# **Cruise Report**

California Current Ecosystem LTER Program CCE-P0704, Process Cruise #2 R/V THOMPSON, 2 - 21 April 2007

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Cruise ID: CCE-P0704, aka TN 204 Depart: 2 April 2007 at 0800 (PST) Return: 21 April 2007 at 0700 Vessel: R/V THOMPSON Operator: University of Washington Master: Captain Alan J. McClenaghan Chief Scientist: Michael R. Landry Marine Technicians: Bill Martin, Rob Hagg







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#### SCIENTIFIC OBJECTIVES

This was the second 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. The cruise was designed to investigate the relationships among watercolumn light, temperature, nutrients, thermocline and nutricline depths, phytoplankton and zooplankton standing stocks, phytoplankton and bacterial growth and production rates, micro- and meso-zooplankton grazing rates, and active and passive contributions to organic export. The results from this cruise will provide an empirical basis for modeling of CCE springtime dynamics and for comparative studies of late summer conditions and climate-altered (e.g., El Niño) states.

#### **GENERAL OVERVIEW OF THE SCIENCE PLAN**

Our study region in the southern California Current Ecosystem is along the axis of CalCOFI sampling line 80, which extends seaward off Point Conception, California (**Figure 1**). This is typically an area of pronounced variability in water- column and community characteristics, especially during the spring upwelling period. The science plan was based around 3 main activity cycles of Lagrangian design, in which water masses of differing initial characteristics (near coast upwelling, offshore anticyclonic eddy, intermediate site) were marked with *in situ* instruments and drift arrays and studied over the course of 4-5 days. We used 3 satellite-tracked *in situ* instruments/drifters on the present cruise -- a drogued drift array for *in situ* experimental incubations (recovered/redeployed daily), a drogued drift array with sediment traps at 100 m to assess passive vertical export (sinking particulates), and a



Fig. 1. The CCE study area off Southern California. The CalCOFI sampling grid is represented by open triangles. CTD cast locations during each cycle are marked by colored symbols, with clusters showing the drift paths of drogued experimental arrays. The initial cycle locations coincide roughly with positions along CalCOFI line 80 off Point Conception.

profiling SOLOPC drifter with environmental sensors (CTD, fluorometer and optical plankton counter) to investigate the depth distribution and variability of large particles (zooplankton and aggregates).

CYCLE 1 was conducted at the near-shore end of Line 80 and is believed to have captured the decline phase of a coastal upwelling bloom as it was being advected offshore. CYCLE 2, located well offshore, provided sharply contrasting picoplankton-dominated conditions in an anti-cyclonic, warm-core eddy. The intent for CYCLE 3 was to conduct experiments in high ChI *a* waters inshore of the start of CYCLE 1, where strong winds were believed to have stimulated coastal upwelling during the several days of our offshore studies during CYCLE 2. While we were successful in locating and initially sampling such water, a sediment trap array deployed was rapidly driven by 35 kt winds and high seas to the southeast (rather than west as in CYCLE 1), and the array had to be subsequently rescued after running aground (100-m depth) in the northern entry to the Channel Islands. Before this retrieval operation, an *in situ* experimental drift array that had been prepared with water collected at the start location for CYCLE 3 was transported and deployed at a safer site, which became the start of CYCLE 4 for the remaining cruise activities.

Daily CTD sampling at 0200 was conducted to assess changes in water mass characteristics due to growth, mortality and associated changes in community composition and biogeochemical parameters. Measured variables included: temperature, conductivity, density, nutrients (dissolved inorganic N, P, Si), total organic carbon and nitrogen (TOC, TON), particulate carbon and nitrogen (POC, PON), stable isotopes of C and N, particulate biogenic silica (BSi), thorium-uranium disequilibrium, fluorometric Chla and HPLC accessory pigments, microscopical and flow cytometric assessments of community composition, and samples for molecular analyses. The same water collection was also used experimentally to assess taxon-specific rates of phytoplankton growth, 14C-primary production and microzooplankton grazing impact by a combination of dilution and pigment labeling approaches. These incubations were conducted for 24 hours in net bags attached on the drift array (therefore incubated under *in situ* conditions of temperature and light).

Using the drift array as a moving frame of reference, additional CTD sampling was conducted at mid-day for bio-optical parameters, for shipboard assessments of primary production, and microbiological studies (bacterial production, bacteria particle interactions and enzyme activities), and typically in the evening for additional shipboard experimental studies of mesozooplankton grazing and reproduction. The latter were accompanied by short bongo net tows to collect live animals.

GO-Flo samples were taken for iron (Fe) analyses and for grow-out experimental studies of Fe limitation. MOCNESS net tows were taken at mid-day and mid-night to determine the depth structure and day-night variability of the mesozooplankton community. Sampling of mesopelagic fishes and invertebrates was conducted with a large (5 m<sup>2</sup>) mid-water trawl (Oozeki) net during two daily cycles (intermediate and offshore sites) to assess the contribution of actively migrating mid-water animals to organic export from the euphotic zone. Bongo net tows were also taken around mid-day and mid-night to get depth-integrated assessments of the zooplankton biomass structure and gut fluorescence in the euphotic zone. One side of the paired nets from these collections was formalin preserved for species identification. The other was

size-fractioned on shipboard for biomass (dry weight, C, N) and gut pigment analyses. During each cycle, bongo net collections were taken at 2-3 h intervals over 24-h to better resolve the diel periodicity in feeding (gut fluorescence) and migration into the euphotic zone. At least twice during each cycle, a McLane pump was used to collect large volume samples from below the euphotic zone for C:Th ratios and the estimation of carbon export by the thorium disequilibrium method.

Daily activities also often included a 4-h bow-tie survey with a Moving Vessel Profiler (MVP) to determine the variability in water-column characteristics around the drift array, both along and orthogonal to the direction of current flow. Longer transect tows with the MVP and VPR (Video Plankton Recorder) were taken in transit between stations to document the cross-shore variability in water-column characteristics and to survey the selected sites before each cycle.

In summary, each cycle of activity was designed to follow the temporal evolution of a marked parcel of water for 4-5 days (i.e., the net rates of change in the ambient physical and chemical environment and the biological community) while conducting experimental studies to assess the contributions of phytoplankton and bacterial growth, micro- and meso-zooplankton grazing and active vertical migrations to particle export and net community change.

#### SHIP AND TECHNICAL SUPPORT

We scheduled our cruise at this particular time of year to study the impact of a predicted 2007 El Niño, which ultimately did not materialize. We were wrong there, but certainly not in the choice of ship. R/V THOMPSON was an exceptional vessel for the size and complexity of our activities (personnel and lab space), and we would have lost many days of science time due to weather on a less able vessel. We had one significant mishap when the Oozeki trawl was damaged in the ship's propellers. This was partly an issue of design incompatibility (the trawl bridle exceeded the A-frame clearance; rather than the typical underway deployment, a crane had to be used to lift the net into the water while the ship held position), and partly operator error (the propulsion system was in "auto" rather than manual mode; the net was swept into the propeller when the system made an unexpected corrective maneuver to hold position). The trawl was salvaged by the ship's engineers and ultimately functioned well later in the cruise. The bridge displayed great skill in all other activities, many (e.g., drifter and trap recoveries) requiring extremely precise handling under high sea and wind conditions. We effectively completed our full agenda while a smaller ship (R/V JORDAN) that was running the CalCOFI sampling program at the same time had to seek port refuge for several days and ultimately abandon its science mission due to weather.

