Cruise Report

California Current Ecosystem LTER Program

CCE-P1908 Cruise

R/V *Atlantis*, 5 August – 6 September 2019

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

Scripps Institution of Oceanography, University of California, San Diego

Cruise ID: CCE-P1908 (= AT42-15)

Depart: 5 Aug. 2019, 1400 (PDT), MarFac

Return: 6 Sept. 2019, 0800, MarFac

Vessel: R/V *Atlantis*

Master: Captain Al Lunt

Chief Scientist: Mark D. Ohman

Science Technicians: Catie Graver (SSSG), Joe McCabe (SSSG), Carl Mattson (SIO), John Calderwood (SIO)

Operator: Woods Hole Oceanographic Institution

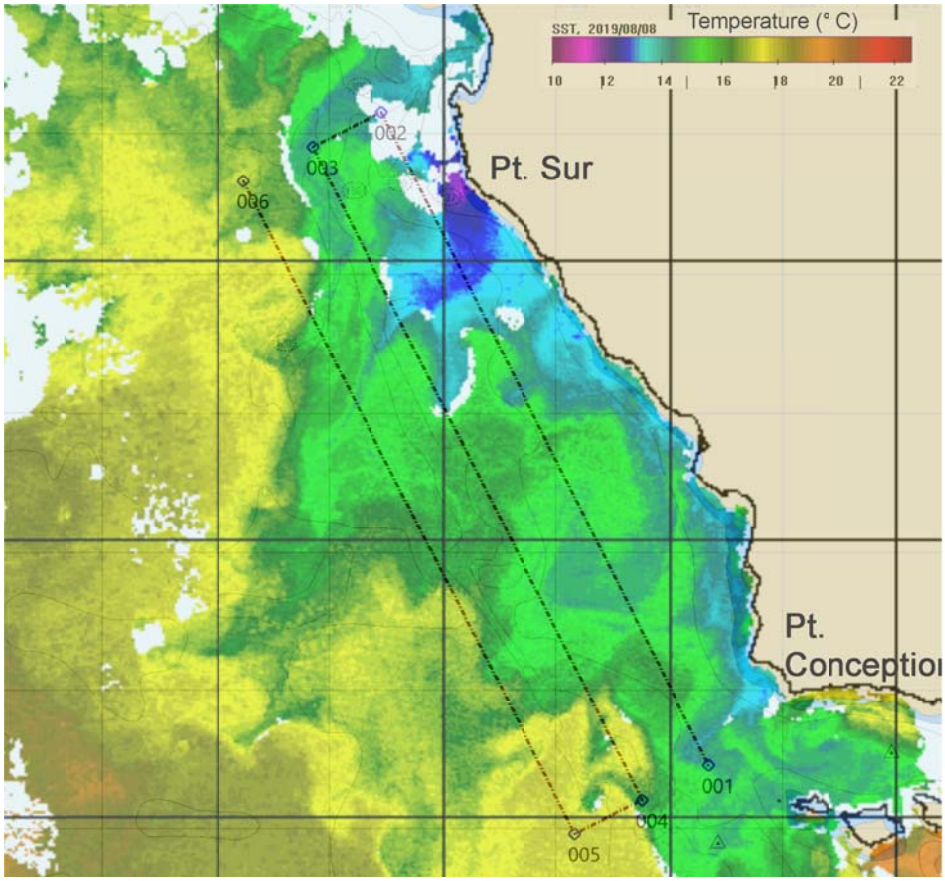

Fig. 1: The Pt. Sur Filament, which was the primary focus of P1908. Satellite image of sea surface temperature (SST, °C) on 8 Aug. 2019. Note the magenta-shaded cold upwelled water west of Pt. Sur, which became an offshore-flowing coastal filament. Dashed line indicates the location of Seasoar #1, which surveyed the region from 6-9 Aug., prior to beginning measurements at our Lagrangian Cycles. Satellite image courtesy of M. Kahru, SIO.

