Cruise Report

California Current Ecosystem LTER Program CCE-P0605, Process Cruise #1 R/V KNORR, 8 May - 7 June 2006

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Cruise ID: CCE-P0605, aka KN 182-14 Depart: 8 May 2006 at 1500 (PST) Return: 7 June 2006 at 0700 Vessel: R/V KNORR Operator: WHOI Master: Captain Kent D. Sheasley Chief Scientist: Michael R. Landry WHOI SSG Technicians: Amy Simoneau, Sacha Wichers







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SCIENTIFIC OBJECTIVES

This was the first "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 present cruise was designed to investigate the relationships among water-column light, temperature, nutrients, thermocline and nutricline depths, phytoplankton and zooplankton standing stocks, phytoplankton growth and production rates, and micro-and meso-zooplankton grazing rates during a "normal" spring (upwelling) period. The results from this cruise will provide an empirical basis for modeling of CCE springtime dynamics and for comparative studies on subsequent cruises during late summer and El Niño conditions.

GENERAL OVERVIEW OF THE SCIENCE PLAN

The general concept of the science plan was based upon 5 cycles of activity in which water masses of varying characteristics would be marked with a drogued drift array and followed over the course of 4-5 days. The cycle sites were situated along the axis of CalCOFI sampling line 80, which extends seaward off Point Conception, California (**Figure 1**). This is generally the line with the greatest variability in water-column and community characteristics, especially during the spring upwelling period.



Fig. 1. The CCE study area off Southern California. The CalCOFI grid is represented by black dots. The location of CTD casts made over the course of Cruise P0605 is represented by blue diamonds. Clusters of these show the five experimental cycles following the drift paths of drogued experimental arrays. The initial cycle locations coincide roughly with positions along CalCOFI line 80 off Point Conception.

CYCLE 1 was conducted in a diatom-dominated bloom under relatively nutrient-rich conditions. CYCLE 2 sampled the pico-/nanoplankton dominated, nutrient-deficient core of the California Current, as indicated by its reduced salinity. CYCLE 3 sampled a dinoflagellate-dominated nearshore bloom. CYCLE 4 captured a well-mixed euphotic zone of intermediate trophy under conditions of strong and persistent winds. Previously (between CYCLEs 1 and 2), this area, situated between two fronts, had been the location of the highest Chl *a* along the line 80 transect; thus, it may have been a region of recent high export from the euphotic zone by the time we began CYCLE 4. CYCLE 5 sampled the offshore, nutrient deficient end of line 80 and caught an unusually strong deep chlorophyll/particle maximum at 70-75 m.

Initial and daily CTD sampling at approximately 0200 was conducted to assess daily changes in water mass characteristics due to growth, mortality and associated changes in community composition. 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, with the incubations conducted for 24 hours in net bags attached on the drift array at the depth of collection (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 studies and shipboard assessments of primary production, and typically in the evening for additional shipboard experimental studies of growth, grazing and mesozooplankton reproduction. The latter were accompanied by short bongo net tows to collect live animals.

Go-Flo and trace-metal pump samples were taken for iron (Fe) and nickel (Ni) analyses and for grow-out experimental studies of Fe- and Ni- limitation. MOCNESS net tows were taken at mid-day and mid-night to determine the depth structure of the meso-zooplankton community. These samples were preserved in formalin. Bongo net tows with a laser optical plankton counter (LOPC) were also taken at mid-day and mid-night to get depth depth-integrated assessments of the zooplankton biomass structure in the euphotic zone. One side of the paired nets from these collections was formalin preserved for species identification. The other was physically size-fractioned on shipboard for biomass (dry weight, C, N) and gut pigment analyses, the latter a crude assessment of mesozooplankton feeding on phytoplankton. During each cycle, bongo-LOPC 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 the C:Th ratios and the estimation of carbon export by the thorium disequilibrium method.

Daily activities also typically involved a 4-h bow-tie survey with the 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 growth, micro- and meso-zooplankton grazing and particle export to community change.

SHIP AND TECHNICAL SUPPORT

The R/V KNORR provided an excellent platform for this project, and Captain Sheasley and crew were most helpful and accommodating in the support of the science. We extend special thanks to the 2nd mate, bosun and early morning watch for their skill and hands-on help with daily recovery and redeployment of the drift arrays, and to the 1st mate for her quick action and assistance with the clean-up from a leaky nitric acid bottle in the chemical van. Josh Eaton performed admirably in support of the MOCNESS and VPR sampling activities, and contributed above-and-beyond in diagnosing and fixing hardware and software problems in other equipment that was not his primary responsibility. SSGs Amy Simoneau and Sacha Wichers were available round the clock to facilitate the data collection, CTD training and technical aspects of data processing, retrieval and web access. All of their efforts were very much appreciated.

The lab and deck space were adequate for all activities. In particular, the Lower Lab (centered on the ship and low to the water) was an exceptional location for microscopy, the best yet encountered on a UNOLS vessel. The food and the galley crew were excellent, and we appreciated the opportunity to enjoy celebratory beverages between CYCLES.

SCIENCE OPERATIONS AND ISSUES

Despite its ambitious agenda and a few operational glitches, the CCE-P0605 cruise was highly successful overall. We successfully completed 18 of 20 planned *in situ* drifter incubation experiments, 75 CTD casts, 80 tows with the bongo/LOPC net system, and 27 tows with the 10-net MOCNESS system. The MVP system completed 838 depth profiles, including 6 long transit sections and 14 bow-tie patterns around the drift array. The SRRAY 9 glider provided invaluable, continuous survey support at the CYCLE 1 and CYCLE 4 study sites, including maintaining a water-column sampling presence in the dynamic frontal region while the ship conducted CYCLE 2 and 3 activities. The VPR experienced technical difficulties during its first deployment on the initial long-shore transit to the study area for San Diego, but it produced 16 hours of excellent data during two subsequent cross-shelf transects in the study area. The vast majority of experimental studies of growth and grazing rate estimates, primary production, meso-zooplankton feeding and reproduction, and trace-metal effects on community biomass and composition were completed as planned.

Some equipment-related problems during the cruise were either relatively minor or had minimal impact on the science. For example, the left wing of the VPR was damaged on recovery during rough sea conditions, but the severed part fortunately contained no critical mechanical or electrical functionality. A new section fabricated at WHOI was welded on in port so that the VPR could be used on the next cruise. The VPR was not a critical element of our particular science plan, although the two transects that it did complete will be very useful for calibrating the LOPC sensors on the bongo nets and MVP. Similarly, although the "options module board" failed on MOCNESS tow 20, the net system continued to function well for the remaining tows (without ancillary information from O_2 , fluorescence and beam c transmission sensors), and the science was minimally impacted.

Three equipment issues were, however, more serious. One drift array (15) was lost when it failed to report its position after a recovery/redeployment operation, and another float subsequently failed on its first deployment after functioning on deck. The latter was recovered and replaced with a functional third float, which operated well for the remainder of the cruise. It does seem however that the satellite receiver design might have been too fragile for operations in which the float was knocked or handled roughly (normal conditions for shipboard recovery), and a redundant or back-up system may be needed for future cruises. The lost array was quite disruptive to the flow of daily science activities, which were broken off to search, and it resulted in a full day's loss of incubation experiments as well as the physical context for the CYCLE 4 science activities in the moving water mass. In addition to the lost array, a tether line was severed between the float and drogue on Array #5 (possibly due to a kink when the line was laid out on deck in transit between cycles), resulting in the loss of most of the incubation bottles for that day, and Array #6 was lost for most of a day (poor transmission because the float was being pulled underwater), requiring a search, late recovery and loss of a new array deployment for that day. These problems were solved, respectively, by ordering a thicker tether line for Leg #2 and by using an additional 2 kg of subsurface flotation on the array line.