Captain McClenaghan and the THOMPSON crew were exceptionally helpful and accommodating in the support of the science. The Marine Techs, led by Bill Martin, were superb. They participated directly in all critical deck operations, ran all CTD console operations, acquired and processed all ship system data, and provided just the right amount of lecturing/advising to the science party on the fine points of shipboard procedures and safety. Josh Eaton (WHOI) and Steve Hartz (Univ Alaska) provided enthusiastic and essential support of the VPR and MOCNESS sampling activities, respectively, and contributed above-and-beyond in diagnosing and fixing hardware and software problems on other gear. We extend a special thanks to the mates and seamen

(and women) for their skill and hands-on help with recovery and deployment of the drift arrays.

The one item of ship functionality that we hope improves in the future is the HiSeasNet. Although the present system has served UNOLS well in general ship to shore communications, science operations involving remote sensing and transmitting instruments are increasingly dependent on it. On this cruise, for example, we were trying to maintain communications with 3 drifter packages and a glider and were sometimes unable to do that for hours at a time with the ship on the wrong heading into heavy winds and seas. A request has been sent to UNOLS to consider design improvements to provide more reliable 360° accessibility to the satellite feed.

## SCIENCE OPERATIONS AND ISSUES

Despite our ambitious agenda and rough sea conditions during parts of the cruise, the CCE-P0704 cruise was highly successful. With very few exceptions, almost all activites were completed as planned. Initial site survey and transect work with the MVP and VPR systems was not possible due to equipment problems. Those problems were solved during the first week, and both major equipment items worked flawlessly for the remainder of the cruise. As an alternative, we successfully conducted the initial site survey for CYCLE #1 using a flow-through bio-optical and phytoplankton sensor system (ALF - Advanced Laser Fluorometer) so no real time was lost to the MVP and VPR initial problems.

The large mid-water net system (5-m<sup>2</sup> Oozeki trawl) was swept into the screws on CYCLE #1, damaging and bending the net frame extensively and resulting in the loss of all planned (7) tows with that net during the first (nearshore) work cycle. The trawl was initially believed to be a total loss, but was returned to service with the assistance of the ship's engineering crew, notably Mic Blaga, whose optimism and skill in literally hammering the pieces back into shape with a heavy sledge hammer were both impressive and much appreciated. The frame was reconfigured with a new net and bridles and performed well for collections during the remaining work cycles.

Heavy weather was responsible for the cancellation of one MOCNESS and two mid-water (Oozeki) trawls. One of the Oozeki trawls was later worked back into the schedule as conditions calmed. CTD and GO-Flo water sampling operations were also cancelled due to weather on one occasion but had no measurable impact on the science plan. All deployments and recoveries of the drift array, sediment traps and SOLOPC were made on schedule under occasionally nasty conditions (30-35 kt winds). These were delicate operations conducted tight to the ship, a testament to skill on the bridge.

Some time was also lost transporting a member of the scientific personnel to Santa Barbara Harbor. This move required us to leave CYCLE #2 (offshore) activities a day earlier than initially planned. We, however, completed an adequate suite of measurements at this location before leaving and turned the run back to the coast into an opportunity to conduct a long transect across the study site with the VPR.

In the final analysis, all science objectives, with the exception of trawl sampling during work CYCLE #1, were completed successfully (give or take a CTD or net tow).

## **CCE-P0704 ACTIVITY SCHEDULE**

#### <u>2 April</u>

- 0800 Depart San Diego Harbor
- 1300 ETA test station, **33°12'N**, **118°23'W** enroute to study region
- 1300 MVP test deployment
- 1400 GO-Flo bottles, test cast procedures, fill & soak
- 1500 MVP test #2
- 1600 MOCNESS test
- 1800 CTD test cast (CTD #1)
- 1900 Oozeki trawl test
- 2100 Continue transit to Point Conception study region

## <u>3 April</u>

- 1600 Underway site survey ALF
- 2200 ETA position 34°15'N, 120°50'W, begin CYCLE #1
- 2300 CTD, water for zooplankton experiments

#### <u>4 April</u>

- 0000 Deploy sediment trap array
- 0100 Net tow, animals for experiments
- 0200 CTD, setup *in situ* experiments (200m)
- 0300 GO-Flo trace-metal sampling, setup grow-out experiments
- 0430 Deploy *in situ* (drift) array
- 0500 CTD, organics, bacteria, thorium (600 m)
- 0600 Deploy SOLOPC
- 0630 MVP small bow-tie survey
- 1030 Bongo, zooplankton biomass & gut pig sampling
- 1130 CTD (<sup>14</sup>C-PP, PvsE), simultaneous Radiometer off stern
- 1300 IOP cast (hydrowire)
- 1430 MOCNESS, zooplankton sampling
- 1730 Thorium pump, Lihini surface pump
- 1900 CTD, water for evening experiments
- 2000 GO Flo trace-metal sampling & experiments
- 2100 Net tow, animals for experiments
- 2200 Bongo, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

#### <u>5 April</u>

- 0200 CTD, setup *in situ* experiments (200m)
- 0430 Recover/redeploy in situ array
- 0500 MVP small bow-tie survey
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 Bongo, zooplankton biomass & gut pig sampling
- 1400 Lihini, surface pump
- 1600 Bongo, zooplankton biomass & gut pig sampling

- 1800 Bongo, zooplankton biomass & gut pig sampling
- 1900 CTD, dilution experiment
- 2000 Bongo, zooplankton biomass & gut pig sampling
- 2200 Bongo, zooplankton biomass & gut pig sampling
- 2230 MOCNESS, zooplankton sampling

#### <u>6 April</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover/redeploy in situ array
- 0430 Bongo, zooplankton biomass & gut pig sampling
- 0630 Bongo, zooplankton biomass & gut pig sampling
- 0730 GO-Flo trace-metal sampling
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling
- 1800 CTD, water for evening experiments
- 1900 GO-Flo trace-metal sampling & experiments
- 2000 Thorium pump (deep cast)
- 2200 Net tow, animals for experiments
- 2300 Bongo, zooplankton biomass & gut pig sampling

#### <u>7 April</u>

- 0200 CTD, setup *in situ* experiments (200m)
- 0430 Recover/redeploy *in situ* array
- 0500 CTD organics, bacteria, thorium (600 m, at array position)
- 0600 MVP bow-tie survey
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern (at array position)
- 1200 IOP cast (hydrowire) (at array position)
- 1300 MOCNESS, zooplankton sampling
- 1630 Oozeki trawl, deep (2 h) [Net damaged in screws]
- 1800 CTD, water for evening experiments
- 1900 GO-Flo trace metal sampling, simultaneous Lihini surface pump
- 2100 Net tow, animals for experiments
- 2130 Bongo, zooplankton biomass & gut pig sampling
- 2200 Net tow, animals for experiments & gut pigment blanks
- 2300 MOCNESS, zooplankton sampling

#### <u>8 April</u>

- 0200 CTD, in situ & Th & organics (final samples only)
- 0300 Thorium pump
- 0400 Recover *in situ* (drift) array
- 0500 Recover sediment trap array
- 0630 CTD, bacteria experiments
- 0800 Recover SOLOPC
- 1100 Transit Begin MVP transect to offshore CYCLE #2

## <u>9 April</u>

- 1000 ETA position **33°39.5'N, 123°08'W**, begin CYCLE #2
- 1000 Deploy sediment trap array
- 1100 Bongo, zooplankton biomass & gut pig sampling
- 1200 CTD (<sup>14</sup>C-PP, PvsE), simultaneous Radiometer off stern
- 1300 IOP cast (hydrowire), biochem pump
- 1400 MOCNESS, zooplankton sampling
- 1700 Deploy SOLOPC
- 1800 Thorium pump, Lihini surface pump
- 1900 CTD, water for evening experiments
- 1930 GO-Flo trace-metal sampling & experiments
- 2100 Net tow, animals for experiments
- 2200 Bongo, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

