Cruise Report

California Current Ecosystem LTER Program CCE-P1208, Process Cruise #5 R/V MELVILLE, 27 July - 26 August 2012

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Cruise ID: CCE-P1208, aka MV1210 Depart: 27 July 2012 at 0800 (PST) Return: 26 July 2012 at 0700 Vessel: R/V MELVILLE Operator: Scripps Institution of Oceanography Master: Captain Christopher Curl Chief Scientist: Michael R. Landry Marine Technicians: Drew Cole, Ryan Engle, Carl Mattson, Bud Hale







Figure 1. SeaSoar (Survey #1) tracks on satellite SSH anomaly (AVISO), courtesy M. Kahru. Science activities during P1208 focused on the frontal system between a warm-core (anticyclonic, positive SSH anomaly) and cold core (cyclonic, negative SSH anomaly) off of Point Conception.

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CCE-P1208: CRUISE PERSONNEL

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- 2. Mark Ohman
- 3. Ralf Goericke
- 4. Katherine Barbeau
- 5. Tony Koslow
- 6. Peter C. Davison
- 7. Michael Stukel
- 8. Dana Lebental
- 9. Adam Darer
- 10. Alexis Deru
- 11. Mark Hafez
- 12. Jian Liu
- 13. David Jensen
- 14. Megan Roadman
- 15. John Wokuluk
- 16. Jennifer Brandon
- 17. Alexandra Freibott
- 18. Angel Ruacho
- 19. Brian Smithers
- 20. Alain De Verneil
- 21. Catherine Nickels
- 22. Jessie Powell
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SCIENCE OBJECTIVES

This was the fifth Process Cruise of the CCE LTER (California Current Ecosystem, Long-Term Ecological Research) Program, the objective of which is to understand the coupling of physical, chemical and biological dynamics in the California Current ecosystem and, ultimately, the system responses to long-term climate variability. During the present phase of CCE research, we are targeting frontal gradients in order to understand how 1) (sub)mesoscale perturbations alter nutrient transport, primary production, plankton community structure, predator-prey interactions, and export relative to adjacent waters and 2) the extent to which these effects vary among features. P1208 was our first attempt to investigate the frontal interface between two offshore eddies. We therefore termed the feature studied the E-Front.

OVERVIEW OF THE SCIENCE PLAN

The science plan involved three major components. 1) SeaSoar surveys were done to assess broad-scale hydrography and circulation characteristics of the study area. 2) Two rapid sampling transects were also made through the front to get detailed, semi-synoptic sections of physical, chemical and biological variables. 3) Detailed experimental studies were done between transects to characterize chemical and biological concentrations and rate relationships at comparative sites/stations in the front axis and in water masses to the east and west of the front.

Study Site Selection

July 2012 was a period of unprecedented cloudiness in the offshore region off of southern California (Fig. 2). As a consequence, no clear satellite images of sea surface temperature or chlorophyll were available leading up to the cruise. In addition, as we began our cruise, large sectors in the study region were closed due to naval maneuvers. We therefore selected our study site based on open areas available and using sea surface height (SSH) anomaly to identify a frontal feature offshore of Point Conception. As shown in Fig. 1, the frontal zone was between two eddies lying largely parallel to the coastline, an anticyclonic (warm, +SSH) eddy to the north and cyclonic (cold, -SSH) to the south. A series of images showed these features to be persistent prior to the cruise (20-28 July), and, in fact, they remained strong with only modest westward drift for the duration of the cruise.



Figure 2. Fraction of valid satellite data for monthly Chl *a* images in the region of $33.5-35^{\circ}$ N, 121.5-123°W from 1996 to 2012. Typically, there is full coverage (fraction of valid data = 1.0). However, only 20% of the pixels had any data in July 2012. The previous record cloudiness (0.75) was January 2000. Courtesy of M. Kahru. Except for SSH, satellite coverage remained poor for the cruise, yielding only one useful satellite image of sea surface Chl *a* for the month. That image, for mid-August, shows little detail of the front per se, but does suggest that high Chl *a* water was flowing into the study area from strong coastal upwelling to the north (Fig. 3).



Figure 3. Weekly composite sea surface Chl *a* for 13-19 August, 2012. Courtesy of M. Kahru.

SeaSoar Surveys

Survey mapping with SeaSoar was conducted in radiator patterns on 3-4 day runs at the beginning and end of the cruise (30 July to 3 August and 21-25 August). We used faired cable to reach depths of ~300 m, and achieved 9 or 10 E-W transects at ~10-km spacing on each survey. Fig. 4 shows the parameter plots for temperature, salinity, density, chlorophyll fluorescence, beam attenuation coefficient and dissolved oxygen on SeaSoar survey 1, which corresponds to the track depicted in Fig. 1.



Figure 4. Parameter plots from SeaSoar survey 1 across the E-Front (courtesy M. Ohman, D. Jensen).

Cross-Front Transect Sampling

Site selection for the experimental cycles and sampling locations for intensive front crossings were guided by underway surveys with the flow-through Advanced Laser Fluorometer (ALF) to detect surface features and the Moving Vessel Profiler (MVP) to measure subsurface structure.

