.
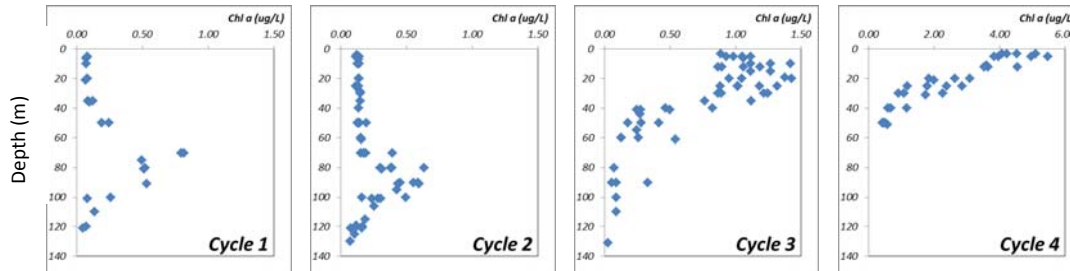

Fig. 7: Chl *a* profiles for the four cycles. Note the different scale for Cycle 4.

Phytoplankton Community Structure: The pigments of microalgae are often characteristic of their taxonomic affiliation. Concentrations of taxon-specific pigments, e.g. chlorophylls and carotenoids, can be used to determine relative contributions of different taxonomic groups to total phytoplankton pigment-biomass. We collected samples for the analysis of phytoplankton pigments from most casts. These samples will be analyzed ashore by HPLC for concentrations of pigments and phytoplankton community structure will be determined from these data.

Phytoplankton size as another dimension of community structure was determined using Chl *a* size fractionation on samples from the mixed layer or the deep chlorophyll maximum (DCM). Results from these experiments are shown in Table 2. The size distribution for the surface layer is shown in Fig. 8 for all 4 cycles. The patterns observed during Cyc 1-3 are consistent with the total phytoplankton biomass present, based on past observations. The pattern observed during Cyc 4 is unusual; the size spectrum is dominated by cells in the 3 to 20 µm size range, rather than by cells > 20 µm. This may either reflect an unusual oceanographic condition or the decline of the phytoplankton bloom.

Table 2: Chlorophyll size fractionation experiments: Experiments were done with water from the 02:00 am casts from the mixed layer (ML) and the noon CTD with water 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 less than 1 µm, 1 to 3 µm, 3 to 8 µm, 8 to 20 µm, and larger than 20 µm size fractions.

| Cruise	Cycle	Location	Depth	N	TChl a	Less_1um	1umTo3um	3umTo8um	8umTo20um	Larg20um
-	-	-	(m)	-	(ug-Chl/L)	(%TChl a)	(% TChl a)	(% TChl a)	(% TChl a)	(% TChl a)
CCE-P1604	1	ML	5	1	0.07	58	19	11	8	4
CCE-P1604	1	DCM	90	2	0.4 ± 0.10	60 ± 2	22 ± 3	12 ± 1	4 ± 1	2 ± 0
CCE-P1604	2	ML	7	3	0.1 ± 0.01	54 ± 2	22 ± 3	13 ± 1	8 ± 0	3 ± 0
CCE-P1604	2	DCM	92	4	0.3 ± 0.06	48 ± 2	29 ± 1	14 ± 1	6 ± 1	3 ± 1
CCE-P1604	3	ML	12	4	0.6 ± 0.09	66 ± 11	19 ± 7	6 ± 1	4 ± 1	4 ± 3
CCE-P1604	3	DCM	23	3	0.7 ± 0.08	62 ± 5	25 ± 5	7 ± 0	4 ± 1	2 ± 1
CCE-P1604	4	ML	12	2	2.1 ± 0.02	22 ± 3	16 ± 3	27 ± 6	33 ± 1	2 ± 1.3
CCE-P1604	4	DCM	20	2	1.7 ± 0.45	21 ± 7	14 ± 0	31 ± 5	32 ± 3	2 ± 0.7
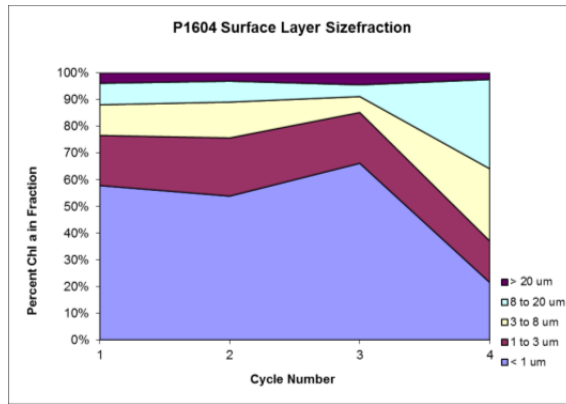
Fig. 8: Average Chl *a* size distributions for the 4 Cycles. Chl *a* concentrations in the mixed layer increased with cycle number (Cyc 1-4: 0.07, 0.1, 0.6, and 2.1 µg-Chl *a*/L, respectively)

Primary Production: Rates of primary production were determined from the incorporation of ^{14}C into particulate carbon and dissolved organic carbon. Samples will be analyzed ashore.

Phytoplankton community structure and physiology were also analyzed using a modified Advanced Laser Fluorescence (ALF) system, designed by Alexander Chekalyuk. We used a new prototype of the next generation ALF system (provisionally called CLASS, Custom Laser Active Spectroscopic System). Continuous measurements were made on water from the ship's clean seawater system and from water collected at different depths using the CTD rosette. Depth profiles of ALF-measured properties for the four cycles are shown in Fig. 9. Chl *a* fluorescence covaried closely with filtered, acetone-extracted Chl *a* (Fig. 7). The F_v/F_m ratio, which is thought to be sensitive to the nutritional status of the algae, did not vary systematically between cycles. This result is surprising since concentrations of nutrients differed dramatically. In the offshore (Cyc 1 & 2) only fluorescence due to blue-water cyanobacteria and cryptophytes was observed, albeit weakly. In the coastal zone strong fluorescence was observed for these two groups as well as coastal cyanobacteria. Many of these properties had strong diel signals (e.g., Cycle 3, Fig. 10) primarily driven by light but possibly also by diel variation in nutrient availability.
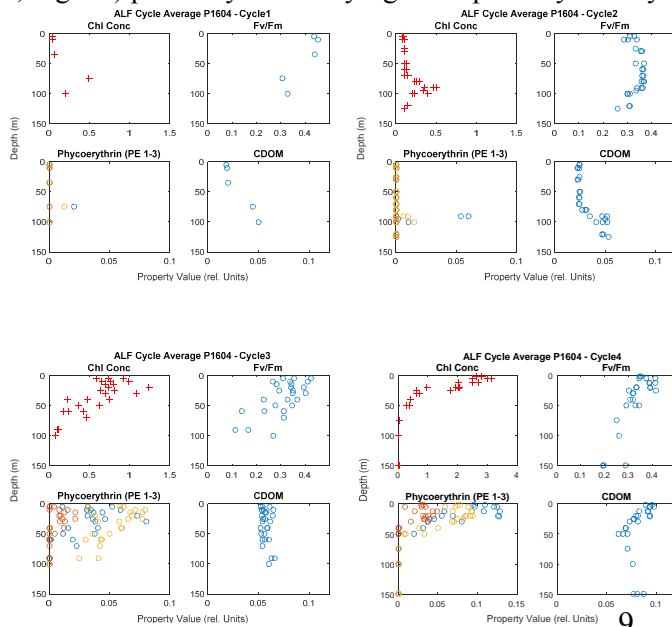