## <u> 10 April</u>

- 0200 CTD, setup *in situ* experiments (200m)
- 0300 GO-Flo trace-metal sampling
- 0430 Deploy *in situ* array
- 0500 MVP small bow-tie survey
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD (<sup>14</sup>C-PP, PvsE)
- 1200 IOP cast (hydrowire)
- 1300 Bongo, zooplankton biomass & gut pig sampling
- 1400 Lihini surface pump, thorium pump
- 1600 Bongo, zooplankton biomass & gut pig sampling
- 1630 VPR test deployment
- 1800 Bongo, zooplankton biomass & gut pig sampling
- 1900 CTD, dilution experiment, thorium & organics
- 2000 Bongo, zooplankton biomass & gut pig sampling
- 2200 Bongo, zooplankton biomass & gut pig sampling

## <u>11 April</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0130 Proceed to drift array station
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover/redeploy in situ array
- 0430 Bongo, zooplankton biomass & gut pig sampling
- 0630 Bongo, zooplankton biomass & gut pig sampling
- 0730 GO-Flo trace-metal sampling
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, radiometer & biochem pump
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling
- 1500 VPR test deployment
- 1800 CTD, water for evening experiments
- 1900 GO-Flo trace metal sampling, simultaneous Lihini surface pump

- 2000 Oozeki trawl, euphotic zone (1 h)
- 2130 Net tow, animals for experiments
- Bongo, zooplankton biomass & gut pig sampling
- 2300 Oozeki trawl, deep (2 h)

#### <u> 12 April</u>

- 0130 Proceed to drift array location
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Deploy *in situ* array
- 0430 Oozeki trawl, euphotic zone (1 h)
- 0530 GO-Flo trace-metal sampling
- 0700 Oozeki trawl, deep (2 h)
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern (at array position)
- 1200 IOP cast (hydrowire) (at array position)
- 1300 Oozeki trawl, shallow (2 h)
- 1630 Oozeki trawl, deep (2 h)
- 1900 Thorium pump, simultaneous Lihini surface pump (array position)
- 2100 IOP cast (hydrowire)
- 2130 CTD Bio-optics (200 m); water for evening experiments
- 2200 Net tow, animals for experiments
- Bongo, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

## <u>13 April</u>

- 0200 CTD, in situ & Th & organics (final samples only)
- 0400 Recover *in situ* (drift) array
- 0530 Recover sediment trap array
- 0700 Recover SOLOPC (asap after sediment trap recovery)
- 0900 Transit to Santa Barbara Harbor

## <u>14 April</u>

- 1200 MVP site survey
- 1930 ETA position **34°13.2'N**, **120°37.2'W**, begin **CYCLE #3**
- 2000 CTD, water for evening experiments
- 2100 Net tow, animals for experiments
- 2130 Bongo, zooplankton biomass & gut pig sampling
- 2200 MOCNESS, zooplankton sampling

## <u>15 April</u>

- 0100 Deploy sediment trap array
- 0200 CTD, setup *in situ* experiments (200m)
- 0300 GO-Flo trace-metal sampling, setup grow-out experiments
- 0430 Deploy *in situ* (drift) array, **34°13.6'N, 121°11.6'W**
- 0800 Recover sediment trap (ran aground)
- 0900 Transit to position **34°13.6'N**, **121°11.6'W**, begin **CYCLE #4**
- 1030 Bongo, zooplankton biomass & gut pig sampling
- 1130 CTD (<sup>14</sup>C-PP, PvsE)

- 1300 IOP cast (hydrowire)
- 1400 MOCNESS, zooplankton sampling
- 1530 Relocate to drift array position
- 2100 Recover drift array (complete night incubation in deck incubators)
- 2200 Transit to Cycle #4 position

#### <u> 16 April</u>

- 0000 Deploy SOLOPC
- 0100 Deploy sediment trap array
- 0200 CTD, setup *in situ* experiments (200m)
- 0300 GO-Flo trace-metal sampling
- 0430 Deploy *in situ* array
- 0500 CTD, organics, bacteria, thorium (600 m)
- 0600 MVP small bow-tie survey
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern, biochem surface pump
- 1200 IOP cast (hydrowire)
- 1300 Bongo, zooplankton biomass & gut pig sampling
- 1400 Thorium pump
- 1600 Bongo, zooplankton biomass & gut pig sampling
- 1800 Bongo, zooplankton biomass & gut pig sampling
- 1900 CTD, full dilution experiments, thorium & organics
- 2000 Bongo, zooplankton biomass & gut pig sampling
- 2200 Bongo, zooplankton biomass & gut pig sampling

#### <u> 17 April</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover/redeploy in situ array
- 0430 Bongo, zooplankton biomass & gut pig sampling
- 0630 Bongo, zooplankton biomass & gut pig sampling
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern, biochem surface pump
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling
- 1800 GO-Flo trace-metal sampling & experiments
- 1900 CTD, water for evening experiments
- 2000 Thorium pump (deep cast), biochem surface pump
- 2100 Net tow, animals for experiments
- Bongo, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling CANCELLED (weather)

#### <u>18 April</u>

- 0130 Return to drifter position
- 0200 CTD, setup *in situ* experiments (200m)
- 0300 GO-Flo trace-metal sampling
- 0430 Recover/redeploy *in situ* array
- 0500 CTD organics, bacteria, thorium (600 m, at array position)

- 0600 MVP bow-tie survey
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern, biochem surface pump
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling
- 1630 Oozeki trawl, deep (2 h)
- 1800 CTD, water for evening experiments
- 1900 GO-Flo trace metal sampling, biochem surface pump
- 2000 Oozeki trawl, euphotic zone (1 h) CANCELLED (weather)
- 2130 Net tow, animals for experiments
- 2200 Bongo, zooplankton biomass & gut pig sampling
- 2300 Oozeki trawl, deep (2 h) CANCELLED (weather)

## <u>19 April</u>

- 0130 Return to drift array position
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover/redeploy in situ array
- 0430 Oozeki trawl, euphotic zone (1 h)
- 0530 GO-Flo trace-metal sampling
- 0700 Oozeki trawl, deep (2 h)
- 1000 Bongo, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern, biochem surface pump
- 1200 IOP cast (hydrowire) (at array position)
- 1300 Oozeki trawl, shallow (1 h)
- 1530 Bongo, live animals for experiments
- 1630 Oozeki trawl, deep (2 h)
- 1900 Thorium pump
- 2000 CTD water for evening experiments
- 2100 Net tow, animals for experiments
- 2200 Oozeki trawl, euphotic zone (1 h)
- Bongo, zooplankton biomass & gut pig sampling
- 2330 MOCNESS, zooplankton sampling

## <u>20 April</u>

- 0130 Proceed to drift array position
- 0200 CTD, in situ & Th & organics (final samples only)
- 0400 Recover *in situ* (drift) array
- 0530 Recover sediment trap array
- 0700 Recover SOLOPC (asap after sediment trap recovery)
- 0830 MVP bow-tie survey
- 1300 VPR line transect survey
- 1600 Transit to San Diego (ETA 0800, 21 April)

## **CCE-P0704: CRUISE PERSONNEL**

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K. Buck debarked in Santa Barbara Harbor on 14 April

#### Site Surveys and Areal Sampling

Mark Ohman, Josh Eaton

#### MVP and VPR

Two towed vehicles were used to map the 2-dimensional or 3-dimensional structure of the ocean, the Moving Vessel Profiler (MVP) and the Video Plankton Recorder (VPR2). These instruments proved invaluable in situating the experimental cycles in particular oceanographic features of interest and in assessing our ability to track the same water parcel over time. The MVP was used for nine bowtie surveys, each of which sampled both along the major axis of the current flow (as determined by drifters and ADCP) as well as orthogonal to the major axis of flow, on a scale of 10 x 10 nm. These surveys mapped the 3-D fields of planktonic particles across a size spectrum of 150-6000  $\mu$ m, ChI a fluorescence, temperature, salinity and density. The MVP was also used for a lengthy section across the California Current from east to west (CYCLE 1 to CYCLE 2), in order to identify the major frontal features that helped define the lateral boundary of the eddy that was the focus of experimental CYCLE 2. The MVP has a free-fall multi-sensor fish that profiles vertically from the surface to 200-m depth with the ship steaming at 11-12 knots.