Rapid sampling transects across the front were completed on 2 occasions (4-5 August and 20-21 August). Sampling of 10-13 stations on each transect began in late afternoon/early evening of Day 1 and continued through early morning of Day 2, the idea being to catch most of the stations during the nighttime period when migrants are up in the water column and photo-quenching of phytoplankton pigments in minimal. The main sampling was done by shallow CTD (300 m) and vertical net tows, and surface (pole) samples for iron analyses at each station. Additional samples were taken at every other station for PvE experiments of phytoplankton photosynthesis and bacterial production and activity. Depth profiles of trace elements were also taken with the TM rosette at a few (~5) stations representing the adjacent water masses and frontal region). All routine measurements on CTD hydrocasts, including nutrients, full microscopy, flow cytometry, HPLC pigments, POC/PON, bSi and size-fractioned Chl *a*. Net tows were split into analyses for zooplankton composition and size-fractioned biomass and gut fluorescence.

Process Studies

Between the two transect samplings, we conducted five experimental process studies of about 2 days each (3 days for Cycle 1; 1 day for Cycle 5). Each cycle experiment was done in semi-Lagrangian fashion, following a satellite-tracked drifter with a mixed-layer drogue at 15 m (Fig. 5). Cycle 1 focused on the near-surface front maximum of Chl *a* identified during the first transect crossing. Cycles 3 and 4 targeted adjacent waters of the cooler and warmer eddies, respectively. Relative to Cycle 1, Cycle 2 and 5 experiments explored more subtle subsurface characteristics on the warmer/seaward side of the frontal region.



Figure 5. Initial locations and drifter trajectories during experimental Cycles 1-5. Also shown for reference are sampling station locations during E-Front transect 1 and underway sampling lines for SeaSoar survey 1. Double lines for each cycle indicate drift paths for experimental and sediment trap drifters. For process studies, initial and daily CTD sampling was done at approximately 0200 (local time) at the drifter position to assess daily changes in water mass characteristics. Water from the same hydrocast bottles was used experimentally to assess ¹⁴C-primary production and specific rates of phytoplankton growth and microzooplankton grazing impact by the dilution approach. 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). A second drifter was deployed with attached sediment traps to measure particle fluxes during the experiments (initial deployment and final recovery only).

Measured variables on CTD sampling included: temperature, conductivity, density, nutrients (dissolved inorganic N, P, Si), total organic carbon and nitrogen (TOC, TON), particulate carbon and nitrogen (POC, PON), particulate biogenic silica (bSi), thoriumuranium disequilibrium, total and size-fractioned fluorometric ChI *a*, HPLC accessory pigments, microscopical and flow cytometric assessments of microplankton community composition, and samples for molecular analyses. An ISUS nitrate sensor and an Underwater Vision Profiler system (UVP5) were also integrated into the CTD rosette system to provide continuous measurements nitrate concentration and sizes and abundances of particles (aggregates and organisms) on each cast down to typically 300-500 m.

Using the drift array as a moving frame of reference, additional CTD sampling was conducted at mid-day for bio-optical studies, shipboard assessments of primary production by the ¹⁴C-uptake method, microbiological studies (bacterial production, bacteria particle interactions, and enzyme activities), and typically in the evening for additional shipboard experimental studies of mesozooplankton reproduction. Other sampling activities were conducted around-the-clock, including a) net sampling of zooplankon with MOCNESS, bongo and ring nets; b) sampling of mesopelagics with a 5 m² mid-water trawl net (MOHT, Matsuda-Oozeki-Hu); c) trace-metal rosette sampling for iron (Fe) analyses and experiments, and d) wire deployments of a McLane pump for C:thorium of suspended particles. Mesozooplankton biomass and grazing estimates will be derived from size-fractioned dry weights, carbon biomass and gut fluorescence analysis of bongo net samples collected at mid-day and mid-night.

Surface Current Drifters

Twelve expendable SVP ARGOS drifters were provided by Carter Uhlmann (UCSB) for the purpose of computing the kinematics (divergence, vorticity, etc.) of frontal physical dynamics from the drifter tracks. On the morning of 4 August 2012, we deployed an array of nine drifters (1-9) in a double square pattern as depicted in Fig. 6. Drifters 10 and 11 were released approximately one day later at the beginning and ends of an MVP rapid sampling run along the cross-front transect line (Table 1). Drifter 12 (114604) was released several days later at the end point of experimental Cycle 1; its trajectory thus marks the advective path of surface water with the highest Chl *a* concentration at the front. The two Clearwater drifters did not report positions.

Drifter	Lat (°N)	Long (°W)	Serial #	Туре	Local Time	GMT	Event	
1	34.501	122.746	114605	SIO2	08:24	15:24	76	
2	34.576	122.739	109611	SIO2	08:50	15:50	77	
3	34.651	122.731	109464	SIO2	09:15	16:15	78/79	
4	34.657	122.821	109463	SIO2	09:44	16:44	80	
5	34.583	122.829	93585	Technocean	10:04	17:04	81	
6	34.508	122.837	93586	Technocean	10:24	17:24	82	
7	34.515	122.927	93587	Technocean	10:55	17:55	83	
8	34.589	122.919	82372	Clearwater	11:23	18:23	84	
9	34.664	122.911	82373	Clearwater	11:50	18:50	85	
10	34.558	122.531	114613	SIO2		15:22	5 Aug	
11	34.600	123.076	109599	SIO2		01:57	6 Aug	
12	33.531	122.862	114604	SIO2		11:57	9 Aug	

 Table 1: Deployment locations and information for SVP ARGOS drifters used on P1208. Drifters

 1-9 were deployed on 4 August (GMT & local); others as noted (GMT).