Fig. 9: Depth distributions of phytoplankton biomass (as Chl *a*), photosynthetic capacity (F_v/F_m), colored dissolved organic matter (CDOM), and phycoerythrins characteristic of oceanic cyanobacteria (PE1, blue circles), coastal cyanobacteria (PE2, red circles), and cryptophytes (PE3, yellow circles) at Cycles 1 - 4. All units are relative.
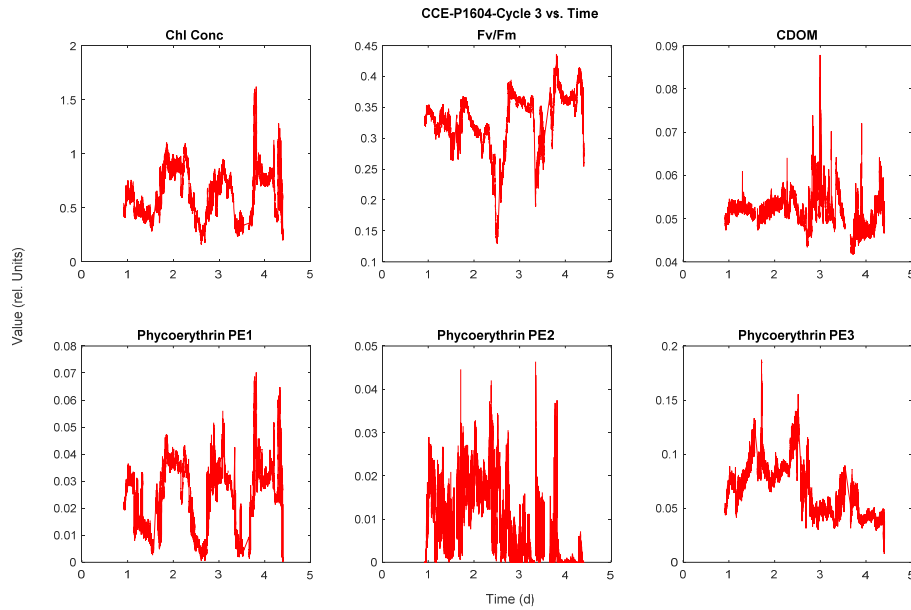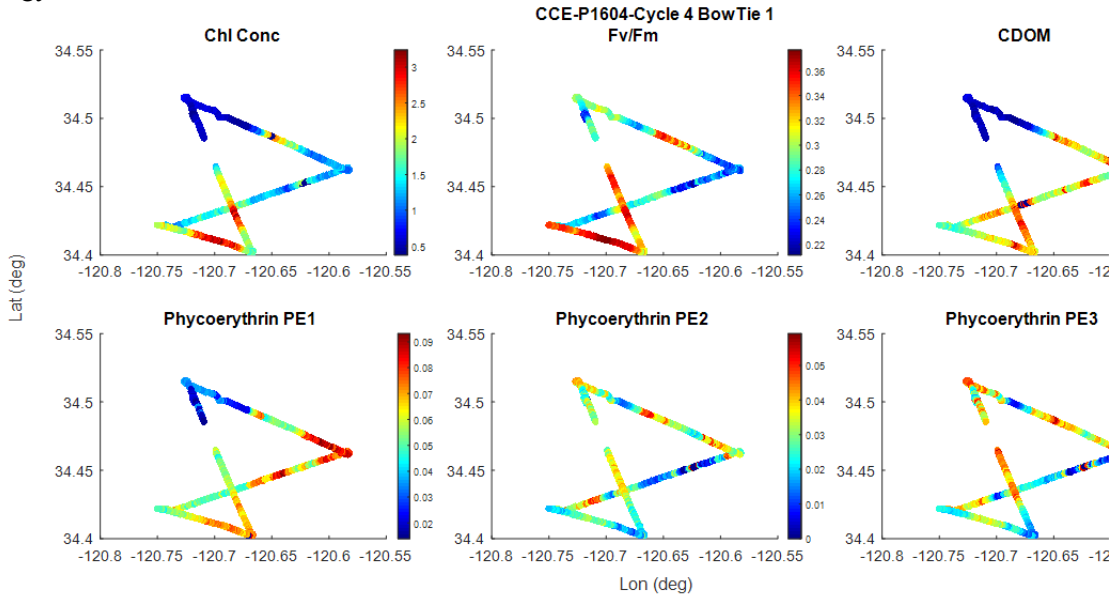
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Fig. 10: Diel variations of the ALF-measured properties phytoplankton Chl *a* fluorescence, photosynthetic capacity (F_v/F_m), colored dissolved organic matter (CDOM) and distributions of phycoerythrins characteristic of oceanic (PE1) and coastal (PE2) cyanobacteria, and cryptophytes (PE3) during Cycle 3.

ALF continuous underway data for our initial site survey for Cycle 4 (Fig. 11) show dramatic differences in the abundance of algae over short distances and corresponding difference in algal physiology, as reflected in F_v/F_m ratios.

Fig. 11: Spatial patterns of phytoplankton Chl *a* fluorescence, photosynthetic capacity (F_v/F_m), colored dissolved organic matter (CDOM). and distributions of phycoerythrins characteristic of oceanic (PE1) and coastal (PE2) cyanobacteria, and cryptophytes (PE3) during the initial bow tie site survey for Cycle 4, as determined by ALF. All units are relative.

Measurements of colored dissolved organic matter (CDOM) are complementary to work done by Dr. Aluwihare who is measuring total and dissolved organic carbon (DOC). CDOM is thought to be a tracer for some classes of dissolved organic matter, a relationship that will be further explored once measurements of DOC are available. Fluorescence due to CDOM varied by a factor of 4 in the mixed

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layers of the four cycles (Fig. 9), consistent with the expectation of low CDOM signals in the offshore where CDOM is bleached in the surface layer of the ocean and high CDOM signals in the coastal areas where it is derived from deeper waters via upwelling.

Trace Metal Studies – Barbeau Group (Kathy Barbeau, Angel Ruacho, Maitreyi Nagarkar)

Despite damage to the trace metal rosette frame during the early part of the cruise, the trace metal group completed 22 rosette sampling casts, including 9 profiles for dissolved iron and nutrient distributions. The remainder of the rosette casts were used for trace metal clean water for various incubations and experiments.

Experiments to assess iron stress in the phytoplankton community were carried out at Cycles 3 and 4, where nitrate was present in surface waters. This included 6 on-array incubations (one carried out each day of Cycles 3 and 4, in near surface waters on the Landry array). On-array studies consisted of iron addition incubations with paired $^{15}NO_3$ additions. We also carried out "traditional" deckboard iron addition growout experiments on the first and last day of Cycles 3 and 4 (four experiments in all, lasting 2-4 days each). Preliminary indications are that there was a perceptible influence of iron stress on the phytoplankton community at Cycle 3, intensifying over the length of the Cycle (see Fig. 12). Iron stress was less apparent at Cycle 4.
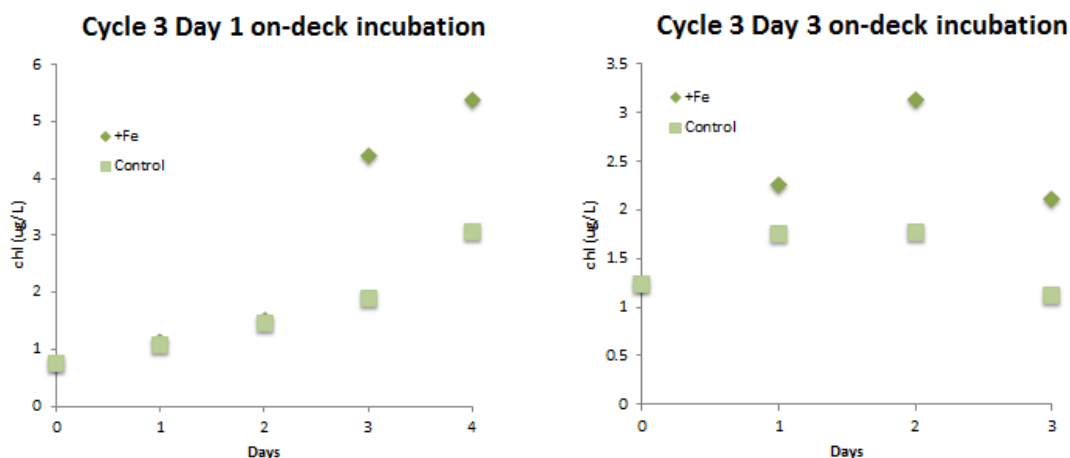

Fig. 12. Deckboard iron-addition growout studies initiated with near-surface waters (20-25 m) on Day 1 (left) and Day 3 (right) of Cycle 3 indicate that the phytoplankton community at Cycle 3 was likely experiencing some level of iron stress.

Four photochemical experiments were also carried out to examine the impact of sunlight irradiation on copper speciation. In addition, an extended "bloom and crash" nutrient-amended incubation was carried out with offshore surface waters from Cycle 1 to study the influence of phytoplankton and microbial community composition on iron speciation.

At the conclusion of Lagrangian cycle work, a study of iron supply from the benthic boundary layer (BBL) was carried out, utilizing paired CTD and GO Flo casts to identify and sample the BBL. An along-shore transect of six shelf stations extending from CalCOFI station 77.49 in the north to the shelf

just southeast of Point Conception in the south (Fig. 13) revealed that the Santa Ynez River shelf area is likely an important source of iron to the CCE study region, due to the presence of a prominent BBL.