The VPR2 was deployed on the return section from CYCLE 2 to CYCLE 3, towyoing from the surface to 100 m depth while moving at 8-8.5 kts. In addition to environmental data (ChI a, CTD, PAR, turbidity), the VPR uses a rapidly sampling digital camera to image planktonic organisms in situ. This tool significantly enhanced our ability to recognize changes in plankton assemblages (larger phytoplankton and mesozooplankton) in real time, and thus to select appropriate water parcels for our research. Post-cruise analyses will permit us to assess the fine-scale patterns of vertical distribution of organisms assessed by the VPR with those sampled independently with much coarser resolution by MOCNESS and bongo nets. At the end of CYCLE 4, we performed a back-to-back sampling comparison of the VPR and MVP.

At the beginning of the cruise we spent time rectifying a faulty MVP tow cable and leaky VPR2 servo connector and connector inside the pressure case. Josh Eaton did an excellent job of trouble-shooting both instruments, although the VPR and not the MVP was his professional responsibility.

#### Satellite Imagry and Spray gliders

During this cruise, we had excellent satellite image support from the SIO photobiology group, notably from Mati Kahru. On a daily basis MODIS-Aqua and/or SeaWifs images were posted on a web site accessible to us at sea, permitting us to identify larger-scale near-surface features and processes of interest for our experimental work. Our updated drifter tracks were usually superimposed on the images, enabling us to closely follow the evolution of the ChI a and SST fields.

In addition, we are currently operating 2 *Spray* gliders in this sector of the California Current, one of them along CalCOFI line 80, which was the geographic focus of our current cruise. The glider profiles from 500-m depth to the surface and telemeters results back via Iridium at the end of each dive cycle, permitting us to resolve the sub-surface ocean structure in regions where we were not sampling. The glider

discovered the presence of a major anti-cyclonic eddy in the offshore domain, which became the focus of our second experimental cycle. The combination of glider and satellite imagery, together with detailed profiling by VPR and MVP, enabled us to allocate our time extremely productively in specific, pre-identified ocean features.

## Notes on Cruise Hydrography

Ralf Goericke

During each activity cycle, CTD casts were carried out every 8 to 12 hours in the vicinity of a free-floating drift array (drogued at 15 m) and a sediment trap array, both of which recorded position and sea surface temperate (SST). The R/V Thompson's sensors recorded SST, SS-Salinity, SS-Fluorescence and various meteorological parameters (DAS-system). The CTD package was instrumented for continuous depth-profile measurements of temperature, salinity, oxygen concentrations, fluorescence by ChI a, attenuation of light by particles (beam transmission), photosynthetically active radiation (PAR) and nitrate concentration (ISUS UV-nitrate sensor). Discrete samples were also collected from the rosette bottles at about 8 depths per cast for concentrations of plant nutrients (nitrate, nitrite, silicic acid, phosphate and ammonium), salinity, ChI a (determined fluorometrically aboard the ship), particulate organic carbon and nitrate (POC, PON) and concentrations of taxon-specific pigments (HPLC analyses). A sample was taken from the mixed layer on each cast to determine the size distribution of ChI a. Initial impressions from these casts are summarized below.

**CYCLE 1** (4-8 April): This cycle began in the vicinity of CalCOFI station 80.0 55.0. The drifter moved NW and then W for a total 46 km. Initially the euphotic zone was 50-60 m deep and weakly stratified; Isus-estimated nitrate was about 8-10  $\mu$ M (**Figure 2**). Within 1.5 days the mixed layer (ML) shoaled to about 20 m where it remained for the remainder of the cycle. This dramatic change in the ML may have been due to the submergence of the original surface layer underneath layers of lighter and warmer water that were already present at the fringes of the study area during the initial site survey. Water at the initial site was clearly derived from recent upwelling, but it is not possible to say if this occurred locally or off Pt. Conception, further north. Upwelling may have occurred at the site during day one but not after that.

The cast-to-cast CTD variability of ML properties (salinity, Fluor on Density) suggests that we did not sample the same parcel of water over the course of the cycle. Temperature variability at the drifter and trap confirms this. Even though it was mostly sunny to slightly cloudy during the day, Air-Sea Temp differences were about zero or negative during the cycle (up to -2 °C), suggesting that some convective cooling occurred at night.

Concentrations of ChI a in the ML declined from initially 2.2  $\mu$ g/L to 0.8  $\mu$ g/L at the end of the cycle. Changes in BeamTrans and CTD-Fluor over the course of the cycle are consistent with these measurements. Throughout the cycle phytoplankton biomass was dominated by the smaller size classes. These were also responsible for the changes in Total ChI a concentrations over the duration of the cycle; the >20- $\mu$ m size class did not change significantly.





<u>CYCLE 2 (9-13 April)</u>: The initial site for this cycle was located about halfway between CalCOFI lines 80 and 77 and stations 80 and 90. The drifter moved initially SSW and then SW for a total of 72 km. It had been the intention to sample near the center of the anticyclonic eddy; however, the drifter track indicates that we started to the east and SE of the rotational center. The feature may have been a meander of the California Current, as suggested by low salinities, ranging from 33.05 to 33.08 (DAS data). Air-

Sea temp differences were large over the cycle, ranging from -1 °C initially to -2.5 °C towards the end. This temperature differential likely explains the cooling of surface layer temperature from 14.45 to 14.05 °C. Convective mixing from cooling and winds ranging from 15 to 30 kn deepened the ML from initial values of ~30 m to ~60 m at the end of the cycle. ML salinity remained constant over the course of the cycle ( $\pm$  0.05). The small variations of ML properties over the cycle suggest that the drifter successfully stayed with the tagged parcel of water during this cycle.

The weather was sunny during most days of the cycle. ML nitrate concentrations (ISUS) were <1  $\mu$ M; it can not be determined if these were zero without chemical nitrate measurements. Concentrations of ChI a in the ML increased slightly over the course of the cycle from 0.2 to 0.28  $\mu$ g/L. At the ChI a maximum concentrations ranged from 0.5 to 0.8  $\mu$ g/L, corresponding to depths of 60-80 m. The size distribution of ChI a was typical for this environment, with fractions >1, 1-3, 3-8, 8-20 and >20  $\mu$ m contributing 58, 21, 15, 3 and 3 % of total ChI a.



Fig. 3 CTD time-depth contours along drifter tracks during CYCLE 2.

**CYCLE 3** (14-16 April): The site for this cycle was initially located about 15 km SE of CalCOFI station 80.0 55.0. No attempt was made to follow a parcel of water throughout the cycle. The site was abandoned after < 1 day because the sediment trap ran aground after moving S-SE for a total of 7 km. Water in the ML was cold and salty, consistent with recent upwelling either locally or north of Pt. Conception (**Figure 4**). Isus Nitrate was 15 to 20 μM.