Figure 6. Deployment pattern of SVP ARGOS drifters on 4 August 2102 relative to sampling stations on Transect 1. Positions as in Table 1.



Figure 7. Trajectories of SVP ARGOS drifters as of 23 August 2012.

GROUP REPORTS

Hydrography, Primary Production – Ralf Goericke and Megan Roadman

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 concentrations, chlorophyll fluorescence, light attenuation by particles, photosynthetically active radiation, and nitrate concentration (ISUS). Generally, samples were collected from 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 nitrate and concentrations of taxon-specific pigments. Samples for dissolved organic were also collected for analysis by the Aluwihare lab. Additionally, a sample was taken from the mixed layer on each cast to determine the size distribution of Chl a. Results from these observations are summarized in Table 2 below for individual Cycles, and results of hydrographic properties are shown in Fig. 8. Samples for plant nutrients and particulate organic carbon and dissolved organic carbon will be analyzed ashore.

Cycle	Temp	Salinity	Oxygen	Oxygen	NO ₃ _ISUS	Chl a	Transm	UVP
	°C		mМ	% Sat	μM	µg/L	%	Volt
1	14.7	33.52	259	103	3.1	3.13	82.6	1.23
2	15.3	33.11	248	99	6.1	0.39	91.6	1.00
3	15.5	33.59	242	98	0.6	0.90	87.7	1.69
4	16.9	33.15	235	97	0.0	0.10	93.9	0.15
5	15.5	33.22	252	101	1.8	0.62	90.9	1.80

Table 2: Surface-layer properties for individual experimental cycles.

Phytoplankton community pigments: Concentrations of taxon-specific pigments, chlorophylls and carotenoids, were sampled from most 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.

Another dimension of phytoplankton community structure is the distribution of biomass over different size categories. An example from the 2nd crossing of the front is given below (Fig. 9).

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. Sample will be analyzed ashore.



Figure 8: Hydrographic properties for E-Front transect 1 plotted as longitude vs. depth on density. Note that most variables are simply expressed as voltage signals.

Figure 9. Chlorophyll size distribution for samples collected in the surface layer for E-Front transect 2. Note that these measurements were done only every other station.



Chl a SizeFractionation EFront 2 (2m Sample)

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

During the P1208 cruise two custom-built ALF (Advanced Laser Fluorometer) instruments were used for underway fluorescence and discrete sample analysis during the two front crossing samplings and experimental cycles. The ALF is a portable bench top instrument that combines high-resolution spectrally and temporally resolved flowthrough measurements of laser-stimulated emission from seawater, allowing for realtime 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, ALF was connected to the ship's uncontaminated seawater system which provided a steady flow of water. Underway measurements were taken along MVP and SeaSoar surveys. During the Front Transects, one ALF instrument was used for discrete sample analysis while the second took underway measurements. Both instruments imported MET and GPS data from the ship. The instruments provided an indication of frontal features during repeated crossings and in sample analysis. Figs. 9 and 10 below were for the first MVP survey run across E-Front (selected time of day marked at top of plot), which was used to establish the spacing of stations for intensive cross-front transect sampling.



Figure 10. ALFA underway data from MVP Transect 1. Chl *a* and CDOM fluorescence normalized to Raman (405 nm excitation), Fv/Fm, SST, and salinity.



Figure 11. ALFA underway data from MVP Transect 1. PE fluorescence normalized to Raman (532 nm excitation) of blue-water and green-water types of *Synechococcus* (PE1 and PE2, respectively) and cryptophytes (PE3), SST, and salinity.

Trace Metal Studies – Barbeau Group (Kathy Barbeau, Adam Darer, Angel Ruacho, Carole Wang)

Once issues with the hydrowinch sheave and cable termination were worked out, the newly purchased combination of the coated Space-Lay wire rope and InterOcean counterbalanced snatch block worked well for the combined application of trace metal rosette casts and bongo net tows. Placement of the MOCNESS further forward of the squirt boom relative to CCE-P1106 also alleviated issues with trace metal rosette deployment. The trace metal group completed 31 sampling casts, including 23 profiles for dissolved iron distributions, totaling over 200 samples. Five 8-bottle profiles were completed on each of the two E-front transect crossings, with additional surface pole sampling at stations in between casts. Multiple depth profiles were completed at Cycles 1-4, including profiles down to 1000 meters at Cycles 1, 3 and 4. One 12-bottle profile to 300 meters was completed at the 1-day Cycle 5. Samples for organic iron speciation studies were taken on various profiles.