Fig. 13. Locations of Benthic Boundary Layer stations.

DOM Characterization and Decomposition – Aluwihare Group (Lihini Aluwihare, Sara Rivera)

The Aluwihare group examined two separate questions during this cruise. The first tested the hypothesis that nitrogen isotope signatures at the base of the food web are higher during El Niño periods relative to non-ENSO periods in the CCE region (Rau et al. 2003. DSRII 50:2451; Ohman et al. 2012. DSR 60:46). Models and CalCOFI data suggest that upwelling waters originate from shallower depths during ENSO periods resulting in a lower flux of nitrate into the euphotic zone. In upwelling regions such as the CCE where excess nitrate can be found in surface waters, a lower flux should result in greater nitrate utilization (i.e., a greater percentage of nitrate is consumed). Based on the Rayleigh closed-system isotope fractionation model it would follow that increased nitrate utilization would result in a higher nitrogen isotope signature for nitrate, which would then be propagated through the local food web. We collected samples to measure N and O isotopes in nitrate, and N and C isotopes in suspended POC, sinking POC (in collaboration with M. Stukel), zooplankton (Cat Nickels) and copepod fecal pellets (Belli Valencia). For comparison we have a similar dataset from 1408 and have been collecting samples for nitrate isotopes during CalCOFI cruises, which include a previous dataset (pre-blob and pre-El Niño) generated by Patrick Rafter (now at UCI) and Danny Sigman (Princeton). We also hope to be able to use the current sample set to examine the importance of nitrification in the euphotic zone nitrate budget during this time period. We have collected 100s of samples and hope to have data soon.

Our second research question examined dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) reactivity in the CCE. DOC and DON are produced in the euphotic zone during primary production and under certain conditions these reservoirs of organic C and N can accumulate on > seasonal timescales. It has been proposed that this C and N could be available for export to other regions of the Eastern North Pacific Ocean. Some studies have suggested that the subduction of surface DOC enhances its "reactivity," possibly due to mixing with new populations of bacteria that are better adapted to consuming this material. However, enhanced stratification during El Niño periods could facilitate longer-term accumulation of "labile" carbon in the mixed layer. To test the reactivity of DOC and DON we measured standing stocks of these variables during each cycle. In addition, we conducted dark incubation studies with 0.2μm filtered seawater isolated from the bottom of the mixed layer with GF/B filtered

seawater sampled below the nitracline. The aim of this experiment was to examine the "latent" reactivity of DOM accumulating in the mixed layer. In all cases we sampled for bulk organic concentrations, compound-specific analyses (using several different DOC and DON extraction methods), bacterial numbers, bacterial protein production, and we also isolated cells from different depths and at t=0 and t=f of each incubation experiment for metatranscriptomic analyses. Again, we collected 100s of samples to be analyzed in the lab.

I would like to add that the facilities and support on the Sikuliaq for my science were excellent. I used the cold room on the ship to conduct all of my DOM extractions (as they take several hours to days to complete) and to maintain by dark incubations. It was wonderful to have that option.

Microbial Community Biomass, Growth and Grazing – Landry Group (Mike Landry, Andrew Taylor, Ali Freibott, Belli Valencia, Mariana Guenther)

Our primary goal was to assess microplankton dynamics within the planktonic food web. As a core part of this project, we used a Lagrangian experimental array that was deployed and recovered daily on each Cycle. This array served as a moving frame of reference for experiments on this cruise, allowing us to relate experimental results to *in situ* community changes. Simultaneously, the array served as a platform for *in situ* incubation of plankton samples for primary production, nitrate uptake, and protistan grazing rate measurements at six depths spanning the euphotic zone.

A core portion of our program is daily measurements of microzooplankton grazing rates using seawater dilution experiments. By diluting natural plankton communities with 0.1-µm filtered seawater from the same depth and comparing net phytoplankton growth rates in the diluted treatments to the net phytoplankton growth rates in non-diluted control bottles, we can simultaneously determine rates of phytoplankton growth and mortality due to grazing from the protistan community. Only a single profile of dilution measurements was made on Cycle 1, due to medical issues. On all subsequent cycles we conducted three, 24 hour long experiments at each depth. From each experiment we took initial and final subsamples for Chlorophyll *a*, HPLC phytoplankton pigments, flow cytometry, epifluorescence microscopy, and DNA analyses. In combination, these samples will allow us to quantify the growth rates of many different phytoplankton taxa and their specific mortality rates resulting from grazing by the protistan grazer community. Most of these samples will require analysis ashore, however, we were able to analyze Chl *a* at sea to get an estimate of phytoplankton growth and mortality due to grazing. The results (currently available for Cycles 1 – 3, Fig. 14) show that growth and grazing rates were closely balanced during Cycles 1 and 2 in the oligotrophic, offshore region and the California Current, respectively. For Cycle 3, which was conducted in recently upwelled water, growth was greater than
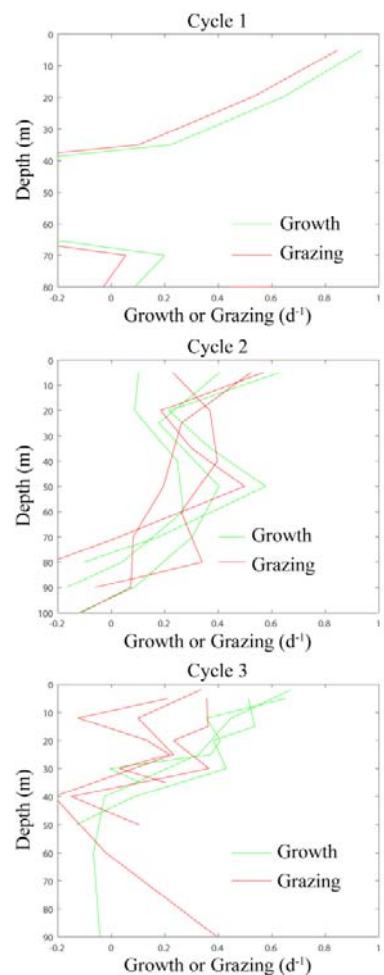

Fig. 14. Preliminary results from seawater dilution experiments.

grazing in surface waters. This could suggest positive net growth rates *in situ*, which would lead to a growing phytoplankton bloom, or indicate that substantial excess production was available to the mesozooplankton grazing community. In addition to these measurements of the phytoplankton community rates within the dilution experiments, we also took microscopy and DNA samples to enumerate the phytoplankton and protist grazer communities. These analyses will allow us to compare grazing rates to the protistan grazer community in order to link specific taxa to important roles in the community.

In addition, Alexandra Freibott conducted additional three-point dilution experiments in which the plankton community was separated by size class to separately determine nano- and microplankton growth and grazing rates. Experiments were conducted once each during Cycles 1 and 2, and daily during Cycles 3 and 4, at a single depth during each 24-hour incubation period. There were replicates at each dilution level (18%, 45%, and 100%) and the community was separated by size using 20-µm and 200-µm mesh. Initial samples were taken for Chl *a*, epifluorescence microscopy, flow cytometry, and DNA analyses to determine the starting plankton community composition and biomass. The bottles were incubated *in situ* on the drifter array for 24 hours. After incubation, samples were collected from each bottle for Chl *a*, flow cytometry, and DNA analysis for determination of growth and grazing rates in each size class. Results of the size-fractioned dilution experiments will shed light on the different grazing pressures of protistan consumers on individual size classes of phytoplankton prey and potentially point to trophic cascades occurring amongst the different size-classes of plankton.

Bacterial Biomass and Production – Aluwihare and Azam Group (Sara Rivera)

Seawater samples were taken at 6-8 depths from each mid-day (1100) CTD cast, as well as from on deck incubations (Fe addition, DOC and POC turnover), 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. Seawater samples were also taken at 6-8 depths from each mid-day (1100) CTD cast, as well as from on deck incubations (Fe addition, DOC and POC turnover), to estimate rates of bacterial protein synthesis using the leucine incorporation method. For each sample, 1.8-mL seawater samples were incubated with 4 µL of 140 mM ^{3}H-leucine for one hour at 12° C in quadruplicate with duplicate 5% TCA killed controls. After the incubation was complete, samples were stored in a -20°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) –Tristan Biard

The Underwater Vision Profiler 5 (UVP5), an in situ plankton camera from the Laboratoire Océanographique, Villefranche-sur-Mer, France, was mounted inside the CTD-rosette at the bottom of the frame in order to sample undisturbed waters (see Fig. 15). The abundance of particles was displayed live and recorded in the dedicated Seasave application. UVP5 serial number 003 was utilized during the P1604 cruise. The calibration report "Calibrage_UVP5_sn003_2012.doc" provides the settings for this

unit. All casts were performed using the "mixtfd" settings in order to achieve the highest acquisition rate. Image volume is 0.93 L. Pixel size is 147 x 147 μm. Vignette processing uses: Gamma = 5 and Scale = 5. The Ocean Data View–compatible file "baseuvp5_sn003_P1604_cal_lpm_odv.txt" includes LPM abundances and biovolume spectra binned in 5m intervals.