As noted, the glider (SPRAY 9) performed well in support of CYCLE 1 & 4 sampling activities. It malfunctioned in the later stages of CYCLE 4, likely a failure of its rotation control motor. Thus, the glider's normal distress behavior, which involves alternating rolls to receive and transmit its GPS position with in-wing antennae, did not function properly, and it was only able to get off a few position fixes as the ship was conducting CYCLE 5 activities. Two grid searches of several hours each, one shortly after it was lost and the other after CYCLE 5, failed to locate the missing glider.

The last significant science mishap was the loss of an ISUS nitrate sensor, which was left on the CTD during a 2500 m cast. The ISUS pressure housing was only rated to 1000 m, but functioned apparently to 2400+ m before imploding. The battery pack was recovered undamaged. The circumstances that led to this loss involved miscommunications at many levels. The Chief Scientist was aware of the ISUS depth rating but was distracted by other events – organizing the evening search pattern for the missing drift array; the MOCNESS options module failure was also that day. The individual who would have been in charge of the deep cast left the cruise prematurely after leg 1 so was not there to catch the problem. WHOI depth-sensitive instruments were removed from the CTD prior to the cast, but the SSG did not know about the ISUS depth rating. In the end, it was an expensive lesson about being fully aware of the physical limitations of all equipment that goes over the side and the circumstances under which it is being deployed. This was the only very deep CTD cast of the cruise, and it caught us unprepared.

CCE-P0605 ACTIVITY SCHEDULE

<u>10 May</u>

- 0500 CTD test
- 0630 Glider deployment
- 0900 Resume MVP survey, near-shore sections
- 1600 ETA position 34°20'N, 120°48'W, begin CYCLE #1
- 1600 CTDs, PAR light depths, water for evening experiments
- 1930 Bongo tows, animals for experiments
- 2130 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 MOCNESS/Zooplankton sampling

<u>11 May</u>

- 0200 CTD, setup *in situ* experiments (150m)
- 0300 Go-Flo trace-metal sampling, setup grow-out experiments
- 0430 Deploy in situ Array #1
- 0500 CTD, dissolved organics, POC, PON, bacteria (600 m)
- 0600 MVP small bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 Mid-day CTD, ¹⁴C-PP CalCOFI & PvsE
- 1300 Mid-day Radiometer & IOP casts (stern)
- 1430 MOCNESS/Zooplankton sampling
- 1730 Fe clean pump, water for evening experiments
- 1930 Thorium pump
- 2200 Bongo LOPC/Zooplankton biomass & gut pig sampling
- 2300 Bongo tows, animals for experiments

<u>12 May</u>

- 0200 CTD, setup *in situ* experiments (150m)
- 0300 Go-Flo trace-metal sampling
- 0430 Recover Array #1/deploy *in situ* Array #2
- 0500 MVP small bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1430 Lihini surface pump
- Bongo/LOPC, zooplankton biomass & gut pig samplingCTD, full dilution experiments
- 2000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 MOCNESS/Zooplankton sampling

<u>13 May</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0200 CTD, setup *in situ* experiments (150m)
- 0400 Recover Array #2/deploy *in situ* Array #3
- 0440 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0500 CTD thorium sampling (150 m)
- 0600 Bongo/LOPC, zooplankton biomass & gut pig sampling

- 0700 Go-Flo trace-metal sampling
- 0830 Lihini surface pump
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS/Zooplankton sampling
- 1500 MVP bow-tie survey
- 1900 CTD, water for evening experiments
- 2000 Lihini surface pump
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 Bongo, animals for experiments

<u>14 May</u>

- 0200 CTD, setup *in situ* experiments (150m)
- 0300 Trace-metal pump sampling
- 0430 Recover Array #3/deploy in situ Array #4
- 0500 CTD organics (600 m)
- 0600 MVP bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS/Zooplankton sampling
- 1800 Lihini surface pump
- 2100 Bongo, animals for experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 MOCNESS/Zooplankton sampling

<u>15 May</u>

- 0200 CTD, in situ & Th & organics (final samples only)
- 0400 Recover in situ Array #4
- 0430 Thorium pump
- 0530 Begin MVP transect to next study area
- 1000 Go-Flo, soak cast (enroute)
- 1100 Resume MVP survey, core California Current region
- 2040 ETA position 33°40'N, 122°15'W, begin CYCLE #2
- 2130 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 MOCNESS, zooplankton sampling

<u>16 May</u>

- 0200 CTD, setup *in situ* experiments (200m)
- 0300 Go-Flo trace-metal sampling, setup grow-out experiments
- 0430 Deploy *in situ* Array #5
- 0500 CTD, organics, bacteria, thorium (600 m)
- 0600 MVP small bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD (¹⁴C-PP, PvsE), simultaneous Radiometer off stern
- 1300 IOP cast (hydrowire)
- 1430 MOCNESS, zooplankton sampling
- 1730Thorium pump, Lihini surface pump
- 1900 CTD, water for evening experiments

- 2000 Go Flo trace-metal sampling & experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 Bongo tows, animals for experiments

<u>17 May</u>

- 0200 CTD, setup *in situ* experiments (200m)
- 0300 Go-Flo trace-metal sampling
- 0430 Recover Array #5 (wire cut, top depth only)/deploy in situ Array #6
- 0500 MVP small bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1400 Lihini, surface pump
- 1600 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1800 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1900 CTD, full dilution experiments & thorium
- 2000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 MOCNESS, zooplankton sampling

<u>18 May</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover *in situ* Array #6 (recovered late 1045 after search)
- 0430 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0630 Bongo/LOPC, 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 Thorium pump (deep cast), simultaneous Lihini surface pump
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 Bongo, animals for experiments

<u>19 May</u>

- 0000 CTD, setup *in situ* experiments (200m)
- 0200 Deploy in situ Array #7
- 0215 Go-Flo trace-metal sampling
- 0330 CTD organics, thorium (600 m)
- 0530 MVP bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling (1000 m, EtOH preserved, genetics)
- 1800 Go-Flo trace metal sampling, simultaneous Lihini surface pump
- 2100 Bongo, animals for experiments
- 2300 Bongo/LOPC, zooplankton biomass & gut pig sampling

<u>20 May</u>

- 0100 CTD, setup *in situ* experiments (200m)
- 0300 Recover *in situ* Array #7, Deploy Array #8
- 0400 Go-Flo trace-metal sampling
- 0500 MVP bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling
- 1630 CTD, Lihini 1000 m
- 1900 Thorium pump, simultaneous Lihini surface pump
- 2100 Bongo, animals for experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 MOCNESS, zooplankton sampling

<u>21 May</u>

- 0130 Proceed to array position
- 0200 CTD, in situ & Th & organics (final samples only)
- 0400 Recover in situ Array #8
- 0430 Begin VPR (or MVP) transect to next study area
- 0500 VPR transect to Point Arguello
- 1500 MVP survey, Point Arguello region
- 2200 ETA position 34°36.7'N, 120°46'W, begin CYCLE #3
- 2200 Bongo, animals for experiments
- 2300 Bongo/LOPC, zooplankton biomass & gut pig sampling

<u>22 May</u>

- 0000 MOCNESS, zooplankton sampling
- 0130 Pole sampling, trace metals
- 0200 CTD, setup *in situ* experiments, organics, thorium, nickel (70m)
- 0400 Deploy in situ Array #9
- 0430 Run MVP survey pattern (Cancelled: retermination)
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD (¹⁴C-PP, PvsE), simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 MOCNESS, zooplankton sampling
- 1730 Thorium pump, Lihini surface pump
- 1900 CTD, water for evening experiments
- 2000 CTD, organics (10-20 m)
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 Bongo tows, animals for experiments