Seven shipboard iron-addition grow-out experiments were also performed to study iron dynamics and assay for potential effects of iron limitation on the phytoplankton community at cycle locations. Grow-outs at Cycle 1 indicated the potential for iron limitation in the high chlorophyll region of the front (e.g., Fig. 12), but generally low nitrate levels in surface waters at all stations precluded dramatic grow-out effects. ¹⁵N addition experiments were carried out in conjunction with all grow-outs to explore the utility of nitrate uptake rate as a sensitive indicator of phytoplankton iron stress. A simulated bloom experiment was conducted at Cycle 2 by adding macronutrients and iron at varying nitrate:iron ratios. The goal of this experiment was to look at the effect of iron stress during phytoplankton blooms on iron organic speciation.



Figure 12. Iron-addition grow-out experiment set up on Day 2 of Cycle 1, from waters sampled at 20 meters with the trace metal rosette.

Bacterial Biomass and Production – Azam Group (Jon Cheng, Ty Samo)

E-Front Transects 1 and 2 were sampled to measure cell abundance, mean cell carbon content, total carbon biomass, and carbon production of bacterial communities. From CTD casts, cryovials were filled with 1-3 mL seawater, fixed with formaldehyde, and frozen. On shore, the cryovials will be thawed, filtered onto 0.2-µm pore size polycarbonate filters, stained with DAPI and imaged on a Nikon TE-2000U inverted wide field fluorescence microscope at 1000X magnification. The resulting image analysis for abundance and cell size will be converted to concentration and biomass values using established methods (Bratbak 1985; Malfatti et al. 2009).

We used the leucine incorporation method to estimate rates of bacterial carbon production along the transect. Samples of 2 mL were incubated with 20 nM of L-[4,5- 3 H] leucine for one hour at *in situ* temperature in triplicate, with duplicate 5% TCA killed controls. Samples were then filtered onto either 0.2- or 1-µm pore size polycarbonate filters to measure total or >1-µm fractionated production. Filtration was completed after three 1-ml additions of 5% TCA to each filter.

Bacterial production samples will be processed on shore using the centrifugation method. After obtaining a dried cell pellet from each tube, EcoLite scintillation cocktail will be added, and the tubes assayed in a Beckman LS6000A liquid scintillation counter. Disintegrations per minute are converted to protein synthesis rates.

Microbial Community Biomass, Growth and Grazing – Landry Group (Mike Landry, Andrew Taylor, Ali Freibott, John Wokuluk, Alain De Verneil))

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 composition, biomass and size structure of auto- and heterotrophic protists by epifluorescence (EPI) and inverted microscopy, and sampling of particulate biogenic silica (bSi) and net change in bSi during the drifter incubations. During SeaSoar runs, sea surface samples for analyses of microbial community biomass and composition (FCM, EPI microscopy) were taken at 9 locations along each line. During intensive transects, we sampled FCM, EPI and inverted microscopy for 7 depths at each station, and conducted PvE experiments with mixed layer seawater samples at every other station.

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 μ L of alkaline Lugol's solution, 10 mL of buffered Formalin and 500 μ L 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 for analyses of delicate heterotrophic protists, notably cilates, 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.

Growth and grazing rates: Rates of growth and protozoan grazing will be estimated for the total phytoplankton community (Chl *a*) and for individual populations (flow cytometry, taxon-specific pigments) from the results of 2-treatment dilution experiments incubated on 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 and microscopy.

PvE experiments: Experimental assessments of phytoplankton photosynthetic efficiency were done with water from noon CTD casts on experimental cycles and from transect stations. Briefly, samples were collected from three depths (mixed layer, chlorophyll maximum and just above or below the chlorophyll maximum) during mid-day CTD casts and from one depth (mixed layer) during transects across the front. Radioactive ¹⁴C bicarbonate was added to 2-ml of sample water and incubated for one hour (front crossing transects) or two-hours (mid-day cycle CTD casts) in a temperature controlled photosynthetron incubator that was set up for a gradient of 16 different light levels for each depth. A total of 11 experiments were conducted during cycle work and 10 experiments were done during the front crossing transects. Rates will be determined after liquid scintillation counting (LSC) upon return to shore.

Biogenic silica: 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. During experimental cycles replicate 1.1-L samples were incubated at each of 8 depths on the drift arrays and filtered after 24 h to measure net bSi uptake. Samples were concentrated onto 47 mm 0.6- μ m 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.

Mesozooplankton Research – Ohman Group (Mark Ohman, David Jensen, Jesse Powell, Catherine Nickels, Jennifer Brandon, Alexis Deru)

Moving Vessel Profiler (MVP): A free-fall Moving Vessel Profiler (MVP) was used to localize and characterize frontal zones in order to guide site selection for the experimental cycles, determine sampling locations for intensive front crossings, and make high resolution vertical profiles for later estimates of vertical mixing coefficients. The MVP sensors included a Laser Optical Particle Counter (LOPC), Chl *a* fluorometer, and AML Micro fast response CTD. A total of 432 MVP casts was completed, with 421 casts to 200 m depth on 7 transects that crossed the E-Front feature. The panels in Fig. 13 below illustrate the first series of NW to SE sections (MVP Transect 1) across the eddy-associated "E-Front" that was the focus of our cruise. The MVP performed well on all deployments.