Fig. 15. UVP5 mounted on CTD rosette.

UVP 5 Data (LPM and CTD)

A total of 60 casts was performed to maximum depth of 3,000 m. All casts were processed on board ship. Figure 16 highlights some of the typical LPM (Large Particulate Matter) abundance vertical profiles within the four different cycles. *Note on the Cycle_4 profile the sharp increase in LPM concentration at 450m (bottom depth at 505m).*
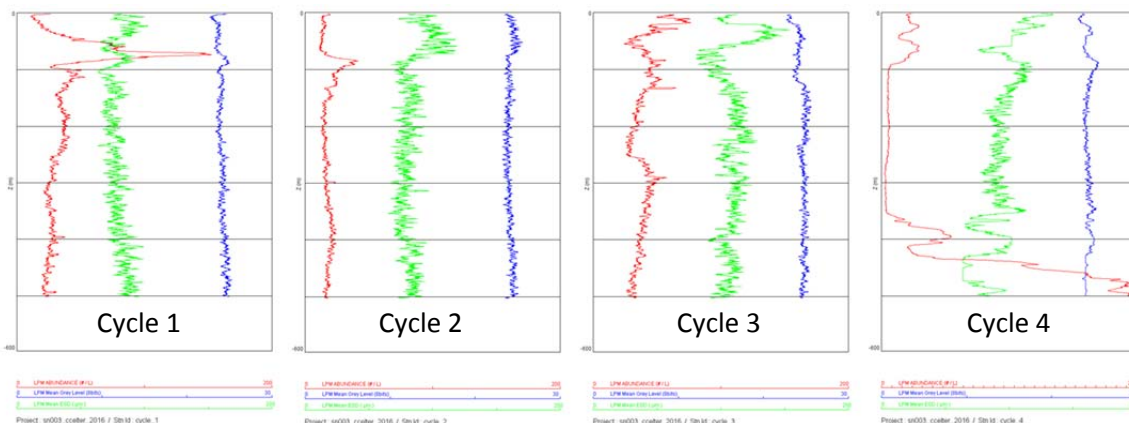
Fig. 16. Vertical UVP5 profiles of Large Particulate Matter concentration (LPM, red line), LPM Mean size as ESD (green), and LPM mean gray level (blue) from 0-400 m depth, at the 4 Cycles.

UVP5 Data (Zooplankton)

A total of 147,422 vignettes was pre-sorted using a 28 category Learning Set, then validated manually. The vignettes were uploaded to the stand-alone Beta version of Ecotaxa. Additional sorting will be needed to fully validate the entire dataset.

Some representative specimens of the different categories are displayed below in Fig. 17. Artifacts, detritus, and fibers are not illustrated here, but represent a large proportion of UVP vignettes.

Fig. 17. UVP5 in situ plankton images. The footer of each vignette indicates: (*note: some pictures have a partial scale)*
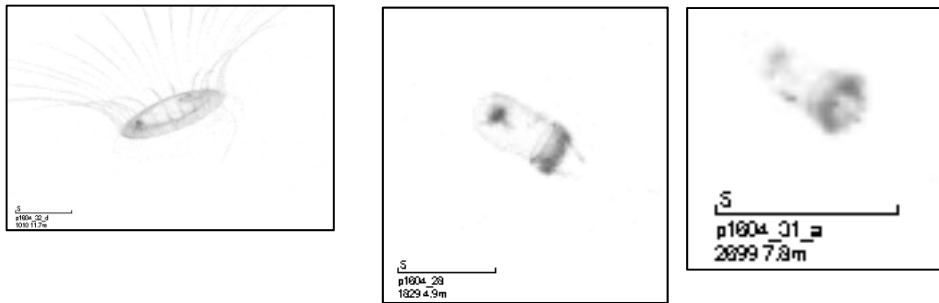- Scale (mm)
- Cast name
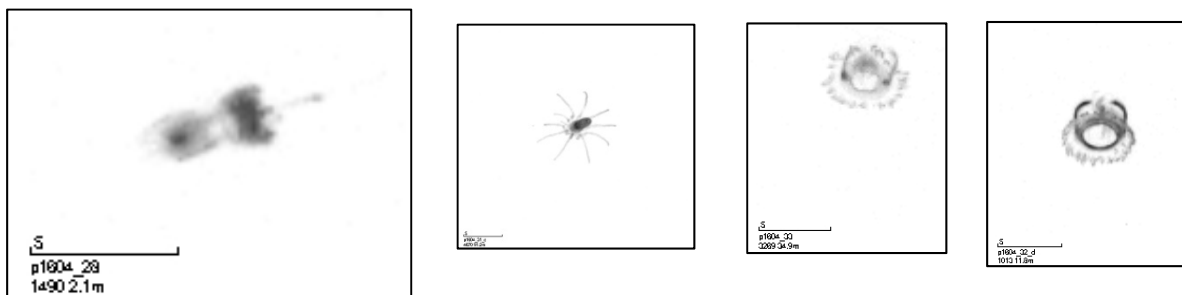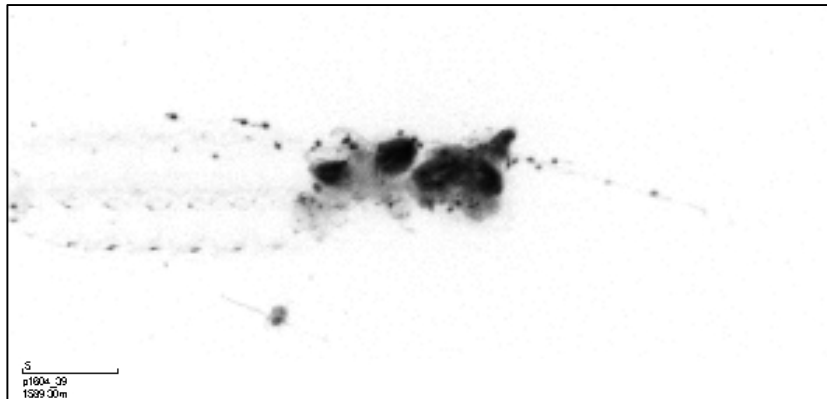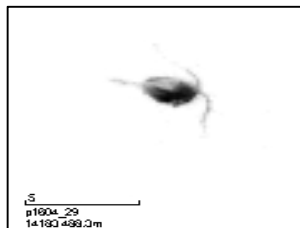- Raw image number
- Depth

Annelida
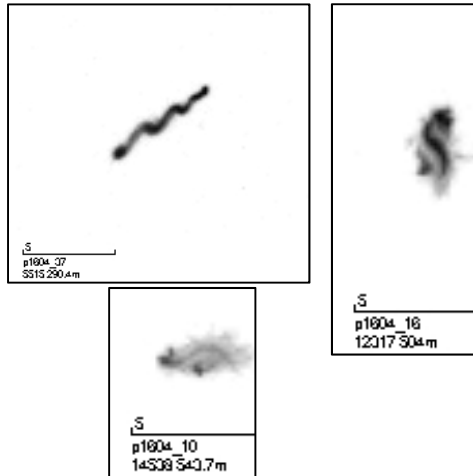
Chaetognatha
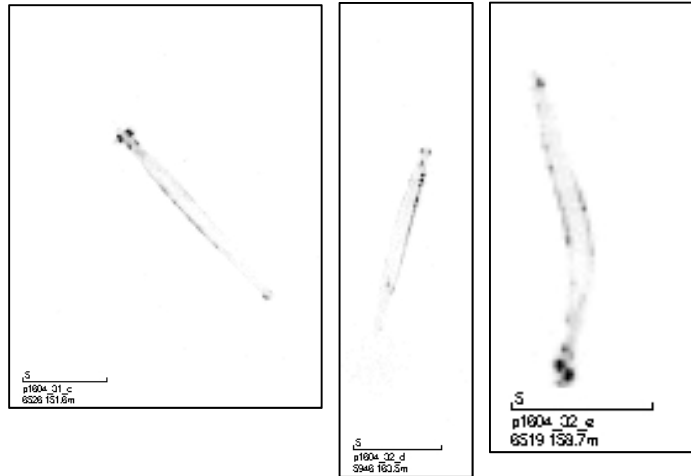
Cnidaria