<u>23 May</u>

- 0200 CTD, setup *in situ* experiments, nickel sampling (70m)
- 0400 Recover *in situ* Array #9/Deploy Array #10
- 0500 Run MVP survey pattern (Cancelled, crab pots)
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, simultaneous Radiometer off stern
- 1200 IOP cast (hydrowire)
- 1300 Bongo/LOPC, zooplankton biomass & gut pig sampling

- 1400 Lihini surface pump, trace metal pole sampling
- 1600 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1800 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1900 CTD, full dilution experiments & thorium
- 2000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 Bongo tow, animals for experiments

<u>24 May</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0200 CTD, setup *in situ* experiments, nickel sampling (70m)
- 0400 Recover *in situ* Array #10/Deploy Array #11
- 0430 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0630 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD, mid-day CalCOFI 14-C production
- 1300 MOCNESS, zooplankton sampling
- 1600 Thorium pump, simultaneous Lihini surface pump
- 1800 CTD, water for evening zooplankton experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 Bongo tows, animals for experiments

<u>25 May</u>

- 0000 MOCNESS, zooplankton sampling
- 0200 Recover in situ Array #11
- 0300 CTD, in situ & Th & organics (final samples only)
- 0330 Begin transit to Santa Barbara Harbor
- 1100 Personnel transfers, Santa Barbara
- 1400 Begin transit from Santa Barbara to 34°N, 120° 32'W
- 1830 Deploy VPR, begin offshore transect to station
- 2330 ETA position **34° 3'N, 121° 18.2'W**, begin CYCLE #4

<u>26 May</u>

- 0000 CTD, organics, bacteria, thorium (600 m)
- 0200 CTD, setup *in situ* experiments (200 m)
- 0400 Deploy *in situ* Array #12
- 0430 Go-Flo trace-metal sampling, grow-out experiments
- 0530 MVP bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD (¹⁴C-PP)
- 1200 MOCNESS, zooplankton sampling
- 1600 Thorium pump, Lihini surface pump
- 1900 CTD, water for evening experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

<u>27 May</u>

- 0200 CTD, setup *in situ* experiments (200 m)
- 0400 Recover *in situ* Array #12; Deploy Array #13
- 0430 Go-Flo trace-metal sampling

- 0530 MVP bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling CTD (¹⁴C-PP) 1100
- 1300 Bongo/LOPC, zooplankton biomass & gut pig sampling 1400 Trace metal pump; Lihini surface pump
- 1600 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1800 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1900 CTD, deck dilution experiments & thorium
- 2000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 Bongo/LOPC, zooplankton biomass & gut pig sampling

28 Mav

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling 0200 CTD, setup *in situ* experiments (200 m)
- 0400 Recover in situ Array #13; Deploy Array #14
- 0430
- Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0630 Bongo/LOPC, zooplankton biomass & gut pig sampling 0700 Go-Flo trace-metal sampling
- 0830
- Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1030 Bongo/LOPC, zooplankton biomass & gut pig sampling
- CTD (¹⁴C-PP) 1130
- MOCNESS, zooplankton sampling 1230
- 1600 Thorium pump, simultaneous Lihini surface pump
- CTD, thorium & water for evening experiments 1900
- 2100 Bongo, animals for experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

29 Mav

- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover in situ Array #14; Deploy Array #15
- 0415 Go-Flo trace-metal sampling
- 0530 CTD organics, thorium (600 m)
- MVP bow-tie survey 0700
- CTD (¹⁴C-PP) 1130
- Bongo/LOPC, zooplankton biomass & gut pig sampling 1230
- 1730 Go-Flo trace metal sampling, simultaneous Lihini surface pump
- 1900 CTD, deck dilution, thorium, water for evening experiments
- 2100 Bongo, animals for experiments
- Bongo/LOPC, zooplankton biomass & gut pig sampling 2300

30 May

- 0200 CTD, setup *in situ* experiments (200 m)
- 0400 Array #15 lost (MIA); Deploy Array #16
- 0430 Go-Flo trace-metal sampling
- 0600 MVP bow-tie survey
- CTD (¹⁴C-PP) 1100
- Bongo/LOPC, zooplankton biomass & gut pig sampling 1200
- 1300 MOCNESS, zooplankton sampling
- 1600 CTD deep cast - organics, bacteria, thorium (2,500 m)

- 1900 Thorium pump, simultaneous Lihini surface pump
- 2100 Bongo, animals for experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

<u>31 May</u>

- 0200 CTD, in situ & Th & organics (final samples only)
- 0400 Recover *in situ* Array #16
- 0500 Begin transit CYCLE 4 site to end of CalCOFI 80 line
- 2000 MVP site survey to station
- 2300 ETA position **32° 51'N, 124°W**, begin CYCLE #5
- 2330 MOCNESS, zooplankton sampling

<u>1 June</u>

- 0200 CTD, setup *in situ* experiments (200 m)
- 0300 Go-Flo trace metal sampling, grow out experiments
- 0400 Deploy *in situ* Array #17
- 0430 Bongo, animals for experiments
- 0600 CTD, organics, bacteria, thorium (600 m)
- 0800 Trace metal pump (or more Go Flos)
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD (¹⁴C-PP)
- 1200 MOCNESS, zooplankton sampling
- 1600 Thorium pump, Lihini surface pump
- 1800 CTD, water for evening experiments
- 1900 Go Flos or trace metal pump, to be determined
- 2200 Bongo, animals for experiments
- 2300 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2315 Bongo, animals for experiments

<u>2 June</u>

- 0200 CTD, setup *in situ* experiments (200 m)
- 0400 Recover *in situ* Array #17; Deploy Array #18
- 0430 Go-Flo trace metal sampling
- 0530 MVP bow-tie survey
- 1000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1100 CTD (¹⁴C-PP)
- 1300 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1400 Trace metal pump; Lihini surface pump
- 1600 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1800 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1900 CTD, deck dilution, thorium, water for evening experiments
- 2000 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2230 Bongo/LOPC, zooplankton biomass & gut pig sampling

<u>3 June</u>

- 0100 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0200 CTD, setup *in situ* experiments (200m)
- 0400 Recover *in situ* Array #18; Deploy Array #19
- 0430 Bongo/LOPC, zooplankton biomass & gut pig sampling

- 0630 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 0700 Go-Flo trace-metal sampling
- 0830 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1030 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1130 CTD (14 C-PP)
- 1230 MOCNESS, zooplankton sampling
- 1600 "Dying quivers" sampling, Go-Flos, CTD, Lihini surface pump (by request)
- 2100 Bongo, animals for experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

<u>4 June</u>

- 0200 CTD, setup *in situ* experiments (200 m)
- 0400 Recover *in situ* Array #19; Deploy Array #20
- 0430 Go-Flo trace-metal sampling
- 0600 MVP bow-tie survey
- 1100 CTD (¹⁴C-PP)
- 1200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 1230 Bongo, animals for experiments
- 1330 MOCNESS, zooplankton sampling
- 1800 Thorium pump, simultaneous Lihini surface pump
- 1900 CTD, fill carboys w/ offshore seawater, Checkley, Landry
- 2100 Bongo, animals for experiments
- 2200 Bongo/LOPC, zooplankton biomass & gut pig sampling
- 2300 MOCNESS, zooplankton sampling

<u>5 June</u>

- 0200 CTD, final *in situ* samples, Th & organics (600 m)
- 0400 Recover *in situ* Array #20
- 0430 Begin transect to glider recovery site, 32°58'N, 121°26'W
- 1700 Search pattern for lost glider
- 2000 Transit to line 80, 33°35'N, 121°50'W

<u>6 June</u>

- 0200 Deploy MVP, transit to CYCLE #1 position, 34°20'N, 120°45'W
- 0700 Bongo, animals for experiments
- 0730 Transit to San Diego, ETA 0700, 7 June

CRUISE PERSONNEL

BOTH LEGS:

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4. Shonna Dovel

5. Ryan Rykaczewski

7. Marcos Yoshinaga

6. Benjamin Maurer

8. Bridget Seegers

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o-PI, Chief Scientist roject PI roject co-PI SSSG Res Tech SSSG Res Tech **VPR/MOCNESS** Tech lesearch Tech lesearch Tech lesearch Tech Grad Student Grad Student Grad Student Grad Student Grad Student Grad Student Frad Student teer teer teer teer

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SIO Grad Student SIO Grad Student Volunteer

Hydrographic Setting

Ralf Goericke, SIO

Status of Data Analysis: This is a preliminary description of the hydrographic settings and processes encountered during experimental CYCLES 1 to 5 of CCE Process Cruise 1 (P0605). The description is presently incomplete with respect to nutrient data, CTD profiles and glider sections.