Figure 13. MVP Transect 1 survey, representing 4 successive crossings of the E-Front on P1208, 3-4 August 2012. 154 free-fall vertical profiles were made to 200 m depth with the ship underway.

Vertically stratified MOCNESS sampling: Vertically stratified plankton sampling was carried out with a 1 m², 202-µm mesh MOCNESS, deployed at experimental Cycles on either side of the E-Front, and within or near the frontal feature. The MOCNESS was equipped with sensors for temperature, salinity, O₂, beam attenuation coefficient, and Chl *a* fluorescence. Sampling was conducted to assess changes in mesozooplankton vertical distributions and diel vertical migration behavior in relation to frontal features. Sampling also addressed possible changes in vertical habitats occupied by thecosome pteropods and heteropods, as well as shell calcification, in relation to changes in aragonite saturation horizons. Apart from the initial MOCNESS test station over the Santa Barbara basin, all other 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 shell calcification and molecular genetics. For the test station, 100% of each samples was preserved in buffered Formalin.

Thirteen MOCNESS tows were completed, at 1 daytime test station plus 2 day and 2 night vertical series at each of Cycles 1, 3, and 4. After the test station, for which the options module was not functioning, all sensors on the MOCNESS subsequently functioned correctly. The net response indicator showed some intermittency, which was rectified by adjusting the fore-and-aft location of the net response bar.

Underwater Vision Profiler (UVP5): The Underwater Vision Profiler 5 (UVP5), an in situ plankton camera on loan from IFREMER, France, was mounted inside the CTD-rosette frame so that it imaged a volume of water virtually undisturbed by the frame. The system collected images during the downcast only.

Mesozooplankton biomass and grazing rates: Bongo tows were made with a 71cm diameter, 202-µm mesh bongo net, for determination of mesozooplankton biomass and grazing rates, the latter by gut fluorescence. At experimental cycles samples were taken to a depth of 210 m, with one net sample fixed in 5% buffered Formalin for taxonomic analyses and the other anaesthetized immediately in soda water, then sizefractionated into 5 size categories (0.2, 0.5, 1.0, 2, 5 mm) and frozen in liquid N₂. The latter sample was divided such that 3/8 will be used for biomass determination, 3/8 for mesozooplankton gut fluorescence, and ¼ for other studies. At the front crossings, the bongo frame was modified to be deployed and retrieved vertically, to facilitate more rapid sampling. The net was lowered to 100 m at approximately 30 m min⁻¹, allowed to sit for 30 s, and then retrieved vertically at approximately 40 m min⁻¹. Samples were processed as above upon recovery, except that size fractionation was not carried out. One sample was fixed in Formalin, the other split and frozen in liquid N₂, with half for biomass and half for gut fluorescence.

Twenty oblique bongo tows were completed, representing replicate day and night sampling at most experimental Cycle, except for 3 day/3 night at Cycle 1 and 1 day/1 night at Cycle 5. Twenty-two vertical bongos were completed, on the 2 front crossings.

Copepod egg production experiments: Incubation experiments were performed with two of the numerically dominant calanoid copepods in our study site (*Calanus pacificus* and *Eucalanus californicus*), to assess mesozooplankton reproductive responses to the frontal gradients. 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, then egg hatching success recorded after a time corresponding to 1.5X the embryonic duration.

Software development: Dave Jensen modified computer code at sea to display SeaSoar data in real-time, drawn as continually updated 3D plots. This software improved greatly upon the preliminary code he developed on the previous process cruise (P1106). This code also displayed real-time particle count data, from an LOPC that we newly integrated into the SeaSoar instrument package. It further illustrated aragonite saturation values (omega-aragonite), based on the proxy relationship from Alin et al. (2012. JGR 117, doi: 10.1029/2011JC007511).



Figure 14. Further parameter plots from SeaSoar survey 1 (30 July – 3 August, 2012; 0-300 m depth). Left to right, top row to bottom: SeaSoar track, LOPC particle counts (0.1-0.5 mm), LOPC particle counts (0.5-1.0 mm), omega-aragonite, LOPC biovolume (all sizes, log scale), LOPC MEP particles (1.1-1.6 mm, 0.6-1.0 opacity, log scale). Dark lines at top of figures indicate nighttime hours.

Export Flux - Mike Stukel

We assessed carbon export using two different approaches, ²³⁸U:²³⁴Th disequilibrum and sediment traps. VERTEX-style sediment traps were deployed at a depth of 100-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 (~1.25-3.25 days). Sediment trap tubes were sorted to remove zooplankton swimmers, split, and used for several different analyses including C/N, C:²³⁴Th, particulate Si, CaCO₃, pigments, and taxonomic enumeration. Preliminary pigment analysis (chlorophyll *a* and phaeopigments) and microscopic analysis of the >200-um size fraction suggested high vertical flux in the frontal region, particularly during Cycle 1 at the core of the front. Cycles 4 and 5 both had a large contribution of marine snow aggregates in the larger size fraction, and the 70-m sediment trap during Cycle 5 in particular had the highest chlorophyll:phaeopigment ratio that we have measured in the CCE (~4:5), although at 100-m depth the ratio had dropped to 1:4. Three different ²³⁴Th sampling patterns were employed on the cruise: surface grid surveys of the study region, vertical sections across the front, and vertical profiles during Lagrangian experimental cycles. During grid surveys of the study region (which coincided with SeaSoar 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).