Hydrozoa

Siphonophora

Copepoda
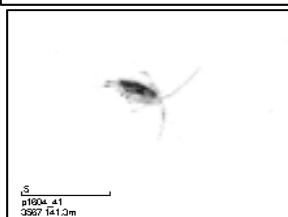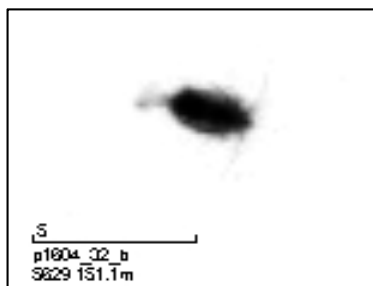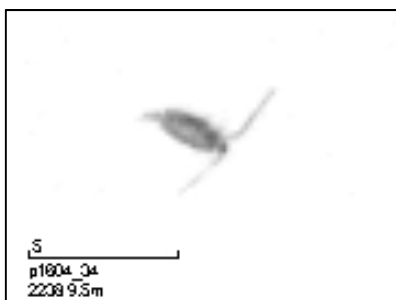
Copepod-like
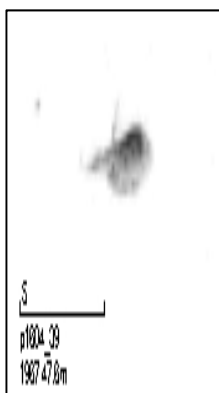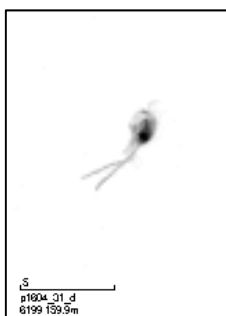
Eumalacostraca
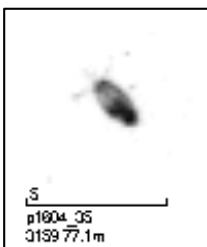
Ostracoda
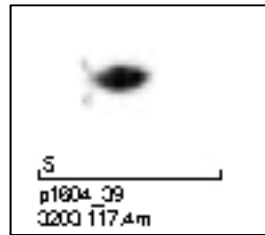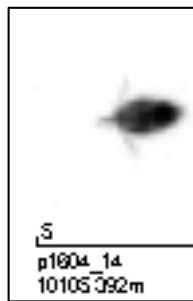
Ctenophore
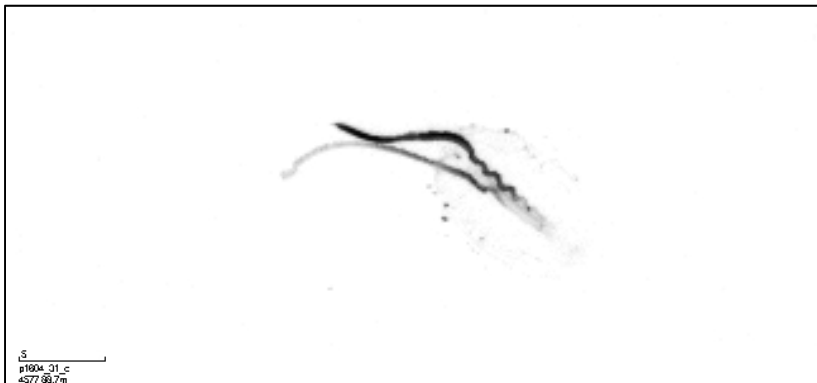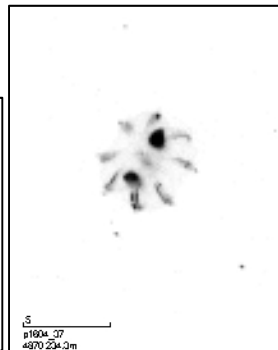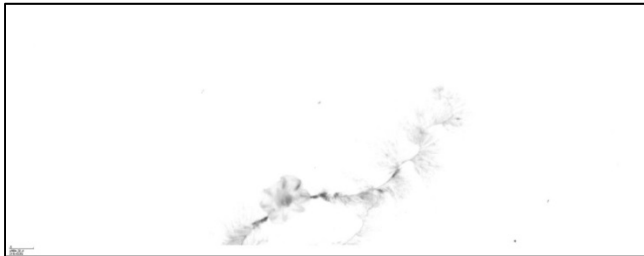
Rhizaria *(unidentified rhizarians)*
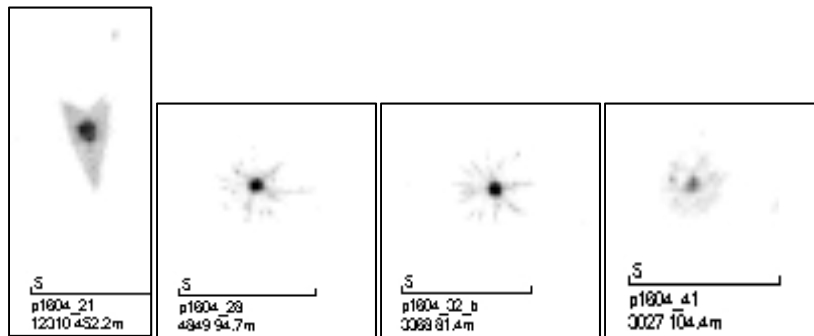
Acantharia
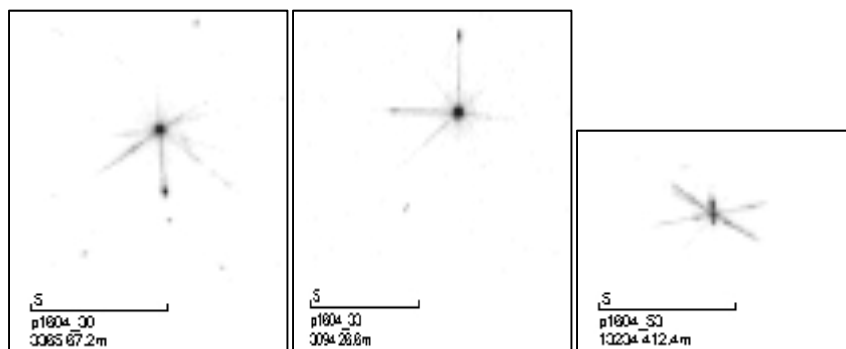
Collodaria_colonial

Collodaria_solitary_black

Phaeodaria_leg
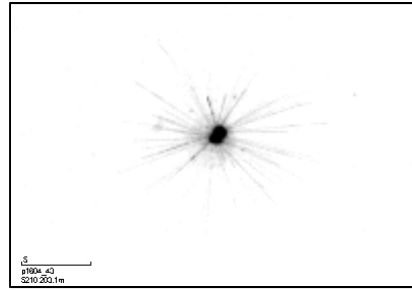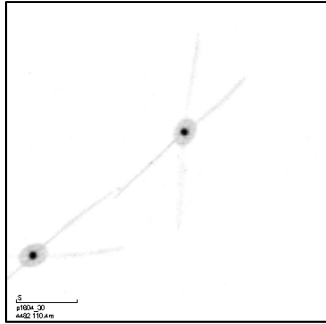
Phaeodaria_sphere_eye