The Climatology of Line 80: The CCE-P0605 cruise occurred during a month (early May-June) that is not well covered by the CalCOFI data set. This limits our ability to tie cruise observations firmly into long-term climatology, as we must rely on CalCOFI

observations made mostly during April and early May for comparison. The longterm climatology for April (**Figure 2**) shows the California Current and its offshore branches generally flowing in a southeasterly direction. Assuming currents on the order of 20 cm s⁻¹, lateral advection is on the order of ~17 km per day or ~120 km per week. This implies that water-column changes at a given location are strongly affected by advective transport and processes.

CalCOFI data suggest that the spring bloom along Line 80 usually occurs during April (**Figure 3**). Large negative Air-Sea Temp differences, as observed



Fig. 2. 'Long-term mean (1950-92) circulation patterns based upon 0/500 dbar dynamic height for the target months of the CalCOFI quarterly surveys' (from Bograd et al., 2000).

during CYCLES 4 and 5, differ from the long-term climatology. Usually positive Air-Sea Temp differences are observed along CalCOFI Line 80 during late spring and summer (**Figure 4**), with values ranging from 0 to 3 °C. Since SST or surface layer temperatures did not appear to be unusually high, this suggests that air temperatures were unusually low.



Fig. 3. Mean concentrations of Chla and nitrate at 10 m on CalCOFI Line 80 for all cruises since 1984.

CYCLE 1 – Vicinity of CalCOFI Stn 80.55: The CYCLE 1 study area was located inshore of the main California Current (CC). Average mixed-layer (ML) properties for Stn 80.55 for the second quarter are: T = 12.5 °C, Sal = 33.5, Chl = 3.8 µg L⁻¹, NO₃ = 6.8 µM, AirTemp = 13.7 °C. Low SST and percent oxygen saturation (78%), and the high salinities observed initially during the cycle suggest that the source of the surface water was upwelling over the previous few days. Fields of Temp and Fluor in the vicinity of the study area (MVP surveys: Survey-Cy1-Trans-4, Cy1-Bow1-Ax2 and Cy1-Bow2-Ax1) that display in some areas low Temp and very low Fluor suggest that upwelling still occurred in the vicinity of the study area during CYCLE 1.

The drifter moved southwest at a speed of 0.13 m sec⁻¹ over the next 4 days, covering 48 km. Over this time SST rose from 11.3 to almost 13.5 °C (Fig. 5). Decreasing salinities over the last two days suggests that this change was driven, at least in part, by the submersion of the original water mass under a layer of fresher and warmer water that had advected into the area from the west (Cy1-Bow3-Ax2). Chl a in the upper 10 m more than doubled over this time period (**Figure 5**), increasing from 3 to 8 μ g L⁻¹.



Fig. 4. Average Air-Sea Temp difference along Line 80 over the seasons. Note that highest values are usually observed during May and July.



Fig. 5. CTD surface layer (z < 6m) properties over the course of CYCLE 1. A. temperature, B. percent oxygen saturation, C. Chl-fluorescence, approx. μ g Chl L⁻¹.

Cycle 2 – Vicinity of CalCOFI Stns 80.70 and 80.80: The CYCLE 2 study area was in the California Current proper, as evidenced by low surface salinities (32.9). The CYCLE 1 to 2 MVP Transect and the CYCLE 2 MVP Survey located the CC between ~121.8 and 122.3 °W. The CC flowed approximately SE (ADCP data) during the time the area was occupied, and the drifter tracks followed a similar course (160 °W).

Average mixed-layer (ML) properties for this area for the second quarter of the year are: T = 14.3 °C, Sal = 33.2, Chl = 0.46 μ g L⁻¹, NO₃ = 0.9 μ M, AirTemp = 14.75 °C. Values observed during CYCLE 2 are: T = 14.5 °C, Sal = 33.9, Chl = 0.12 μ g L⁻¹, AirTemp = 14.6 °C. The lower Chl a concentrations, relative to the long-term averages, likely reflect the earlier timing of the spring bloom (CalCOFI April cruises).

Lower salinities reflect that the core of the CC coincided with the study area; when this core is further offshore salinities at this station are higher.

During CYCLE 2, observations were carried out along two drifter tracks --Deployment 1 from 05/16 to 05/18 and Deployment 2 from 05/19 to 05/21. Since the starting point of D2 did not coincide with the end point of D1, detailed interpretations of the time course of surface layer properties and water column structure are not possible. ML properties (**Figure 6**) and water-column structure (MVP bowties) did not vary appreciably over the course of the cycle. The drifters showed a diel signal in SST; trends are not evident from those data. The low concentrations (0.12 µg L⁻¹) and size-structure of ChI a (45% < 1 µm) suggest a community dominated by picophytoplankton at approximate steady state with respect to biomass.



Fig. 6. CTD surface layer (z < 25m) properties over the course of CYCLE 2. A. temperature, B. salinity, C. Chl-fluorescence (approx. μ g Chl L⁻¹; CTD fluorometer reading substantially exceeds extracted Chl a).

Cycle 3 – On the Shelf, North of Point Conception: The CYCLE 3 study area was located on the shallow shelf, north of Point Conception and cannot be linked to any regularly occupied CalCOFI station. The water depth in the study area ranged from 68 to 190 m. Only an initial MVP survey was made; no subsequent bowties were carried out. It is likely that upwelling occurred in this area in the days or the week before our arrival; however, during our occupation winds were moderate (5.4 m sec⁻¹), coming from the SW and not conducive to coastal upwelling. The initial MVP survey shows evidence of fronts close to the coast. These were associated with high concentrations of Chl *a* at depth (Chl a spikes at depth of up to 35 m, coincident with density fronts; MVP CYCLE 3 Survey). It is unclear if these were current-induced jets or filaments or tidal fronts. The average Air-Sea Temp difference during this cycle was 0.9 °C, ruling out convective mixing as an important factor affecting water-column structure.



Fig. 7. CTD surface layer (z < 25m) properties over the course of CYCLE 3. A. temperature, B. salinity, C. Chl-fluorescence, approx. μ g Chl L⁻¹.

The initial MVP survey and subsequent CTD casts showed that environmental heterogeneity was very high in the study area and that the water column was strongly stratified, with extremely shallow or even absent mixed layers and most phytoplankton biomass confined to the upper 5 to 10 m of the water column. The high variability of SST, as measured by the R/V Knorr's IMET system, observed CYCLE 3, suggests persistence of the high environmental heterogeneity observed initially. The drifter temperature sensor (upper 1 m) recorded strong diel temperature variations (2 to 3 °C) during the first two days of the cycle. However, temperature changes over the last day of CYCLE 3 were very small; a surprising result since insolation and diel variations of the air temperature were essentially unchanged over the 3 days of study. Phytoplankton biomass was high throughout CYCLE 3 but did not vary systematically with time (**Figure 7**). The high variability of surface layer properties over, likely, short spatial scales, and the absence of MVP surveys during the cycle rules out a detailed interpretation of observed property changes during the cycle.