Samples were taken on every other survey line (34-km spacing between sampling lines), with 14.3-km along-line spacing between samples (Fig. 15). The UFS system was cleaned within five days of the start of each grid survey. To ensure that UFS sampling did not bias our samples, before and after each survey we took triplicate samples from both the UFS system and surface-tripped Niskin bottles and found no difference between sampling methods.

During two ~18-hour sampling transects across the frontal feature, we took 3.5-L Niskin samples from 6 depths spanning the upper 100-m of the water column at 13 different stations (across-front lateral spacing varied from 1.6 to 8.3 km). During



Fig. 15. Preliminary assessments of ²³⁴Th deficiency is surface sea water along SeaSoar survey 1. Higher values are indicative of higher export.

experimental cycles, we took 4-L Niskin samples at 12 depths spanning the upper 200 m of the water column twice per cycle (except on Cycle 5, a one-day cycle with only a single ²³⁴Th profile), as we tracked a water parcel with a Lagrangian drift array for a duration of 2-3 days. Twice we sampled deep water (2000 m) that was expected to be at secular equilibrium to verify the accuracy of our ²³⁴Th measurements. Preliminary

results showed a strong gradient in surface ²³⁴Th disequilibrium at the front, indicating higher vertical flux rates in the onshore side of the front. Vertical profiles during the front transect confirmed the surface pattern found during the SeaSoar grid survey, and indicated a subsurface maximum in ²³⁴Th deficiency that may have originated from subduction of ²³⁴Th deficient seawater or autochthonous gravitational export (possibly coinciding with the subduction of senescent phytoplankton communities).





We also measured ¹⁵NO₃uptake as an estimate of new production. ¹⁵NO₃uptake was measured *in situ* daily at eight depths during the mini-cycles. Samples were typically spiked with ¹⁵NO₃ at a concentration of 2-10% of ambient nitrate (as assessed spectrophotometrically) and incubated for 24 hours. ¹⁵NO₃ uptake was also measured at a single depth in the mixed layer (incubated onboard at 33% light level) for 12 hours at each of the stations of our front crossing transects.

Micronekton – Koslow Group (Tony Koslow, Pete Davison and Jian Liu)

The abundance, vertical and horizontal distribution, size and species composition of the micronekton were examined based on sampling with pole-mounted Simrad EK-60 multifrequency acoustics (38, 70, 120, 200 kHz) and a Matsuda-Oozeki-Hu trawl (MOHT) (5-m² mouth opening, 1.7-mm mesh, with a TSK flowmeter in the mouth to estimate volume water filetered). Quantitative acoustic data were obtained to 1000 m with the 38 kHz transducer, reducing to 200 m at 200 kHz. Daytime net trawls were generally to ~1000 m (2000 mwo) and night trawls to ~200 m (500 mwo). Replicate samples were collected day and night at each cycle. The proportions of the midwater community conducting vertical migrations will be assessed based on the difference between shallow night and deep daytime tows.

The trawl samples were sorted into fish and invertebrates on board the vessel and preserved in formalin. All fish will be identified to species and measured in the laboratory; invertebrates will be sub-sampled to estimate abundance by major taxonomic groups and their size-composition determined. Acoustic estimates of abundance will be based on multifrequency volume back-scattering data and target strength (TS) estimates of the abundance-weighted species composition of the trawl catch. The TS models are based on the size, gas content (if any), and acoustic properties of the catch. The presence of inflated swimbladders and specific gravity of the fish body (without gas) were measured on 221 fishes captured at sea, supplementing an existing data set. The stomach contents of dominant fish species will be examined in the lab to assess mean stomach fullness as a proportion of body weight within the different pelagic habitats (cycles). If possible, field estimates of feeding and gut evacuation rates will be determined based on mean stomach fullness through the diel cycle.

The trawl data showed a marked increase in the abundance of both invertebrates, notably salps and krill, and fish at the front (Cycle 1). The acoustics data were generally excellent, also showing striking and consistent changes in distribution and abundance onshore, offshore and across the front (Fig. 17).



Figure 17. (Upper) Acoustic backscattering at 38 kHz across collected from a daytime transect across the study region. The frontal zone with its high concentration of acoustic backscattering is seen clearly. (Lower) Acoustic backscattering at 38 kHz during the initial SeaSoar survey of the study region. The inshore, offshore and frontal zones are seen clearly along each transect.

Seabirds - Bill Sydeman, Marcel Losekoot, Brian Smithers

Seabird surveys covering 1611 linear kilometers and 484 square kilometers were conducted on P1208 by Brian Smithers (Farallon Institute) over 22 days between 28 July and 25 August. During the surveys, 794 individual seabirds representing 17 species were observed. The average density was 1.6 birds per km², and the peak was 133 birds per km² (Buller's Shearwater). The most abundant taxa were the Storm

Petrels (all species combined), and the largest flock observed was for Buller's Shearwaters. The figures below shows the transect maps and the density distributions of all species in birds per km² (Figs. 18 & 19). The table below summarizes observations for each species in terms of the total number of individuals, the number of sightings and the average density for the entire survey.