Phaeodaria_sphere_thorn

Appendicularian

Salpida

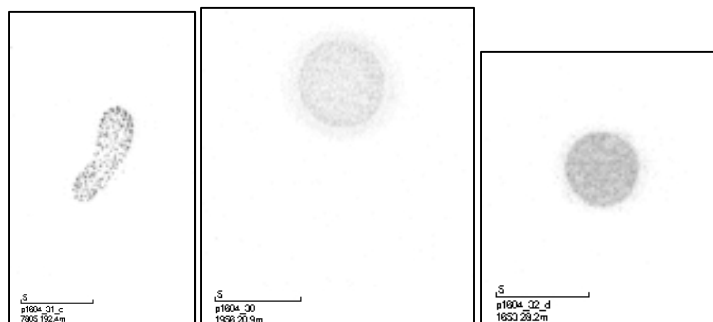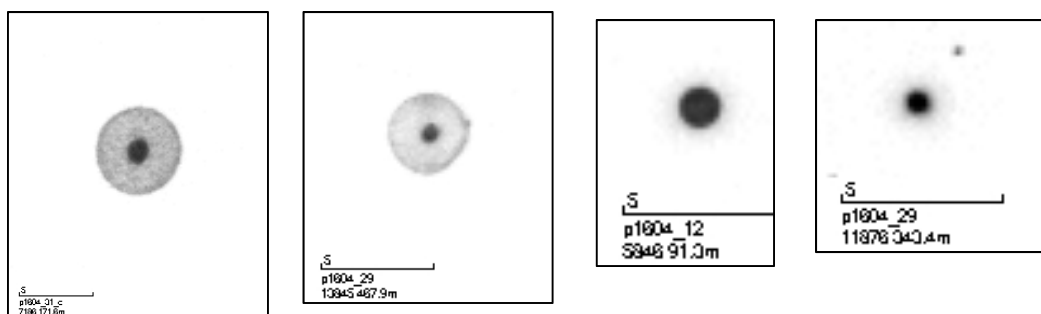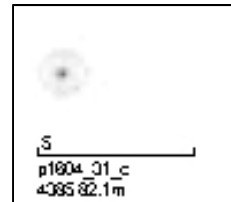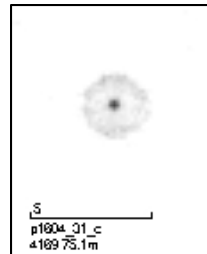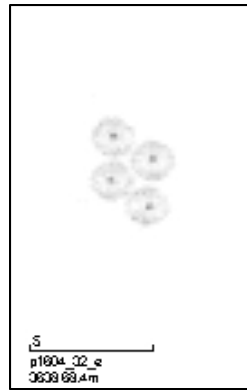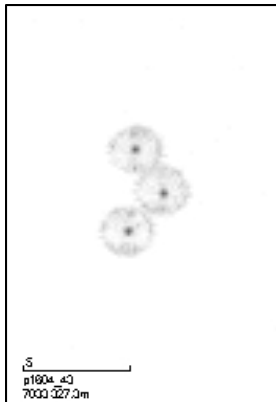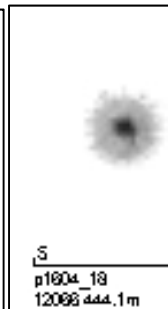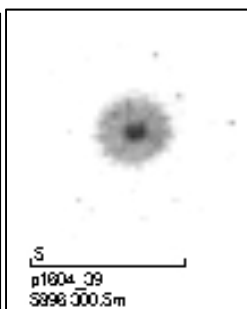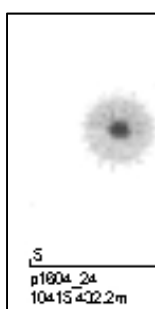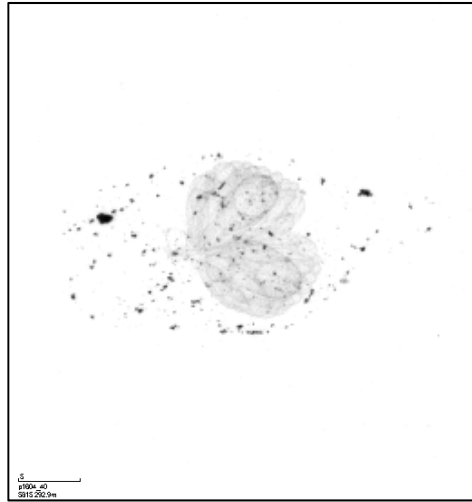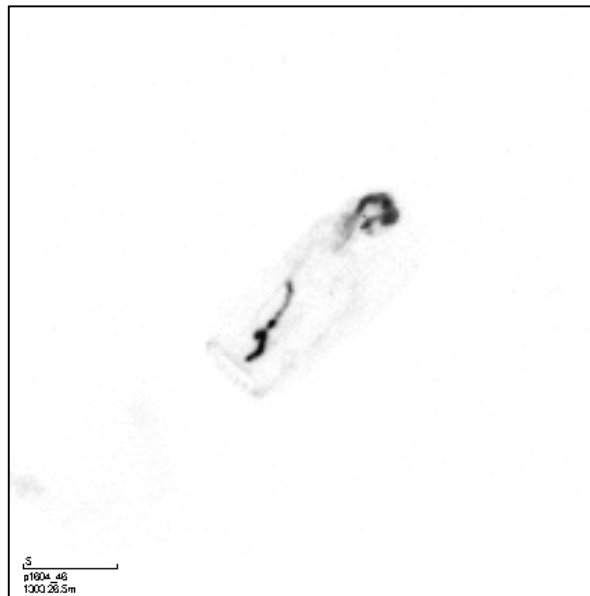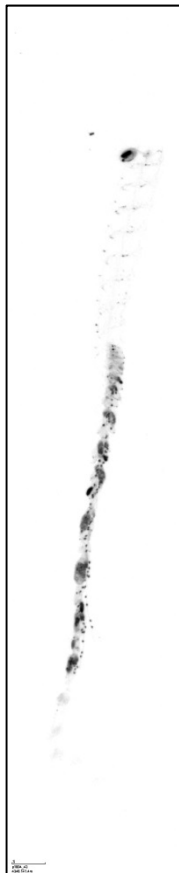**Mesozooplankton Research –** Ohman Group (Mark Ohman, Catherine Nickels, Jennifer Brandon, Ben Whitmore, Laura Lilly, Carolyn Belak, and Brian VerWey)

Moving Vessel Profiler (MVP): A free-fall Moving Vessel Profiler (MVP) was deployed to characterize horizontal gradients in hydrographic and plankton properties and guide site selection for experimental cycles. The MVP sensors included a Laser Optical Particle Counter (LOPC, SN 11432, new March 2015), Welabs FLRT Chl-*a* fluorometer (SN 247), and AML Micro fast response CTD (SN 7209). A total of 282 MVP casts was completed. The MVP tow cable was replaced at sea on 29 April following heavy abrasion of the cable during recovery in high sea states.

Vertically stratified MOCNESS sampling: Vertically stratified plankton sampling was carried out with a 1 m^2 MOCNESS with 202-μm mesh nets, deployed in day and night tows at each of the four experimental Cycles. The MOCNESS frame from the Univ. of Alaska accommodated 9 nets, rather than our customary 10 nets. The MOCNESS was equipped with sensors for temperature, salinity, O_2, beam transmission, Chl-*a* fluorescence, and dissolved oxygen. However, problems with the conductivity cell resulted in no valid salinity or density data. Reliable Chl-*a* fluorescence and dissolved oxygen were not acquired, although beam transmission was measured on Hauls 5-15. Sampling was conducted to assess changes in mesozooplankton vertical distributions and diel vertical migration behavior across different hydrographic conditions, for comparison with El Niño-neutral springs. Samples from one day and one night MOCNESS tow per Cycle were split at sea with a Folsom splitter, with half of each sample fixed in 5% sodium tetraborate-buffered Formalin and half in 95% non-denatured ethanol. For the remaining MOCNESS tows, 100% of each sample was fixed in buffered Formalin. 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, and shell calcification of selected species of calcareous zooplankton. A total of 15 MOCNESS tows was completed, including one day and one night tow at Cycle 1 and duplicate day and night tows at each of Cycles 2-4.

Mesozooplankton biomass and grazing rates: Bongo tows were made with a 71-cm diameter, 202-μm mesh bongo net, for determination of mesozooplankton dry weight 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 3/8 will be used for biomass determination, 3/8 for mesozooplankton gut fluorescence, and 1/4 for other studies, including molecular characterization of zooplankton diets.

Twenty-seven oblique bongo tows were completed, representing 1 day and 1 night tow at Cycle 1, 3 replicate day and night series at Cycles 2-4, 6 tows across 9 Mile Bank, and 1 test tow.

Copepod egg production experiments (Cat Nickels and Laura Lilly): We use the egg production rate of copepods as an estimate of secondary production by copepods. We conducted between 1-3 bongo tows at 0830 at each Cycle with a 333-μm mesh bongo net to collect live copepods for egg production experiments. Animals were collected in the upper 200-250 m. Adult females of *Calanus pacificus*, *Metridia pacifica*, and *Eucalanus californicus* were identified from each tow and placed in individual petri dishes. The dishes contained water collected from the chlorophyll maximum depth the previous night and were kept in an incubator set to 13.5°C to simulate the copepods' *in situ* conditions. Incubation duration was 24 hours for *C. pacificus* and *M. pacifica*, and 72 hours for *E. californicus*. The dishes were

checked for eggs approximately every 12 hours (before 24:00 and after 06:00), the chlorophyll maximum water was refreshed, and the female moved to a new dish if eggs were present before the end of the incubation. After the incubation period, adult females were preserved in Formalin for measurement after the cruise. Eggs were incubated for an additional 36 hours and then checked for hatching success. All three species were not found for all experimental cycles. *M. pacifica* was only present during Cycle 1 and the second tow of Cycle 3. There was no appreciable egg laying during Cycles 1 and 2, but we measured an increase in egg production by *C. pacificus*, in particular, during Cycles 3 and 4.