Fig. 4 CTD time-depth contours along drifter tracks during CYCLE 3.

<u>CYCLE 4 (16-20 April)</u>: At the beginning of the cycle the drifter was deployed about 9 km NNW of CalCOFI station 80.0 60.0. It moved at first SSW, gradually changing direction until moving east on 04/20 for a total of 68 km (as of 04/20/07). The initial site was located in the vicinity of Temp and Sal fronts. The drifter path crossed some of these fronts, resulting in SST changes of ~1 °C (**Figure 5**). The ship also crossed these fronts repeatedly; these are evident in the DAS data as abrupt changes of temperature on the order of 1°C and 0.25 unit changes of salinity.

During the first two days of the cycle, the Air-Sea Temp difference was ~ -1 °C; during the rest of the cycle, it was ~ -2 °C. Wind speeds ranged from 15 kn initially to 35 kn; the deep mixed layers of 50 m are a likely consequence. At other times the mixed layer was only 10 to 20 m deep. Mixed-layer ISUS nitrate ranged from almost 20  $\mu$ M initially to 10  $\mu$ M in patches of warm and fresh water. ML concentrations of ChI a ranged from 1 to 2  $\mu$ g/L; a trend was not evident in the data. Distinct subsurface ChI maxima were not observed. The size distribution of ChI a was normal for this environment, with fractions > 1, 1-3, 3-8, 8-20 and >20  $\mu$ m contributing on the average 38, 16, 11, 8 and 26 % of total ChI a. Most of the variability of total ChI a was due to varying biomass in the < 1 and > 20- $\mu$ m fraction.



Fig. 5 CTD time-depth contours along drifter tracks during CYCLE 4.

## **Particulate and Disssolved Organics**

Laurie Chong (PI: Lihini Aluwihare)

The aims of the organic sampling program on the CCE Process cruise were 1) to quantify the chemical compositions of the dissolved and particulate organic matter fractions, 2) to determine their spatial and temporal distributions, and 3) to use natural abundances of <sup>15</sup>N and <sup>14</sup>C to define pathways of carbon and nitrogen cycling in the California Current.

Samples were collected to study total organic carbon (TOC), total nitrogen (TN), dissolved inorganic nitrogen (DIN), dissolved organic carbon (DOC), dissolved inorganic carbon (DIC), particulate organic carbon (POC), particulate organic nitrogen (PON), bacteria, and organic compounds. Samples were collected from the surface to depths of 600 m, with a few casts going as deep as 1000 m. The deep profiles will be used to compute volume exports of TON and TOC within the California Current region and to assess inter-annual variations in that transport.

The samples for TOC/TN, POC/PON, DIN, DIC, and DOC were collected and preserved for analysis onshore. During the cruise, approximately 1600 L was first passed through 0.5 and 0.2-µm filters to exclude particulates and bacteria, and then ultra-filtered to separate and collect high (>1 kD) and low (< 1kD) molecular weight organic compounds.

#### Phytoplankton Pigments, Production and Growth Rates Ralf Goericke

The pigments of microalgae are generally characteristic of their taxonomic affiliation. From HPLC analyses of taxon-specific chlorophylls and carotenoid pigments in samples collected on the cruise, we will determine relative contributions of different groups to total phytoplankton pigment-biomass. Pigment analyses of size-fractionated samples will also be used to determine the contributions of algal groups to community size structure (**Figure 6**).

In experiments conducted daily on drift arrays, primary production and groupspecific growth rates were determined from the incorporation of <sup>14</sup>C into particulate carbon and pigments. Carbon to ChI a ratios will also be calculated from these data.



Fig. 6. Chlorophyll a size composition during CYCLES 1-4. All samples are for the nearsurface Mixed Layer.

# Microplankton Community Abundance and Biomass

Andrew Taylor

Approximately 600 samples were collected on the cruise for microscopical analyses of cell abundances and size-structured biomass of auto- and heterotrophic

protists and to assess compositional changes during growth and grazing experiments. Microscopical samples were prepared as slides in two size classes (50-ml samples on 0.8-µm filters for assessing small, numerous nanoplankton <10 µm; 100-400 ml samples on 8.0-µm filters for enumerating larger and rarer >10-µm cells). The large volume slides from both initial CTD casts and dilution experiments were imaged and digitized on shipboard using a fully automated Zeiss epifluorescence microscope system. Nanoplankton slides could not be imaged shipboard due to excessive movement in the microscope room and were subsequently imaged back in the laboratory. For imaging, 30 microscopy fields are acquired from every slide, with each image being a composite of three color channels indicative of the presence and concentration of cell DNA (DAPI; blue), protein (FITC; green) and Chl a (autofluorescence; red). Digitized images are analyzed for all individual cells (enumerated and sized) using image analysis and neural network software.

As examples of cruise results, total biomass of both auto- and heterotrophic protists declined sharply after the first two days of CYCLE 1 (**Figure 7**). These changes were well reflected in the community dominant dinoflagellates, which comprise a half to a third of the total biomass in the A and H fractions. Diatoms contributed substantially less to A-biomass (~2% initially) but increased in relative importance during the cycle. Compared to CYCLE 1, protist biomass was 2-3 fold lower in the off-shore mesoscale feature during CYCLE 2 (**Figure 8**). Diatom biomass was especially low there, averaging < 0.2 µg C/L (**Figure 9**).



Fig. 7. Time-depth contours of community composition during CYCLE 1. A-dinoflagellates and diatoms are components of total biomass of autotrophic (Chl a containing) cells. H-dinoflagellates are a component of the biomass of total heterotrophic protists.



Fig. 8. Time-depth contours of total auto- and heterotrophic protists during CYCLE 2. Note scales are reduced compared to Fig. 7.



Fig. 9. Comparisons of depth-integrated protistan biomass (mg C m<sup>-2</sup>) for total autotrophs, total heterotrophs, auto and heterotrophic dinoflagellates, and diatoms. Note scales are reduced between upper and lower panels.

#### **Bio-Optical Measurements**

Haili Wang, Brian Seegers (PI: B. Greg Mitchell)

The photobiology sampling plan was designed to enhance spatial and temporal resolution of phytoplankton biomass, physiology and primary production using biooptical methodology. Ship sampling consisted of daily deployments of bio-optical instruments, water sample collection and analyses from the mid-day CTD cast. Mati Kahru also processed and transmitted SST and ocean color satellite imagery to the ship when cloud-free scenes allowed.

Inherent optical properties (IOP) and kinetics of photosynthetic processes were resolved from vertical profiles (to 300 m) using an integrated bio-optical package. The IOP measurements consisted of backscattering coefficients at 6 spectral channels (Hydroscat-6, HobiLabs), absorption and attenuation coefficients at 9 discrete spectral channels (AC-9 Plus, WET Labs) and single wavelength beam attenuation coefficients at 660 nm (WET Labs). Photosynthetic physiology was assessed with a Fast Repetition Rate Fluorometer system (FAST<sup>tracka</sup> Chelsea).

Radiometric measurements of natural sunlight were obtained with a free-fall Profiling Reflectance Radiometer (PRR) consisting of a free fall under-water profiling unit (PRR 800) and a deck-mounted surface reference radiometer (PRR810). PRR 800 is equipped with 3 sensors measuring downwelling irradiance (Ed), upwelling radiance (Lu) and upwelling irradiance (Eu) in 19 spectral channels. The PRR 810 continuously recorded surface irradiance in 19 spectral channels and was also used as a surface reference unit during the PRR 800 profiles. A typical PRR deployment consisted of 3 replicate casts, one to 150 m and two to 50 m.