Figure 18. Map of seabird survey transects, all days from 28 July through 25 August, 2012. Colors denote different sampling days.



Figure 19. Seabird distribution and abundance for all species combined over all survey day, 2012.

Table 3. Summary of seabird observations during 2012 Fronts process cruise. *Count* refers to the total number of individuals, *Sightings* refers to the number of times the species was encountered, and *Density* is expressed as birds/km². As expected, offshore taxa such as storm-petrels and shearwaters dominated the observations.

<u>Species</u>	<u>Count</u>	<u>Sightings</u>	<u>Density</u>
Ashy Storm-Petrel	2	2	0
Black-Footed Albatross	13	11	0.02
Black-Vented Shearwater	2	1	0
Buller's Shearwater	348	84	0.59
Cassin's Auklet	3	1	0
Common Murre	2	1	0
Common Tern	6	6	0.03
Cook's Petrel	6	6	0.02
Forster's Tern	1	1	0
Leach's Storm-Petrel	165	138	0.23
Least Storm-Petrel	1	1	0
Long-Tailed Jaeger	6	5	0.01
Pink-Footed Shearwater	27	22	0.03
Short-Tailed / Slender-Billed			
Shearwater	2	2	0.01
Sooty Shearwater	20	15	0.03
Unidentified Phalarope	15	8	0.03
Unidentified Shearwater	83	72	0.17
Unidentified Storm-Petrel	84	79	0.15
Unidentified Tern	4	3	0
Western Gull	3	3	0
Xantus's Murrelet	1	1	0

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. As on the previous 2011 cruise (P1106), the event logger behaved erratically on P1208. It needs to be reprogrammed/simplified for more reliable performance before the next process 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

Dana Lebental, a Compton High School chemistry teacher, joined the 2012 cruise as the "Teacher at Sea" for the CCE LTER program. Two other RET teachers, Courtney Goode from Escondido Charter High School and Jennifer Ogo from Lincoln High School, tracked Dana's adventures from land, using the information and images to help support their development of classroom lesson plans.

The Teacher at Sea opportunities provided a formal and informal experience to participate in real-world, interdisciplinary research alongside scientists from the CCE LTER and Scripps Institution of Oceanography. This cruise allowed Ms. Lebental to participate directly in different experimental procedures and sampling techniques. On the CCE LTER Education Outreach webpage, Dana Lebental posted 15 blogs over the 30-day cruise that shared her experiences and discussed the different types of science taking place on the ship in addition to what life was like at sea.

Our education goals are to help promote awareness toward understanding and protecting the world's oceans and its resources through developing and implementing interdisciplinary lessons about the cruise with high school teachers/students.

CCE-P1208 DAILY ACTIVITY SCHEDULE

<u>28 July</u>

- 0800 Depart MarFac
- 1330 MVP (Moving Vessel Profiler) test
- 1500 CTD test
- 1600 TM Rosette (Trace metal) test
- 1700 Oozeki trawl test
- 1800 Oozeki trawl test
- 2000 MOCNESS test

<u>29 July</u>

- 1100 MOCNESS, further testing
- 1245 Oozeki, further testing
- 1400 CTD, test bottle firing
- 1430 Bongo net test
- 1530 Transit to station 33.75°N, 121.5°W

<u> 30 July – SeaSoar Survey #1</u>

1825 Deploy SeaSoar, begin SeaSoar survey of study area

3 August

- 1030 Recover SeaSoar, end SeaSoar survey #1
- 1400 Deploy MVP, begin fine-scale survey of frontal region

4 August – E-FRONT Transect #1

- 0600 Recover MVP
- 0820 Begin deployments of drifter array (front kinematics experiment)
- 1145 End drifter deployments, 9 SVP ARGOS drifters deployed
- 1800 Begin transect #1 station sampling, E-FRONT

5 August – Experimental Cycle #1 (central front jet)

- 1000 End E-Front transect #1
- 1400 Re-lower acoustics pole
- 1800 Underway survey/MVP to relocate front and deploy expendable drifters

6 August

- 0000 Sediment trap deployment, begin CYCLE 1
- 0200 CTD, sampling & in situ experiments
- 0300 TM cast, iron profile
- 0430 Deploy drift array #63
- 0500 CTD, thorium
- 0600 TM cast, iron profile/experiments
- 0830 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 MOCNESS
- 1400 Oozeki trawl (500 m)
- 2000 CTD, zooplankton experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

7 August

- 0200 CTD, sampling & *in situ* experiments
- 0300 Oozeki (200 m)
- 0430 Recover drift array #63/deploy #64
- 0600 TM cast, experiments
- 0830 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 TM cast, experiments
- 1300 Oozeki trawl (500 m)
- 1900 CTD, full dilution, zoopl experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 Oozeki trawl (500 m)