Export Flux and New Production - Stukel group (Mike Stukel, Tom Kelly)

Our goal was to quantify the flux of carbon and nitrogen transported to depth by sinking particles and to determine the sources of these particles and food web controls on their production. Toward this end, we conducted 4 successful sediment trap deployments, one at each Cycle. During Cycles 1 and 2, when the euphotic zone depth was close to 100 m and a deep chlorophyll max was present, each deployment had sediment trap crosspieces at depths of 100 and 150 m. On Cycles 3 and 4, when the euphotic zone was substantially shallower, in addition to 100 and 150 m we also placed sediment traps at 60 m (Cycle 3) and 50 m (Cycle 4). Preliminary results from Cycles 1-4 showed that pigment flux into the traps varied by nearly two orders of magnitude. During Cycles 1 and 2, pigment fluxes at 100 m depth (Fig. 18) were the lowest that we have measured in the CCE (phaeopigment flux on Cycles 1 and 2 was 112 ± 13 and 85 ± 5 µg Chl *a* equiv. m^{-2} d^{-1}, respectively). On Cycle 3 (in the midst of a doliolid bloom) phaeopigment flux was substantially higher (1645 ± 865 µg Chl *a* equiv. m^{-2} d^{-1}). On Cycle 4 (during a bloom of the copepod *Calanus pacificus*) phaeopigment flux was the highest that we have measured in the CCE (8232 ± 835 µg Chl *a* equiv. m^{-2} d^{-1} at 97 m depth). In addition to these samples which were processed at sea, we also took subsamples from the trap for a wide array of analyses that will be conducted ashore. These include: carbon and nitrogen, carbon and nitrogen stable isotopes, biogenic silica, C:^{234}Th ratios, epifluorescence microscopy for protistan communities, light microscopy for fecal pellets, acrylamide gel traps for microscopic quantification of aggregate flux, genomic analyses, transcriptomic analyses (samples preserved in RNAlater to assess gene expression on sinking particles), and amino acid labeling experiments (to determine which organisms on the sinking particles were active). We also quantified the flux of sinking rhizarians into the sediment trap, to assess the

Fig. 18. Preliminary estimates of pigment fluxes collected by sediment trap.

biogeochemical importance of these protists that have recently been shown to comprise a large portion of the oceanic plankton biomass in the world ocean.

In addition to sediment traps, we used ^{238}U-^{234}Th disequilibrium measurements as an independent estimate of sinking particle flux. We measured ^{234}Th concentrations at 12 depths spanning the upper 200 m of the water column on 7 profiles during the cruise. These samples (which require analysis ashore) will allow us to determine whether the sediment traps were over- or under-collecting sinking particles. They

will also allow us to estimate flux attenuation through the water column. In addition to ^{238}U-^{234}Th disequilibrium, we collected a limited number of samples to attempt to measure the ^{90}Sr-^{90}Y disequilibrium. We are attempting to develop a new technique that (if it works) will allow us to estimate particle flux in dynamic coastal regions where the steady-state assumptions required by ^{238}U-^{234}Th disequilibrium often do not hold.

In addition to these export measurements, we also made measurements of nitrate uptake by the phytoplankton community. These measurements, made *in situ* at six depths spanning the euphotic zone on our drift array, allow us to assess "New Production" by phytoplankton using nitrate that has been upwelled into the ecosystem. We made a total of 60 nitrate uptake measurements on the cruise. These measurements will allow us to assess the balance (or imbalance) between new and export production and will inform us about the relative importance of different nutrient sources to phytoplankton communities in the different sub-regions studied.

INFORMATION MANAGEMENT

IM set up an event logger to provide an authoritative listing of each research activity, with assigned event numbers, date, time, and latitude/longitude. 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.

Additional IM activities included input of cruise specifics to the information system study list and participant directory, as well as uploading of cruise data to a project shared disk on a CCE server. Event log cleaning was initiated, including checking for consistency and missing data, in order to facilitate post-cruise coordination of datasets.

EDUCATION, OUTREACH, AND CAPACITY BUILDING

There were five elements of the CCE-LTER Education, Outreach, and Capacity Building (EOCB) program on this RAPID cruise. This cruise inaugurated a new outreach program at the Birch Aquarium at Scripps (BAS), designed to focus on Scripps expeditionary science. The BAS director, Harry Helling, initiated this program to better connect aquarium visitors and the general public with current Scripps research. A public display focusing on Scripps Expeditions has been created in the Birch Aquarium, featuring sampling devices and artifacts related to the present CCE El Niño response cruise. In addition, we sampled deep ocean water from 3,001 m depth at our offshore-most sampling location and dispersed some into labelled vials, intended for the general public. This deep, old Pacific water will be ^{14}C-aged by L. Aluwihare's lab at Scripps, and used to inform the public about deep ocean circulation, natural acidification of ocean waters, and the changes expected due to El Niño and other sources of climate variability and climate change.

A third aspect of our outreach program was a live Skype call at sea to visitors to the Birch Aquarium. One such call was scheduled for 23 April, to coincide with a CCE-LTER Teacher Training workshop at BAS on 23 April, but the call had to be cancelled for technical reasons. Another call was successfully made on 6 May. The primary audience was a group of middle school students (all girls) from San Marcos, CA, accompanied by teacher Debra Brice, but other visitors to the aquarium were also able to

observe the video conference (Fig. 19). Debra Brice is a former CCE-LTER Teacher-at-Sea (in 2011), supported by the NSF RET program, and she was pleased to be able to bring the experience of shipboard science to her students via a live question and answer session with two faculty (Mark Ohman and Lihini Aluwihare) and two graduate students (Jenni Brandon and Angel Ruacho) aboard the R/V *Sikuliaq*. This 2-way live interaction was received very positively by the shore participants.

Fig. 19. Middle school students and other visitors at Birch Aquarium during live a Skype call from the R/V *Sikuliaq*, 6 May 2016.

A fourth element of our outreach was an at-sea blog generated by CCE graduate student Jenni Brandon, to which other CCE grad students also contributed (http://cce.lternet.edu/blogs/201604/). The blog presents, in accessible language, accounts of our science and life at sea. Finally, on each of the CCE process cruises, the CCE group conducts at-sea science tours of research-in-progress, intended for two audiences. One is the science party itself, so that graduate students, volunteers, and others working intensively on one particular project at sea become better aquainted with others' science and with the overall cruise objectives. The other audience is the ship's crew, as many express great curiosity about what we do, how we do it, and why, and this tour served to open lines of communication with all interested members of the crew.

Selected Mesozooplankton photos (by Mike Stukel)
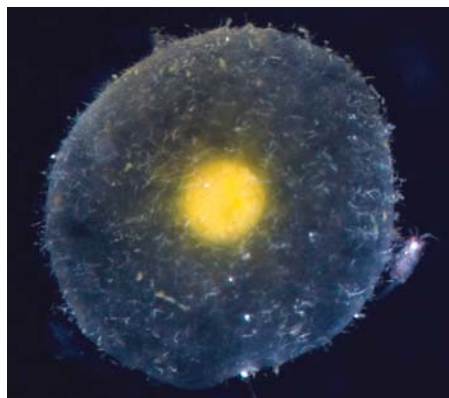
Solitary collodarian (prob.
Thalassosphaera sp.), Cycle 1

Appendicularian netted
from sea surface, Cycle 3

Pyrosome, Cycle 3

Doliolids (*Dolioletta gegenbauri*) dominant at Cycle 3

Hydromedusa , Cycle 3
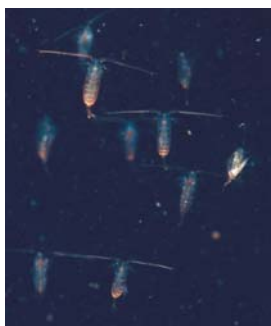
Calanus pacificus , Cycle 4
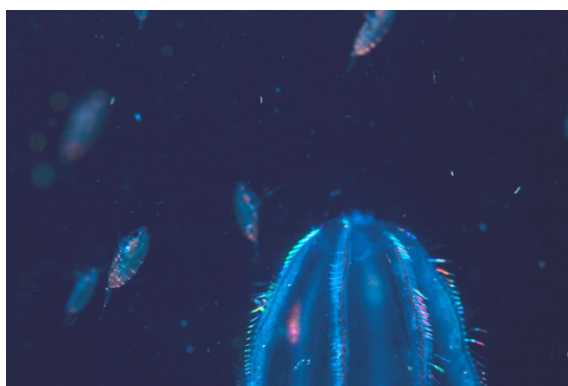
Calanus pacificus and ctenophore, Cycle 4