The IOP and PRR instruments were deployed at 14 stations coinciding with the mid-day CTD cast. Water samples were collected for analyses of high spectral resolution absorption coefficients of particulate and soluble fractions, HPLC pigments, phycobiliprotein (PBP) pigments, CHN composition, photosynthesis vs. irradiance (PvsE) experiments, FRRF measurements, and size distribution of particles. FRRF underway measurements were also conducted during the cruise through the ship's uncontaminated seawater

system (Figure 10).

Optical and phytoplankton physiology data collected during this cruise will be used to validate ocean primary production bio-optical models that can be applied to the optical data from the profilers and ocean color satellites. Satellite time series of the CCE region will be used to set the cruise context.



Fig. 10. Preliminary Fv/Fm results from FRRF underway measurements.

# Advanced Laser Fluorometric Analysis (ALF)

Alexander Chekalyuk, Mark Hafez

Recent technological progress provides ways for implementing the new analytical capabilities of laser fluorometry in oceanographic research and surveying. The Advanced Laser Fluorometer (ALF, **Figure 11**) recently developed at NASA/GSFC



Fig. 11. ALF-1 instrument configured for water sample analysis

Wallops Flight Facility incorporates blue and green diode lasers, a CCD spectrometer for hyperspectral (400-800 nm) measurements of laser-stimulated seawater emission, and a pump-during-probe (PDP) sensor of variable fluorescence. The ALF technology seeks to improve quantitative assessments of chlorophyll-a (ChI), phycobiliprotein (PBP) pigments, chromophoric dissolved and particulate organic matter (COM), phytoplankton photo-physiological/nutrient status and water turbidity, and to provide basic characterization of phytoplankton community structure.

The LTER CCEP-P0704 cruise (Apr. 2007) has provided a unique opportunity to deploy the ALF instrument in diverse water types of the coastal zone of California and the California current. The system was used for the underway flow-through sample measurements and analyses of discrete water samples. The continuous underway measurements were conducted along most of the ship transects and during MVP and VPR surveys (e.g., Figure 12). Mesoscale spatial correlations between surface distributions of phytoplankton and physical structures were studied in the euphotic layer by the simultaneous underway measurements with the moving vessel profiler (MVP) and the ALF. In addition to the underway ALF measurements of horizontal variability, water samples collected at 11 depths at each station were analyzed during cruise CYCLES 1-3 to assess vertical distributions of the seawater constituents and structural changes in phytoplankton population in the euphotic layer. Overall, 14 vertical profiles were measured during the cruise. Among the interesting observations is a consistently observed increase in the relative abundance of the accessory phycobiliprotein pigments (phycocyanin, and allophycocyanin) vs. Chl a towards and below the bottom of the euphotic layer (up to 500 m) that may suggest elevated relative abundance of cyanobacteria vs. eukaryotes in the phytoplankton community. Diel variability in pigment fluorescence was studied during the cruise to improve the accuracy of fluorescence pigment assessments and retrieve additional information about phytoplankton photophysiology.

Fig. 12. Example of ALF underway flow-through fluorescence assessment of seawater constituents during bow-tie survey # 12 (CYCLE 4, 20 Apr., see map in upper panel). Hyperspectral measurements of seawater laser-stimulated emission measured with the blue and green laser excitation are presented in the upper left and middle panels, respectively. The upper right panel in the ALF screen-capture displays Chl-a fluorescence induction assaying of phytoplankton photo-physiological status. Horizontal transects of variable, COM and Chl-a fluorescence are presented in the lower left panel (light magenta, blue, and green/light green colors, respectively). Fluorescence distributions of 3 phycoerythrin spectral types (565, 575 and 589 nm) and phycocyanin/allophycocyanin are displayed in lower mid-left and mid-right panels, respectively. Underway ALF measurements provide for rapid real-time characterization of seawater constituents over a range of spatial and temporal scales.





## **Microplankton Community Dynamics**

Michael R. Landry

As an integral part of the experimental studies, daily water-column sampling was conducted at the beginning and end of each drift array deployment to assess concentrations and net daily changes in nutrients (dissolved inorganic N, P, Si), total organic carbon and nitrogen (TOC, TON), particulate carbon and nitrogen (POC, PON), stable isotopes of C and N, particulate biogenic silica (BSi), fluorometric Chla and HPLC accessory pigments, microscopical, flow cytometric and molecular assessments of microbial community composition in the ambient environment. The same initial water was also used experimentally to assess rates of phytoplankton growth ( $\mu$ ), <sup>14</sup>C-primary production and microzooplankton grazing impact, with the incubations conducted for 24 hours in net bags attached to the drift array at the depth of collection. We used a combination of dilution and <sup>14</sup>C-pigment labeling approaches for these experiments, with initial and end-point sampling for community analyses also by Chla, HPLC pigments, flow cytometry, microscopy and molecular techniques. The full data set will thus provide daily depth profiles of growth and grazing rate estimates for the various taxa and groups discriminated by these methods, as well as comparisons of the dynamics in manipulated bottle experiments relative to the observed net rates of change in the ambient environment.

Most of the samples collected on the cruise require extensive laboratory processing and analyses. Very preliminary results for dilution experiments are available, however, from shipboard fluorometric Chla analyses (**Figure 13**). Although such rate estimates tend to be less reliable than those from HPLC Chla analyses and will require correction for cellular pigment changes to be understood in terms of phytoplankton biomass or carbon, they give a useful visual overview of rough trends in phytoplankton (Chla) distribution and community growth rates among and between the activity CYCLE sites. They are presented below with modest narrative.

**Fig. 13**. Daily depth profiles of Chl*a* and phytoplankton intrinsic growth rate ( $\mu$ , d<sup>-1</sup>) during each of the CCE-P0605 experimental cycles.



Chl *a* decreased significantly in the tracked water-column over the 4 sampling days of CYCLE 1 (mean daily rate = -0.28 d<sup>-1</sup>). However, phytoplankton growth rate estimates did not show a coherent temporal pattern, and net growth in the upper 20 m was strongly positive (+0.32 d<sup>-1</sup>; **Table 1**). This large net rate disparity could conceivably be resolved by high

rates of mesozooplankton grazing or cell/aggregate sinking. Hydrographic parameters also suggest that the drifter may have crossed a frontal feature between water masses (or that variable ship positioning relative to the drifter may have introduced some randomness or bias into the series of daily samples). Microzooplankton grazing accounted for an average daily loss of 51% of phytoplankton production in CYCLE 1 bottle incubations.



CYCLE 2 Chl a was much lower than CYCLE 1, and much of it resided in a "Chl max" at the base of the euphotic zone. Near-surface growth rates (0.32 d<sup>-1</sup>) were about half of the estimates for CYCLES 1, 3 and 4. According to preliminary Chl a results, microzooplankton appear to have consumed >200% of production, which is

inconsistent with the positive net rate of change in the ambient environment (**Table 1**). This discrepancy is largely due to the low near-surface growth rates for Array 27, which we hope to resolve with subsequent analyses of experimental samples. The observed variability in the depth of the ChI maximum between adjacent sampling dates is likely due to the presence of internal waves, which can dramatically affect the light environment of deep-living phytoplankton. It is interesting to note that the upper position of the ChI Max (60 m) produced a relatively strong growth response in Array 25 (~ $0.5 d^{-1}$ ) and that growth progressively weakened when the ChI Max was sampled deeper and consequently incubated at lower light levels (~ $0 d^{-1}$  at 70 m, Array 26; -0.15  $d^{-1}$  at 80 m, Array 27).