Cycle 4 – Between Stns 80.60 and 80.70: The CYCLE 4 area was inshore of the California Current, as evidenced by salinity. Average ML properties for this

area for the second guarter of the year are: T = 13.7 °C, Sal = 33.3, Chl = 2.1 µg L^{-1} , NO₃ = 1.8 μ M, AirTemp = 14.22 °C. Again, some of these long-term averages differ significantly from values observed during CYCLE 4: T = 14.7 °C, Sal = 33.3, Chl = $0.9 \,\mu g \, L^{-1}$, AirTemp = 13.9 °C, most likely because observations were made later in the year. Winds were strong during our occupation of the area and convective mixing likely significant, not only at night but also during the day (Figure 8). As a consequence, deep mixed layers were observed (~40 m) with no pronounced subsurface Chl a maxima. It is tempting to speculate that the gradual salinity increase (Figure 9)



Fig. 8. CYCLE 4 SST (upper trace) and Air Temp (lower trace) plotted against time. The vertical lines delineate days (PST). Note the large, negative Air-Sea temp difference.



reflected the erosion of the thermocline due to convective mixing.

Fig. 9. CTD surface layer (Z < 36 m) properties over the course of CYCLE 4. A. temperature, B. salinity, C. Chl-fluorescence, approx. μ g Chl L⁻¹.

CYCLE 5 – Line 80, Stn 100: The end of Line 80 is at the edge of the Central North Pacific Gyre, and western-most branches of the CC often dominate flow in this area. The low observed salinities and the ADCP currents suggest that this was the case during CYCLE 5. The initial study area (approximately $13 \times 15 \text{ km}$) was characterized by strong temperature, salinity and density gradients. An atypically strong subsurface ChI a maximum was present at depths of 55 to 75 m.

Average ML properties for this area for the second quarter of the year are T = 15.0 °C, Sal = 33.1, Chl = 0.17 μ g L⁻¹, NO₃ = 0.06 μ M, AirTemp = 15.1 °C. Some of these long-term averages differ significantly from values observed during CYCLE 5: T = 16.4 °C, Sal = 33.1, Chl = 0.10 $\mu q L^{-1}$, AirTemp = 15.8 °C. Negative Air-Sea Temp differences were again observed not only at night but also during the day (Figure 10) suggesting convective mixing during CYCLE 5. During the cycle, we drifted to the southwest at a speed of 18 km per day. CTD data (Figure 11) for the



Fig. 10. CYCLE 4 SST (upper trace) and Air Temp (lower trace) plotted against time. The horizontal bars designate the days (PST). Note the large, negative Air-Sea temp difference.

surface layer do not show any systematic trends. Drifter Temp increased slightly over CYCLE 5 and showed a weak diel temperature signal.



Fig. 11. CTD surface layer (z < 41m) properties over the course of CYCLE 5. A. temperature, B. salinity, C. Chl-fluorescence, approx. μq Chl L⁻¹.

Table 1A - Ship's Meteorological Data: A-Temp – air temperature (°C); Wind Dir – wind direction (degree); Wind Sd – wind speed (m sec⁻¹); SST – sea surface temperature; Salinity – sea surface salinity; Fluor – fluorescence (mV); d Air-Sea – air-sea temperature difference (°C).

Cycle	A-Temp	Wind Dir	Wind Sd	SST	Salinity	Fluor	d Air-Sea
1	12.6	270	5.5	12.3	33.8	566	0.3
2	14.6	270	6.3	14.7	33.1	257	0.0
3	14.6	237	5.5	13.7	33.6	783	0.9
4	13.9	326	12.8	14.8	33.4	325	-0.9
5	15.8	319	8.0	16.4	33.3	84	-0.6

Table 1B - CTD Data: Surface layer (z < 15 m) properties for the noon CTD casts from each experimental cycle. Temp. – surface-layer temperature (°C); Salinity – salinity; Density - sigma-theta, (kg m³; a comparison with CTD data suggests that the IMET conductivity sensor is off); O₂ % Sat – percent oxygen saturation (%); Fluor – fluorescence reading from the Wetlab ECO-AFL/F (Volt; readings before 05-19 are unrealiable because of epiphytes growing on the sensor); % Trans - % beam transmission (%, drift correction preliminary).

Cycle	Temp.	Salinity	Density	O ₂ % Sat	Fluor	% Trans
1	12.0	33.6	25.5	96	6.7	90.0
2	14.5	32.9	24.5	99	0.6	98.1
3	13.5	33.4	25.1	112	6.8	85.6
4	14.7	33.3	24.7	98	2.1	95.0
5	16.4	33.1	24.2	98	0.6	98.5

Table 1C - ChI a and Size Fractionations: TChI a – total concentration of ChI a (μ g L⁻¹, by acetone-extraction fluorometric method). Table shows percent of TChI a in the indicated size classes.

Cycle	TChl a	< 1 ≤m	1 - 3 µm	3 - 8 µm	8 - 20 µm	>20 µm
1	5.90	5	11	7	17	60
2	0.12	45	28	14	7	6
3	5.90	11	13	1	29	46
4	0.92	24	29	15	14	19
5	0.10	45	28	16	6	5

Bio-Optical Sampling

B. Greg Mitchell, SIO

The photobiological sampling plan was designed to enhance spatial and temporal resolution of phytoplankton biomass, physiology and primary production using optical technology. Ship sampling consisted of daily deployments of bio-optical instruments and water sample collection and analyses from the mid-day CTD cast. Mati Kahru also collected satellite data ocean color and sea-surface temperature data when clear sky scenes allowed.

Inherent optical properties (IOP) and kinetics of photosynthetic processes were resolved from vertical profiles using an integrated bio-optical package. Radiometric measurements of natural sunlight were obtained with a free fall Profiling Reflectance Radiometer. The IOP measurements consisted of backscattering at 6 spectral bands (HOBI Labs Inc.Hydroscat-6), absorption and beam attenuation at 9 discrete spectral bands (AC-9 Plus, WET Labs) and single wavelength beam attenuation coefficients at 660 nm and 488 nm (WET Labs). Photosynthetic physiology was assessed with a FRRF system (Chelsea).

The bio-optics package was typically deployed to 300 m with down- and up-cast winch speeds of 15 m/min from the surface to 150 m, and 30 m/min from150 m to 300 m. Two higher resolution casts to 50 m (5 m/min) were conducted in the shallow water study area during CYCLE 3. The Profiling Reflectance Radiometer system consists of a free fall under-water profiling unit (PRR 800) and a deck-mounted radiometer (PRR810). The PRR 800 is equipped with 3 data collecting heads and integrates Ed (Downwelling Irradiance), Lu (Upwelling Radiance) and Eu (Upwelling Irradiance) in 19 channels. The PRR 810 continuously recorded surface irradiance at 19 spectral channels each day and was also used as a surface reference 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 11 stations during the first 3 cycles of the cruise. Additionally, the PRR 810 sensor collected surface irradiance data throughout the cruise.

The IOP and PRR casts coincided with the LTER mid-day CTD cast. Water samples were collected from 4 Niskin depths for photosynthesis vs. irradiance (PvsE) experiments and analyses of particulate absorption (ap/ad), HPLC pigments, particulate organic carbon (POC) and phycoerythrin (PE). Only absorption (ap/ad) was analyzed at sea. FRRF discrete samples were also run for 2 casts during CYCLE 3 to support the ALF laser fluorometry work of A. Chekalyuk. Optical and PvsE data collected during CCE-P0605 will be used to validate models of ocean primary production that will 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.