Pleuroncodes planipes , Cycle 4

CCE-P1604 DAILY ACTIVITY SCHEDULE
(19 April – 12 May 2016)

19 April – EK60 Calibration

0845   Depart MarFac

0930   Anchor for EK60 Calibration

1000   EK60 Calibration

2100   Depart SD Bay

20 April – TEST CASTS in transit

0700   MVP test casts

0900   CTD rosette test cast

1100   Trace Metal rosette test cast

1330   Bongo test

1500   Second bongo test

1600   Second Trace Metal rosette test cast

1800   MOCNESS test

1900   Transit to waypoint: 33º 00'N, 122º 45' W

21 April – Prepare for Cycle 1 (Offshore)

0000   Transit to waypoint: 33º 00'N, 122º 45' W

1300   Lower Centerboard; power EK60

1400   MVP Bow Tie survey #1

2100   CTD cast (for copepod EPR)

2200   Sediment trap deployment, **begin CYCLE 1**

22 April -- CYCLE 1 (near 33º 00'N, 122º 45' W)

0200   CTD, sampling & *in situ* experiments

0300   Trace Metal cast

0500   Deploy driftarray #1

0830   Bongo live tows, zooplankton experiments

0930   Bongo, zooplankton net tow, gut fluor

1100   CTD, microbiology, dissolved organics

1500   MOCNESS

1800   CTD, thorium

1900   CTD, full dilution experiments

2130   Bongo, zooplankton net tow, gut fluor

2230   MOCNESS

23 April

0200	CTD, sampling & *in situ* experiments
0300	TM cast – deck incubation experiments
0500	Recover driftarray #1/deploy #2
0600	Unexpected medical issue; transport science party member to Tenth Ave Marine Terminal (TAMT), San Diego

24 April

1130	Depart TAMT, San Diego
1300	Start MVP Bow Tie #2 - EK60 survey, 9 Mile Bank
2000	CTD
2045	Ring Net live tow, zooplankton experiments
2130	Bongo #1
2215	Bongo #2
2315	Bongo #3

25 April

0000	Bongo #4
0100	Bongo #5
0145	Bongo #6
	Depart 9 Mile Bank; Steam to CalCOFI station 93.30 (32º 48'N, 117º 32'W)
0700	CTD, CA Undercurrent sampling
0830	Trace Metal CTD

26 April Transit to recover Cycle 1 sediment trap & driftarray

27 April

	In transit to recover Cycle 1 sediment trap & driftarray
1015	CTD cast for *Spray* glider calibration
1115	Transit to sediment trap: 33° 23.14' N, 123° 11.11' W
1430	Recover sediment trap
1630	CTD cast, end of Cycle 1
1700	Transit to driftarray: 33° 2.97' N, 123° 2.02' W
2030	Recover driftarray
2130	Transit to MVP survey site for CYCLE 2

28 April

0800	MVP Bow Tie #3 – survey before CYCLE 2 (start near 33º 42'N, 122º 18' W)
1530	Deep CTD, to 3000 m
2130	Bongo, zooplankton net tow, gut fluor

29 April – Start CYCLE 2

0000	Deploy sediment trap
0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Deploy driftarray #2
0830	Bongo live tows, zooplankton experiments
0930	Bongo, zooplankton net tow, gut fluor
1100	CTD, microbiology, dissolved organics
1300	MOCNESS
1800	CTD, thorium
1900	MVP
2130	Bongo, zooplankton net tow, gut fluor
2230	MOCNESS

30 April

0200	CTD, sampling & *in situ* experiments
0500	Recover driftarray #2/Deploy driftarray #3
0600	Trace Metal cast
0700	Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830	Bongo live tow, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	MOCNESS (start 2 nm downwind of driftarray)
1900	CTD, full dilution experiments and copepod EPR
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230	MOCNESS (start 2 nm downwind of driftarray)

1 May

0200	CTD, sampling & *in situ* experiments
0500	Recover driftarray #3/Deploy driftarray #4
0600	Trace Metal cast
0700	Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	MVP Bow Tie #4 survey
2000	CTD, zooplankton experiments
2100	Ring Net live tow, zooplankton experiments (start 0.75 nm downwind of driftarray)

2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230	MOCNESS (start 2 nm downwind of driftarray)

2 May

0200	CTD, sampling
0300	Trace Metal cast
0400	Recover driftarray #4
0500	Recover sediment trap
0700	Dispose galley waste; pump tanks
0730	Steam toward CYCLE 3 Bow Tie survey (start near 34º 20'N, 121º 00' W)
1630	MVP Bow Tie #5 survey, prior to Cycle 3
2300	CTD cast, nitrate

3 May – Start CYCLE 3

0000	Deploy sediment trap
0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Deploy driftarray #5
0700	Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	MOCNESS (start 2 nm downwind of driftarray)
1800	CTD, thorium
1900	Trace Metal cast
2030	Ring net live tow, zooplankton experiments (start 0.75 nm downwind of driftarray)
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230	MOCNESS (start 2 nm downwind of driftarray)

4 May

0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Recover driftarray #5, Deploy driftarray #6
0700	Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)

0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	MOCNESS (start 2 nm downwind of driftarray)
1700	Trace Metal cast
1900	CTD, full dilution experiments and copepod EPR
2030	Ring net live tow, zooplankton experiments (start 0.75 nm downwind of driftarray)
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230	MOCNESS (start 2 nm downwind of driftarray)

5 May

0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Recover driftarray #6/Deploy driftarray #7
0700	Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	CTD (UVP5) vs. MVP (LOPC) comparison – series of repeated casts
2000	Trace Metal cast
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)

6 May

0200	CTD, sampling
0300	Trace Metal cast
0400	Recover driftarray #7
0500	Recover sediment trap
0700	Dispose galley waste; pump tanks
0900	CTD, microbiology, dissolved organics
1000	Steam toward CYCLE 4 Bow Tie survey
1300	MVP Bow Tie #6 survey, prior to Cycle 4 (near 34º 20'N, 120º 44' W)
2030	Ring net live tow, zooplankton experiments
2300	CTD cast, nitrate

7 May – Start CYCLE 4

0000	Deploy sediment trap
0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Deploy driftarray #8

0700	Dispose galley waste; pump tanks (> 1.5 nm downwind of driftarray)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	MOCNESS (start 2 nm downwind of driftarray)
1800	CTD, thorium
1900	Trace Metal cast
2030	Ring net live tow, zooplankton experiments (start 0.75 nm downwind of driftarray)
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230	MOCNESS (start 2 nm downwind of driftarray)

8 May

0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Recover driftarray #8, Deploy driftarray #9
0600	Trash burn; dispose galley waste; pump tanks (> 12 nm from shore)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1300	MOCNESS (start 2 nm downwind of driftarray)
1800	Trace Metal cast
1900	CTD, full dilution experiments and copepod EPR
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
2230	MOCNESS (start 2 nm downwind of driftarray)

9 May

0200	CTD, sampling & *in situ* experiments
0300	Trace Metal cast
0500	Recover driftarray #9/Deploy driftarray #10
0600	Dispose galley waste; pump tanks (> 12 nm from shore)
0830	Bongo live tows, zooplankton experiments (start 0.75 nm downwind of driftarray)
0930	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)
1100	CTD, microbiology, dissolved organics
1400	Go-Flo Test Cast
1300	Science Tour
1630	CTD, Thorium
1800	Trace Metal cast
2130	Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of driftarray)

10 May

0200	CTD, sampling
0400	Recover driftarray #10
0500	Recover sediment trap
0730	Dispose galley waste; pump tanks
0830	Steam toward Benthic Boundary Layer (BBL) stations

Line 77 stn 49	35°	5.16'	120°	46.30'
Vandenburg	34	53.34'	120	44.34'
Santa Ynez	34	41.69'	120	42.63'
Pt Arguello	34	34.29'	120	42.59'
Line 80 stn 51	34	26.99'	120	31.39'
Gato	34	24.88'	120	24.73'

0200	CTD cast (1000 m), Thorium calibration, > 2,000 m water depth

11 May

0400	Begin transit toward Pt. Loma
0700	Dispose galley waste; pump tanks

12 May

~1300	Dock at MarFac