CYCLE 3 consisted of a single array profile with no final field sampling for comparison. This experiment was initiated with water from the general area of CYCLES 1 and 4, and the general results are similar (**Table 1**).

CYCLE 4 began downstream of the flow trajectory of CYCLE 1 (**Figure 1**), and these two sets of experiments are similar with respect to mean growth and grazing rates in the upper euphotic layer (**Table 1**). The main differences are the lower and more uniform concentrations of ChI a in CYCLE 4, and (consequently) the deeper penetration of high growth rates.

**Table 1**. Preliminary summary of mean Chl*a* and rates during experimental cycles. All estimates are cycle averages for the upper 4 incubation depths, where rates were generally highest. Percent phytoplankton production (%PP) consumed is calculated as m/µ from dilution incubations, where m = phytoplankton mortality due to microzooplanton grazing and  $\mu$  = phytoplankton growth rate.



#### Iron Biogeochemistry

Andrew King, Kristen Buck, Julien LeBlond (PI: Kathy Barbeau)

In conjunction with Process Cruise activities at CYCLES 1-4, the iron biogeochemistry program carried out sampling and experimental activities directed towards understanding iron distribution, cycling, and the ecological role of iron as a micronutrient in the CCE-LTER study area. Trace metal-clean seawater was sampled using 12 and 30 L GO-Flo bottles individually mounted on metal-free synthetic line and tripped using coated brass messengers. Thirteen GO-Flo casts were conducted to collect four- and five-depth profiles for total Fe (whole samples) and dissolved Fe samples (<0.4  $\mu$ m). Samples for Fe speciation and particulate Fe were also taken for select profiles. In addition, mixed-layer seawater (10-15 m) was used to set up two types of Fe-related experiments.

The first type was our standard Fe-addition grow-out experiments (previously conducted on six CalCOFI cruises and CCE-LTER Process Cruise #1). These experiments are designed to evaluate phytoplankton nutrient limitation by Fe and the influence of Fe availability on phytoplankton macronutrient utilization and community structure. A total of five Fe-addition experiments were conducted on this cruise. Preliminarily, based on changes in Chl *a* in control (unamended) and Fe-addition (+5 nM FeCl<sub>3</sub>) bottles during CYCLE 1, Fe appeared to be marginally limiting for water sampled on day 1.5 and severely limiting for water collected on day 4 (**Figure 14**).



Fig. 14. Chl a concentration in Fe-addition bottle experiments from CYCLE 1, day 1.5 (left) and day 4.5 (right); note change in X- and Y-axis scale. The mean Chl a of control replicates are marked with open circles and Fe-addition replicates are marked with closed circles, error bars represent 1 standard deviation (n=2).

The second type of experiment our group conducted was Fe ligand-addition bottle incubations for estimating the partitioning of Fe from particulate to dissolved phases. For these experiments, we used the ligands aerobactin and desferrioxamine, sampling particulate Fe, dissolved Fe, and Fe speciation in light and dark bottles over a 7-day period. Experimental results are pending laboratory analyses of collected samples.

#### **Microbiological Studies**

Jessica Ward, Ty Samo (PI: Farooq Azam)

Microbiological studies addressed two main objectives on the CCE Process cruise: 1) survey multiple aspects of the bacterial community across sites (e.g., abundance, diversity, productivity, enzyme activity), and 2) determine whether bacteria aggregate along pycnoclines and how this affects bacteria abundance and diversity.

CTD water samples were collected daily at 3 - 5 depths, depending on the presence and location of the pycnocline. When a pycnocline was present, samples were taken above, at three depths along (usually the beginning, middle, and end), and approximately 50 m below the cline. Bacteria production was quantified using tritiated leucine incorporation. Ectoenzyme activities were quantified using fluorogenic substrates for glucosidase, phosphatase and leucine aminopeptidase. Additional samples were prepared for laboratory analyses of community diversity (by denaturing gradient gel electrophoresis), diversity of actively growing bacteria (bromodeoxyuridine incorporation and denaturing gradient gel electrophoresis, BUMP-DGGE), bacteria and virus abundances, relative abundance of bacteria and Archaea using fluorescent in situ hybridization, and transparent polysaccharidic particle abundance.

Size-fractionated bacterial production experiments were carried out at 3-5 depths from water collected on the noontime CTD. Bulk production rates were measured from water filtered onto 0.2-µm membranes, and production rates of attached microbes were calculated from samples filtered onto 1-µm membranes. Rates are consistently higher in the upper mixed layer, with highest values frequently observed within the chlorophyll and/or particle maxima (**Figure 15**). Production rates from the total community usually

exhibited much higher values than the attached community; however, depths at which this did not take place suggest a strong influence of particulate material affecting prokaryotic biogeochemistry. Production estimates ranged from 0.01 to ~3  $\mu g C L^{-1} d^{-1}$ , with consistently higher values observed in coastal regions. Further analysis of the abundances and characteristics of labile particles located at depth, either at or around the pycnocline, or in a random distribution, may shed light on the importance of particle microenvironments located at or within density surfaces in structuring microbial communities and biogeochemical cycles.

Ectoenzyme activity was consistent with activities measured elsewhere,



Fig. 15. Bacterial carbon production measurements from CYCLE 1, day 5. The blue line represents the bulk community while production of bacterial attached to material larger than 1  $\mu$ m are represented with the red line.

assuming  $0.5 \times 10^6$  bacteria ml<sup>-1</sup>. Leucine aminopeptidase activity was consistently higher than phosphatase activity while glucosidase activity was detected at only one location. Interestingly, bacterial production decreased linearly with depth, which is inconsistent with other observations depicting maximum values in relation to high chlorophyll and particle numbers. Results will provide a snapshot of bacteria

abundance, production, enzyme activity, and diversity that will contribute to our understanding of their role within the California Current Ecosystem.

#### MOCNESS Zooplankton Sampling Mark Ohman

The Multiple-Opening Closing Net and Environmental Sensing System (MOCNESS) was used for vertically stratified sampling of mesozooplankton at each of the 4 experimental cycles. The sampling extended across a range of oceanographic conditions, permitting us to evaluate the relationship between mesozooplankton habitat depth and water-column stratification. A 1 m<sup>2</sup> MOCNESS with 202-µm mesh nets was deployed for replicate day and night sampling for a total of 15 tows. Each tow sampled from 450–0 m in 50-m depth intervals, together with continuous real-time recording of vertical profiles of ChI-a fluorescence, beam attenuation, temperature, salinity, and density. All tows were completed successfully. From each tow, the 9 quantitative samples were preserved in borate-buffered Formalin for enumeration by Zooscan and microscopy ashore. The one nonquantitative sample (net 0) was preserved in 95% non-denatured ethanol for molecular genetics studies. Steve Hartz (Univ. Alaska) maintained the MOCNESS in good working order and conducted all deployments and recoveries in a very professional manner.

## **Mesozooplankton Biomass and Gut Fluorescence**

Ryan Rykaczewski

The mesozooplankton community in the upper 200 m was sampled using an oblique tow with the standard CalCOFI BONGO frame and 202-µm mesh. The goal of this sampling was to estimate mesozooplankton biomass and their contribution to the grazing of phytoplankton. A total of 47 of these net tows were completed, most at 1000 and 2200 hours each day. In addition, tows were conducted once every two or three hours for a 24-hour period during Cycles 1, 2, and 4 in order to study diel variability in biomass and gut fluorescence. After each net tow, one of the two BONGO codends was preserved with formaldehyde. The other codend was split three ways for analyses of total biomass, gut fluorescence, and stomach contents (usually three-eighths, three-eighths, and one-fourth, respectively). The portion designated for biomass and gut fluorescence was wet-sieved to yield size fractions in five classes. The biomass portion will be dried and weighed on land to estimate total dry weight of mesozooplankton. Samples for gut fluorescence will be analyzed on land using spectral and genetic techniques.