8 August

- 0200 CTD cast, sampling & in situ experiments
- 0430 Recover #64/deploy drift array #65
- 0600 TM cast, experiments
- 0830 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 TM cast (1000 m)
- 1300 MOCNESS
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

9 August

- 0000 Oozeki trawl (200)
- 0300 CTD, end CYCLE 1 drifter experiments

- 0500 Recover drift array #65
- 0730 Recover sediment trap array
- 0800 Transit north to study area
- 1800 Underway survey/MVP to relocate front

<u>10 August – Experimental Cycle #2 (front gradient)</u>

- 0000 Sediment trap deployment, begin CYCLE 2
- 0200 CTD, sampling & in situ experiments
- 0300 TM cast, iron profile
- 0430 Deploy drift array #66
- 0500 CTD, thorium
- 0600 TM cast, iron profile/experiments
- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 MOCNESS
- 1400 Oozeki trawl (500 m)
- 2000 CTD, zooplankton experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

11 August

- 0200 CTD, sampling & *in situ* experiments
- 0430 Recover drift array #66/deploy #67
- 0600 TM cast, experiments
- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 MOCNESS
- 1400 Oozeki trawl (500 m)
- 1900 TM cast, experiments
- 2000 CTD, full dilution, zoopl experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 Oozeki trawl (200 m)

12 August

- 0000 MOCNESS
- 0300 CTD, end CYCLE 2 drifter experiments
- 0500 Recover drift array #67
- 0730 Recover sediment trap array
- 0800 Transit north to study area
- 1800 Underway survey/MVP to relocate front

13 August – Experimental Cycle #3 (adjacent coastal)

- 0000 Sediment trap deployment, begin CYCLE 3
- 0200 CTD, sampling & in situ experiments
- 0300 TM cast, iron profile
- 0430 Deploy drift array #68
- 0500 CTD, thorium
- 0600 TM cast, iron profile/experiments

- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 MOCNESS
- 1400 Oozeki trawl (500 m)
- 1830 TM cast, deep (1000 m)
- 2000 CTD, zooplankton experiments, deep (2000 m)
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

14 August

- 0200 CTD, sampling & *in situ* experiments
- 0300 Oozeki (200 m)
- 0430 Recover drift array #68/deploy #69
- 0600 TM cast, iron profile
- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 MOCNESS
- 1400 Oozeki trawl (500 m)
- 1900 TM cast, experiments
- 2000 CTD, full dilution, zoopl experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

15 August

- 0130 Oozeki trawl (200 m)
- 0400 CTD, end CYCLE 3 drifter experiments
- 0530 Recover drift array #69
- 0730 Recover sediment trap array
- 0800 Transit north to study area
- 1600 Underway survey/MVP to relocate front
- 1930 TM cast, shallow water samples
- 2130 Oozeki trawl (200 m)

16 August – Experimental Cycle #4 (adjacent oceanic/eddy)

- 0000 Sediment trap deployment, begin CYCLE 4
- 0200 CTD, sampling & in situ experiments
- 0300 TM cast, iron profile
- 0430 Deploy drift array #70
- 0500 CTD, thorium
- 0600 TM cast, iron profile (deep 1000 m)
- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 MOCNESS
- 1400 Oozeki trawl (500 m or deeper)
- 1900 CTD, zooplankton experiments, deep (2000 m)
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

<u>17 August</u>

- 0200 CTD, sampling & in situ experiments
- 0430 Recover drift array #70/deploy #71
- 0600 TM cast, iron profile
- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 TM cast (50 m)
- 1200 MOCNESS
- 1430 Oozeki trawl (500 m or deeper)
- 1830 CTD, full dilution, zoopl experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 MOCNESS

18 August

- 0130 Oozeki trawl (200 m)
- 0300 CTD, end CYCLE 4 drifter experiments
- 0430 Recover drift array #71
- 0600 Recover sediment trap array
- 0700 Transit back to experimental transect line, MVP crossing
- 1200 Underway survey/MVP to relocate front
- 1900 Sediment trap deployment, begin CYCLE 5
- 2130 Oozeki trawl (200 m)

19 August – Experimental Cycle #5

- 0100 CTD, sampling & *in situ* experiments
- 0200 TM cast, iron profile
- 0330 Deploy drift array #72
- 0400 CTD, thorium
- 0500 TM cast, experiments
- 0800 Bongo live tows, zooplankton experiments
- 0930 Bongo, zooplankton net tow, gut fluor
- 1030 CTD, 14C-PP, biooptics
- 1130 Oozeki trawl (deep tow, 3000 m wire out)
- 1900 CTD, zooplankton experiments
- 2130 Bongo, zooplankton net tow, gut fluor
- 2230 Oozeki trawl (200 m)

20 August – E-Front Transect #2

- 0100 CTD, sampling, End of Cycle 5
- 0330 Recover drift array #72
- 0500 Recover sediment trap array
- 0600 Transit to MVP survey
- 1600 Begin Front Crossing Station sampling (E-Front Transect #2)

21 August – SeaSoar Survey #2

- 1000 End of transect/station sampling, transit north
- 1600 Begin SeaSoar sampling, north-to-south

25 August

0200 End SeaSoar