Advanced Laser Fluorometric Analysis (ALF)

Alexander Chekalyuk, NASA

The Advanced Laser Fluorometer (ALF) was recently developed at NASA/GSFC Wallops Flight Facility, incorporating 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 (**Figure 12**). The



Fig. 12. ALF-1 instrument configured for water sample analysis

ALF technology seeks to improve quantitative assessments of chlorophyll-a (Chl), phycobiliprotein (PBP) pigments, chromophoric dissolved organic matter (CDOM), phytoplankton physiological/ nutrient status and water turbidity, and to provide basic characterization of phytoplankton community structure. A screen capture of ALF real-time seawater analyses is shown in **Figure 13**. Initial ALF field tests and deployments at various coastal sites (http:rpf.ciceet.unh.edu/ display/report.php?chosen=784) have demonstrated the potential for discrimination and quantitative assessment of diatoms and dinoflagellates, the dominant coastal bloom-

forming) phytoplankton groups, as well as cyanobacteria vs. cryptophytes. The ALF spectral deconvolution algorithms (upper panels, **Figure 13**) yield accurate real-time assessment of chlorophyll concentration comparable with the HPLC laboratory analyses and provide for improved quantitative retrievals of other water constituents.



Fig. 13. Real-time spectral deconvolution (SDC) of hyperspectral ALF measurements of sample emission stimulated with blue and green lasers (upper panels) and PDP fluorescence induction measurements of variable fluorescence, Fv/Fm (lower right).

During this CCE cruise, ALF was mounted in the R/V Knorr's main laboratory and used both for underway flow-through sampling and analyses of discrete samples. Continuous underway measurements were conduced along most of the ship transects and during CYCLE 1-3 MVP surveys (**Table 2**). Mesoscale spatial correlations between surface distributions of phytoplankton and physical structures were studied with the simultaneous underway measurements by the moving vessel profiler (MVP), using surface ChI measurements by both instruments to spatially link MVP and ALF data. We found significant variability in ChI *a*, ranging from 20 g/l in the surface of the coastal area to 0.02 g/l at the bottom of the euphotic layer. In addition to studies of horizontal variability, water samples collected at eight depths per station were analyzed to assess vertical distributions of the ChI peak revealed significant variability in the relative abundance of diatoms and dinoflagellates. For example, an extremely thin layer of dinoflagellates was found near surface during morning-noon hours on 24 May (CYCLE 3). Diatoms were generally dominant in the upper euphotic zone.

Cycle	Date	Measurement
-	May 8	Transect mapping; San-Diego => CYCLE 1 surveying area
1	May 9-10	Mapping in the Pt. Conception area
1	May 11, 12, 13, 14	2D mapping in the CYCLE 1 surveying area
-	May 15	Transect mapping; CYCLE 1 => CYCLE 2 surveying area
2	May 15, 16, 17, 19, 20	2D mapping in the CYCLE 2 surveying area
-	May 21	Transect mapping; CYCLE 2 => CYCLE 3 surveying area
3	May 21	2D mapping in the CYCLE 3 surveying area

 Table 2.
 ALF flow-through underway measurements conducted during the LTER cruise

An example of underway ALF measurements is presented in **Figure 14**. The most pronounced variability was observed in the phycoerythrin (PE), which exhibited sharp patchy structures with up to 6-fold changes in fluorescence over a few hundred meters (upper right; **Figure 14**). Cryptophytes were identified by hyperspectral ALF measurements as a phytoplankton group responsible for the elevated PE concentration. Cyanobacteria were relatively more abundant in the offshore areas and at the bottom of the euphotic layer. Chl *a* also exhibited significant, 3-fold variability with spatial distribution somewhat anti-correlated vs. the PE patterns (upper right and middle; **Figure 14**). By contrast, the CDOM distribution was well correlated with Chl *a*, which suggests a mostly biological origin for CDOM. Variable fluorescence indicated generally moderate photo-physiological status of the phytoplankton (Fv/Fm ~ 0.3-0.4) but a pronounced decline in the northeastern portion of the surveyed area. In depth profiles, maximum values of Fv/Fm (up to 0.5) were typically observed above the Chl max layer.

We expect that detailed analysis of the ALF data in conjunction with the results of the MVP measurements and other data on the physical and biogeochemical variables will allow comprehensive characterization and interpretation of the observed spatial patterns. **Fig. 14**. An example of the ALF underway flow-through measurements of chlorophyll concentration (Chl, g/l), phycoerythrin, CDOM, and variable fluorescence (PE, CDOM and Fv/Fm, respectively) in the Pacific coastal zone East-North of Santa Barbara, CA (May 12, 2006). The lower 4 panels represent 2D spatial distributions of the ALF measurements.



Micro-Plankton Dynamics

Michael R. Landry, SIO

As previously noted (Overview of Science Plan), a drogued drift array was used on the CCE Process cruise as a reference point for water-column sampling and as a incubation structure for experimental studies of micro-plankton growth and grazing. As an integral part of the experimental studies, daily water-column sampling was conducted at the beginning and end of each 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 arowth (µ), ¹⁴C-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 ¹⁴C-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 15**). 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 sidebar narrative.



Fig. 15. Daily depth profiles of Chl*a* and phytoplankton intrinsic growth rate (μ , d⁻¹) during each of the CCE-P0605 experimental cycles.

In CYCLE 1, ChI *a* increased over the 4 sampling days, and its distribution shoaled toward the surface. Diatoms were dominant. Near-surface growth rates of ~ $0.5 d^{-1}$ tapered off to zero around the 0.5% light level (35 m). The observed ChI decrease at 35 m between Arrays #1 and 2 (green to blue) appears in the bottle rates as a strong negative growth at 35 m during the Array #1 incubation (green). The increase in ambient 12-m ChI *a* in our final cycle hydrocast

coincides with high growth at 12 m during the incubation for that day. Microzooplankton grazing accounted for an average daily loss of 44% of phytoplankton production, yielding mean positive net growth of 0.32 d⁻¹ for the upper euphotic zone (**Table 3**). Ambient Chl*a* increased at a net rate of 0.18 d⁻¹.



CYCLE 2 water was dominated by picophytoplankton. Chla 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 were lower than CYCLE 1 (the high μ at 40 m on Array 8 looks like a "flier" which may change with more precise HPLC pigment analyses). Microzooplankton consumed an average of

84% of production in the upper euphotic zone, leaving a relatively modest mean net growth of 0.08 d⁻¹ (**Table 3**). Net ambient growth was negligible (variability in the depth of the ChI max is likely due to internal waves). Overall, results from CYCLE 2 fit the pattern of a nutrient-limited (oligotrophic) system, with microbial community dominance and a relatively close balance between production, grazing and nutrient remineralization processes.



Dinoflagellates were a major component of the shallow-water coastal community in CYCLE 3. Taken at face value, this cycle was also the most variable in terms of chlorophyll distribution and community growth rates. However, the striking difference in the Chla profile and subsequent rate estimates for Array #10 suggest that the wrong group of Chl samples may have been entered as initials. Array 10 results will thus have to be

reconfirmed with HPLC analyses, or explained by other measured variables, before we can adequately account for the variability observed during this cycle. Both Arrays 9 and 11 indicate shallow depth strata of high growth (0.7 $d^{-1} = 1$ cell doubling d^{-1}), and, overall, the portion of production consumed and net growth rates observed are intermediate between experiments conducted at diatom- and picoplankton-dominated sites (**Table 3**).



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 3**). The main differences are the lower and more uniform concentrations of Chla in CYCLE 4, and (consequently) the deeper penetration of high growth rates. CYCLE 4 may represent a later successional state of the diatom

bloom waters sampled in CYCLE 1 (with storm mixing between cycles). It will be interesting to see what detailed physical and biological analyses will indicate on this point.