Data will not be available until after analyses are completed in the laboratory. However, a number of initial observations were made: 1) Nighttime biomasses at CYCLES 1, 3, and 4 were likely higher than during cruise CCE-P0605, especially in the larger size classes; euphausiids seemed to be much more abundant during this cruise. 2) Diel variability in biomass was more obvious during this cruise than during CCE-P0605, again due to the abundance of euphausiids during night. 3) Large phytoplankton composed a significant portion of the sampled biomass during CYCLE 1 (much more than CYCLES 2 and 4) and caused significant net clogging; this was similar to CYCLES 1 and 3 during CCE-P0605.

## **Zooplankton Feeding Experiments**

Moira Decima

Feeding activity and prey selectivity were investigated in incubation experiments with dominant krill (*Euphausia pacifica, Nematoscelis difficilis*) and large copepod (*Calanus pacificus*) species of the California Current. The objective was to quantify the selectivity and grazing impact on phytoplankton and microzooplankton taxa, and the spatial variability of these impacts.

Eight experiments using ambient prey assemblages were conducted (2, 2, 1 and 3 each during CYCLES 1-4, respectively). Four treatments were run for each experiment: *i*) krill (*Euphausia pacifica* in CYCLES 1, 3 and 4, *Nematoscelis difficilis* in CYCLE 2); *ii*) *Calanus pacificus*; *iii*) ambient sea water; *iv*) ambient sea water in 1:3 dilution to account for the grazing contributions of microzooplankton. Each treatment was conducted with 3-8 replicates, and the jars were incubated in the dark on a rotating grazing wheel for a period of 24 hours. Initial and final subsamples were taken for: *i*) chlorophyll a, *ii*) epifluorescence microscopy, *iii*) acid Lugol's preserved for ciliates enumeration, and *iv*) filtered on 0.2-µm SUPOR filters, and frozen.

## Mesopelagic "Oozeki" Trawls

Tony Koslow, Pete Davison

The primary objectives of the mesopelagic trawl sampling were:

- To field test the newly designed Oozeki et al. (2004) midwater trawl, a 5 m<sup>2</sup> frame trawl, which can be towed at 4 5 kt and therefore samples a larger size range of juvenile fishes and micronekton than research trawls of comparable size (e.g. the Isaacs-Kidd midwater trawl);
- To sample the epipelagic (0-150 m) and upper 500 m over the diel cycle to assess the abundance, biomass, species composition and migratory pattern of the micronekton assemblages at each cycle (station);
- To describe patterns of diel feeding and, if possible, to estimate ingestion and digestion rates, of key mesopelagic species as a means to assess the role of mesopelagic fauna in carbon flux to the deep ocean.

Six or seven trawl samples were collected over diel cycles during CYCLES 2 and 4 (mechanical damage to the net prevented sampling during CYCLE 1). Samples at the offshore site were notably smaller than at the more productive inner site. Fishes and invertebrates were separated and preserved in formalin for further analysis in the laboratory. Some specimens were also preserved in ethanol to expand the SIO fish DNA collection. Rates of ingestion and digestion will be estimated for species that display a diel cycle of stomach contents.

#### SOLOPC

#### Dave Checkley

The SOLOPC is an autonomous, Lagrangian profiling float that measures physical and biological properties and transmits the data ashore via satellite. It is the combination of a SOLO float, a Laser Optical Plankton Counter, and Ecopuck fluorometer. It senses pressure, particles (100 µm to 1 cm equivalent spherical diameter), and chlorophyll *a* fluorescence during descent, and pressure, temperature and conductivity during ascent. At the surface, between profiles, it communicates ashore via Iridium, sending data and GPS information and receiving commands. The SOLOPC was in the water during CYCLES 1, 2 and 4. At each, it was deployed shortly after the start of the cycle, profiled between the surface and 100 m, and was recovered at the end of the cycle. Deployment was usually ~ 2 miles away from the drogued arrays to minimize likelihood of encounter by the ship. 71 depth profiles were made during CYCLE 1, 73 during CYCLE 2, and 78 during CYCLE 4.

Deployment and recovery from the R/V Thompson was successful in each case, despite the size and freeboard of the ship. Credit for this success goes largely to the ship's captain and crew and the maneuverability of the ship, especially dynamic positioning using the Z-drives and bow thruster. In each case, the SOLOPC performed as intended, with transmission of data ashore and forwarding to the ship via the HiSeasNet for near-real time processing. Data were also downloaded, after retrieval, from the SOLO and LOPC RAM. The telemetered data appear identical to the stored data and consistent with CTD observations near the drogue. The contour plots below show examples of profile data from CYCLE 2 (**Figure 15**).



Fig. 15. Variability in temperature, salinity, fluorescence and total particles along the SOLOPC drift track during CYCLE 2.

## **Export Flux**

**Michael Stukel** 

Two approaches were used during the cruise to estimate rates of carbon export out of the euphotic zone, and to assess the biological parameters controlling export. The first approach was the disequilibrium between the particle-reactive thorium isotope <sup>234</sup>Th and its non-reactive parent isotope <sup>238</sup>U. Samples for <sup>234</sup>Th analyses were taken at the beginning and end of each cycle. In order to relate Th deficiencies in surface waters to equivalent exported carbon, McLane pump samples were also taken at depth to determine C:<sup>234</sup>Th ratios of particulates.

Direct estimates of export flux will be determined from an array of 8 replicate sediment traps (VERTEX type) which were deployed at 100 m for the duration of each cycle (CYCLE 1, 2 and 4). Drift trajectories for the sediment trap array closely followed the drift array for *in situ* experiments on all deployments. Material collected in replicate traps was split and filtered on shipboard for subsequent analyses of C, N, P, Si and phytoplankton pigments. Preserved samples were also retained for microscopical analyses of the settled organic matter. To complement these flux estimates, a SETCOL settling chamber was used with samples of the natural plankton assemblage to determination sinking rates as a function of phytoplankton size and taxonomic group.

#### Notes on Cruise Data Management

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Data management for this cruise and its data budgets took place along side planning for sampling design including wire time and water use budgets. The eventLogger, remote-mount share disk, cruise web page, and information system are four data management elements that facilitate data flow from the field to the CCE community data repository.

Data management fieldwork involves development of an activity cruise glossary. It promotes common vocabulary and is used to prepare an eventlogger configuration file. An eventlogger is used to capture cruise activities in an authoritative list with associated event number, date time, and location information was used as a central coordinating device. Other pre-cruise preparations include eventlogger hardware/software updates, shipboard information infrastructure coordination as well as installation and training for eventlogger use on the bridge and in the lab.

During the cruise, ship-to-shore communications permit shore support for eventlogger issues that arise. On this cruise, support was also provided for an education/outreach project called Picture-of-the-Day launched by Beth Simmons in collaboration with student participant Andrew King. A photo with accompanying text was delivered daily via email to classrooms, researchers, and family members. Post cruise the photos were gathered online into a Media Gallery for preservation and web delivery. Additional post-cruise activities include addition of the cruise to the information system study list prior to cleaning and uploading of the cruise CD on a shared disk and of cruise participant information, eventlog, and dynamic mapper station locations to the web. A cruise web page was used for initial ad hoc gathering of cruise information. Training and support for dataset upload and metadata web form use is ongoing as data is submitted to the CCE LTER information system.