CYCLE 5 was conducted by design in the most offshore and oligotrophic waters in the CCE study region. The cycle results have features in common with the (other) picophytoplankton-dominated waters in CYCLE 2, though somewhat more extreme in terms of a strong ChI max, high microzoo consumption (101% of PP) and slightly negative (-0.03 d⁻¹) net changes in both bottle and ambient measurements (**Table 3**).

Table 3. Preliminary summary of mean Chl*a* and rate characteristics for the micro-plankton communities studied during experimental cycles. All estimates are cycle averages for the upper euphotic zone (i.e., 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 μ = phytoplankton growth rate.

			%PP	Net Growt	h Rates (d⁻¹)
CYCLE	Chl <i>a</i> (µg/L)	µ (d⁻¹)	Consumed	Bottles	Ambient
1	5.2	0.51	41	0.36	0.19
2	0.14	0.40	84	0.09	0.02
3	5.8	0.33	68	0.06	-0.07
4	0.82	0.50	40	0.33	0.18
5	0.10	0.28	101	-0.03	-0.03

One can reasonably conclude from the observations and rate summary above that the general cruise strategy of experimentally studying the dynamics of a variety of micro-plankton assemblages in drifter-marked water masses was successful. For the oligotrophic end member (CYCLE 5), microzooplankton grazing closes the budget with respect to the fate of phytoplankton production. For other cycles, the net growth in bottle incubations exceeded (as expected) the net changes observed in the ambient environment, but by modest amounts (< 0.2 d⁻¹) that could easily reflect the grazing impact of mesozooplankton, excluded from the bottles. Independent assessments of grazing rates by the mesozooplankton community will be available from gut pigment analyses. If closed growth-grazing balances can be realized by these complementary methods, net composition differences between the micro-plankton assemblages in bottles and ambient samples may shed light on the selective grazing impact and regulatory roles of the mesozooplankton.

Organic Composition and Prokaryote Gene Expression

Lihini Aluwihare, Roberta Hansman & Roman de Jesus, SIO

TOC samples from 5-8 depths were collected daily from the CTD casts at the beginning of each cycle day. Bulk samples for DIC, TOC, DOC, POC and DIN analyses were typically collected from several depths on days 1 and 4 of each cycle. The DIC, DOC, POC, and DIN samples will be analyzed for bulk isotope analysis (¹³C, ¹⁴C, and ¹⁵N).

Samples were also collected from CTD casts for FISH and RNA extraction to be performed at SIO to determine prokaryotic abundances and gene expression with regards to carbon and nitrogen metabolism. Additionally, prokaryotic organisms from 5,000-10,000 L of surface water were collected for radiocarbon analysis of their cellular components, specifically DNA and lipids. Furthermore, DOC was extracted from 200 L filtered surface seawater samples using ultrafiltration or solid phase extraction. These samples will be processed and analyzed for chemical characterization and bulk and compound specific isotope (¹³C, ¹⁴C, ¹⁵N) analysis.

Iron Concentrations and Fe-Limitation

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Trace metal-clean seawater was collected using 12 and 30-L GO flo bottles (~12 casts), an all-teflon pumping system (~5 casts), and a 7-m pole sampler (~2 casts). Seawater was also sampled using the trace metal-clean system for experiments by R. Goericke, C. Dupont and M. Decima. Dissolved Fe was measured shipboard using a chemiluminescence flow injection analysis method with standard additions. Dissolved Fe concentrations that were measured during CYCLES 1 through 4 were relatively consistent with distance from shore, and thus depth of the seafloor (presumably the largest source of Fe for the region) (**Table 4**). A cursory analysis of samples collected from a Niskin bottle mounted on the CTD-Rosette system suggested that the CTD Niskin bottles had Fe concentrations about 0.1 nM in excess of similar waters collected using trace metal-clean methods.

Cycle	Day	diss Fe (nM)
1	1	2
2	0	0.3
2*	1.5	0.4
3	1	1
4	1.5	0.2





Fig. 16. Fe addition grow-out experiments from CYCLE 1, day 4 (left) and CYCLE 4, day 5 (right); note change in y-axis scale. The mean ChI a of control replicates are marked with open triangles and Fe addition replicates are marked with closed triangles, error bars represent 1 standard deviation (n=2).

Surface (~5-10 m) seawater was used for shipboard Fe addition grow-out experiments to evaluate the influence of Fe on phytoplankton growth and community structure when nitrate was present. Based on changes in Chl *a* in control (unamended) and Fe-addition (+5 nM FeCl₃) experiments, Fe appeared to be a limiting nutrient at the end of CYCLE 1 (day 4; **Figure 16**) and both at the beginning and end of CYCLE 4 (days 3 and 5; day 5 shown in **Figure 16**). In all three cases of Fe

limitation, ChI *a* was about 20% greater in Fe-added replicates relative to controls after 24 hours. ChI a in the experiment from CYCLE 4, day 5 was about 75% greater in Fe-added replicates relative to control after 2 days. In other experimental cycles, Fe was either replete (early CYCLE 1 and CYCLE 3) or nitrate was limiting (CYCLES 2 and 5). Supporting data such as changes in nutrient concentrations and phytoplankton community structure will be analyzed in the laboratory.

To understand the influences of light and iron on the phytoplankton communities at subsurface chlorophyll maxima (SCM), incubations were conducted on water collected from the SCM or at the top of the nitracline in which light and iron levels were manipulated experimentally. On previous cruises, we found that iron frequently influences the growth of diatoms at the SCM, both at ambient and elevated light levels with more diatoms occurring in iron addition treatments. The focus of work on this cruise was to determine whether the apparently unique response of diatoms to iron addition is observed because other taxa are not iron limited or because only diatoms are able to escape microzooplankton grazing control. Dilution experiments to determine *in-situ* phytoplankton growth rates in different treatments were conducted with moderate success (more data needs to be analyzed). A second approach involved measuring size-fractioned F_v/F_m , a photosynthetic characteristic influenced by iron limitation, and size-fractioned phytoplankton pigments in the various experimental treatments, again to determine whether iron was affecting many phytoplankton taxa. Piqment samples will be analyzed on land. Shown below (Figure 17) is an example of the type of chlorophyll response observed in +Light and +Iron+Light treatments during both CYCLES 2 and 4. Because the most dramatic effects of iron are observed at elevated light levels these treatments were used during this cruise to obtain the clear iron responses iron and high biomass necessary to assess the impact of iron on multiple phytoplankton taxa.



Fig. 17. Chl *a* over time in +light (L) and +Fe+L (FeL) bottle grow-out experiments from CYCLE 4.

Nickel Uptake and Utilization

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Long known to have a "nutrient-like" depth profile in oceanic waters, Ni is a cofactor in a variety of metalloenzymes and thus biological functions in marine organisms. However, studies on the biological uptake and usage of Ni by marine communities have been lacking. Using Ni⁶³, a -emitting radioisotope, the biological uptake rates of Ni were measured during the CCE-P0605 cruise. Water was collected and handled in a trace metal clean fashion to avoid contamination with "cold" (non-radioactive) Ni. Following collection, whole seawater was aliquoted, with some samples receiving glutaraldehyde amendments to stop biological activity. Ni⁶³ was added in a range of concentrations, from 10^{-10} to $5x10^{-7}$ moles L⁻¹. After short incubations (<10 h), the experiments were terminated by filtration (0.2- m pore size). This experimental format provides a "snapshot" of the community potential for Ni uptake. A very preliminary set of data from experimental CYCLE 1 are shown below (**Figure 18**). The rates shown are the "biological uptake rates", being the net uptake of live *minus* glutaraldehyde treatments.

From even this preliminary data, there are several relevant implications can be made if we assume a typical surface Ni concentration of 3 nanomoles L⁻¹. First, the turnover time in surface seawater is exceptionally rapid (3 days), unless a sizable portion of the ambient pool is non-bioavailable. Second, the community uptake affinity ($K_m \sim 3nM$) is remarkably high. Third, from a methodological perspective, it is clear that the addition of only a single concentration of Ni (as historically done for other

types of metal uptake experiments) would present a skewed and incomplete perspective. Finally, this particular data set highlights the role of Ni as both a nutrient and toxin, depending upon concentration. The high community affinity attests to the biological importance as a nutrient, while the rapid decline in uptake rates following saturation reflects toxicity. These uptake experiments were conducted at 3 depths during each cycle.

Fig. 18. Ni uptake vs Ni added during CYCLE 1.



Concurrent with Ni uptake experiments, shipboard bottle incubations were conducted with "trace metal clean" seawater samples. These grow-out (ca. 4 days) experiments are designed to test the effects of low-level Ni additions (750 picomoles L^{-1}) upon community biomass and composition. As the organic nitrogen compound urea requires Ni to assimilate, urea and Ni+urea treatments were included. The bulk of the data from these experiments will be analyzed in the laboratory. In all, 6 incubation experiments were conducted during 4 cycles (excluding CYCLE 3).

Site Surveys and Zooplankton Sampling

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Moving Vessel Profiler: The Moving Vessel Profiler 200 (MVP) uses a free-fall profiling fish and a computer-controlled winch to profile the ocean while steaming at 11-12 knots. We used the MVP to characterize the study region of each Cycle prior to deployment of the satellite-tracked drifter. The MVP was also used to complete nearly daily "bowtie" characterizations of horizontal and vertical spatial gradients in the vicinity of the moving drifter. The MVP was equipped with a Laser Optical Plankton Counter (LOPC), Chla fluorometer and CTD package. Eight hundred and thirty eight MVP profiles were completed, typically to a depth of 210 m while the ship was steaming at full speed. The MVP provided invaluable information for definition of frontal regions and characterization of the along-flow and cross-flow characteristics of the hydrographic environment, phytoplankton fluorescence field, and plankton size distributions. The instrument performed flawlessly throughout the cruise. One continental shelf transect was aborted after interception of an anchored crab pot, which required replacement of the MVP mechanical termination. An SSSG completed a very professional re-termination.

Video Plankton Recorder: The Video Plankton Recorder II (VPR II) was used to map the spatial distributions of specific groups of zooplankton and larger phytoplankton in relation to the major frontal features in our study region. Three deployments were completed, the first of which was used to test towing and flight characteristics. The remaining two deployments were conducted (a) between experimental CYCLE 2 (low salinity CC core) and CYCLE 3 (continental shelf), and (b) in transit between San Miguel Island and CYCLE 4. The VPR was tow-yowed between depths of ca. 100 m and the surface. Both VPR transects resolved clear frontal features (detectable as salinity, density and bio-optical properties). Preliminary analysis of plankton distributions using Visual Plankton image classifier software suggests that small copepods were nearly ubiquitous through the region, while rod-shaped diatoms and radiolarian-like organisms showed associations with frontal features. Upon recovery at the end of third deployment, the VPR II sustained damage to the port wing and was secured on deck for repairs.

MOCNESS: Depth-stratified profiles of mesozooplankton distributions were taken with a $1-m^2$ MOCNESS with 202-µm mesh. Twenty-seven MOCNESS tows were initiated and successfully completed, with 4-7 tows conducted during each of the five experimental Cycles. The objectives were to assess changes in vertical habitat of target species of mesozooplankton in different hydrographic provinces of the CCS. A secondary objective was to obtain zooplankton suitable for DNA extraction and amplification. Most samples were preserved in borate-buffered Formalin, but one complete vertical series and one vertically integrated Net 0 sample were preserved in 95% ethanol for molecular genetics research. MOCNESS-CTD profiles were completed with each tow. In addition, vertical profiles of Chla fluorescence, dissolved O_2 , and beam attenuation coefficient were completed for tows 3-19. Failure of an options module board precluded obtaining the latter measurements on tows 20-27.

Mesozooplankton Grazing and Egg Production

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Net hauls were conducted using Bongo frames with 200-um Nitex mesh nets. Tows were done twice daily (mid-night and mid-day) throughout each cycle, as well every 2-3 hours on one day per cycle, as part of a diel study. Tows were done according to standard CalCOFI procedures. The targeted depth was 210 m, wire angle was kept between 38 and 52° and 300 m of wire was let out. Mean tow time was 20 minutes. After retrieval, the nets were rinsed and contents of one cod end were immediately preserved in 5% buffered Formalin; contents of the other cod end were anesthetized with CO_2 and subsampled with a Folsom splitter. Typically, 3/8ths of each sample was processed for gut fluorescence analysis. The subsample was fractioned into 5 size categories by gently wet sieving through nested Nitex screens of 5000, 2000, 1000, 500 and 200-µm. Each size fraction of the sorted fresh subsample was concentrated on a Nitex screen under low vacuum, placed in Petri dishes and frozen in liquid Nitrogen for later analysis. Typically, three-eights of the sample were size-fractioned for biomass analysis. They were processed analogously to the gut fluorescence samples, except they were concentrated on a pre-weighed Nitex filter and rinsed with isotonic ammonium formate solution to remove interstitial sea salt, and frozen in -80 °C for later analysis.

Live tows targeting *Euphausia pacifica* (Euphausiacea) were conducted to estimate mean brood sizes in each cycle, and to conduct experimental incubations with gravid females in order to observe the effect of the incubation on female brood size and hatching success. The tows were conducted at nighttime, at least twice per cycle. Net hauls were conducted with Bongo frames fit with 500-µm Nitex nets. Mean depth of tow depended on the depth and station. When ambient chlorophyll was high, in coastal waters, tows were conducted to approximately 50-70 m, because individual *Euphausia pacifica* are known migrate to shallow waters to feed at night. When ambient chlorophyll was low, tows were conducted to a maximum depth of approximately 250 m, because the targeted species was extremely rare in the offshore oligotrophic waters, and other species of euphausiids were also low in abundance.

On shipboard, organisms were first screened for females bearing purple ovaries (an indication that they might spawn that night). After all gravid females had been removed and put into individual containers; the remaining large females (at least 14 mm, large enough to produce eggs) were incubated in different water treatments. All incubations were conducted in a temperature controlled room, between 12 and 14°C.

Females were monitored every 12-24 h. When females spawned, they were removed from their containers and preserved in 5% buffered Formalin. Eggs were incubated in Petri dishes for up to 72 h and hatching success was noted. Brood size, hatching success and mean female length was estimated for all cycles in which sufficient females were captured.

Thorium-based Export

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The disequilibrium between the particle reactive radionuclide Th-234 and its longlived, conserved parent nuclide U-238 can be used to estimate carbon export from the upper ocean over a time-scale of 24 days if the ratio of Carbon to Th-234 is determined. We measured thorium disequilibrium profiles from the surface to twice the depth of the euphotic zone on multiple casts on each of the 5 cycles and also sampled C:Th in particulate matter beneath the euphotic zone using large-volume *in situ* pumping. These profiles will allow us to estimate carbon export in distinct regions and water masses of the CCE that were sampled during the cruise.

Preliminary data shows relatively high levels of vertically integrated Th:U disequilibrium throughout the region (**Figure 19**). The profiles also show that the maximum disequilibrium can be found at the surface near shore, but at deeper depths offshore. In six months, we will be able to count backgrounds to reduce the uncertainty in these profiles and utilize the C:Th-234 ratios to estimate carbon export.



Fig. 19. Cross-current contour plot (left) and depth profiles (bottom) of Th-234 deficiency in the CCE study area off Pt. Conception (CalCOFI line 80).