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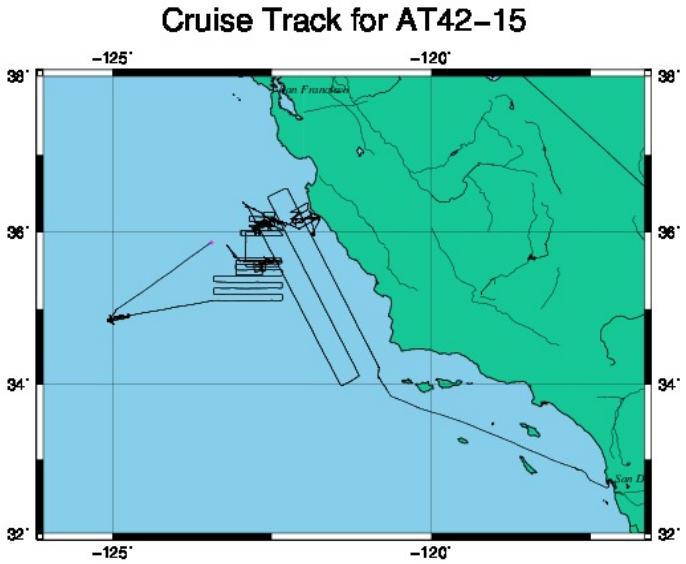

Fig. 2. Partial cruise track for CCE-LTER cruise P1908 (=AT42-15) off the coast of Central and Southern California. While underway, continuous measurements were made of pH/pCO_2, O_2:Ar for Net Community Production, phytoplankton pigments and variable fluorescence by Advanced Laser Fluorescence Analyzer (ALFA), multi-frequency acoustic backscatter by EK60, and standard ocean (Temperature, Salinity, dissolved O_2, Chl-*a* fluorescence, etc.) and meteorological variables. This map does not include sampling locations during our Lagrangian Cycles, or Benthic Boundary Layer stations.

Cruise Participants

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SIO = Scripps Institution of Oceanography; FSU = Florida State University; JCVI = J. Craig Venter Institute;
ENSTA = École Nationale Supérieure de Techniques Avancées, France;
IUEM/UBO = Institut Universitaire Européen de la Mer/Université de Bretagne Occidentale, France

SCIENCE OBJECTIVES

This cruise, designated P1908 by CCE-LTER (but AT42-15 by R/V *Atlantis*), was the second process cruise in Phase III of the *California Current Ecosystem* Long Term Ecological Research (CCE-LTER) program, supported by NSF. P1908 focused on cross-shore fluxes, plankton community changes, and biogeochemical export (of nutrients, organisms, nitrogen, and carbon) associated with coastal upwelling filaments. P1908 employed a series of integrated approaches. The fundamental approach was quasi-Lagrangian experimental studies and in situ measurements carried out while following 4 discrete water parcels, the first 3 of which were part of a coastal upwelling filament we identified off Pt. Sur, California (here designated the "**Pt. Sur Filament**"). The fourth and contrasting water parcel was in the core California Current, farther offshore. These quasi-Lagrangian series of measurements (each of which we term a "Cycle" of repeated measurements) was complemented by several related activities: three intensive cross-filament sampling Transects, deployments of multiple autonomous instruments (*Zooglider*, *Spray* glider, in situ incubation driftarrays, drifting sediment traps), three Seasoar surveys, Moving Vessel Profiler surveys, extensive remote sensing support (including satellite sensors and coastal high-frequency radar), and a survey of the Benthic Boundary Layer over the continental shelf in two locations.

Our specific objectives were to ***understand and quantify key mechanisms that transport coastal production and populations offshore in the CCE region, including the magnitudes and length scales of transport and their climate sensitivities.*** The principal hypotheses we sought to test were:

H_1: Lateral transport dominated by the interaction of Ekman transport and westward propagating coastal filaments provides a significant flux of nutrients and organisms to offshore waters.

H_2: Carbon export associated with offshore transport is determined by in situ evolution of communities and nutrient regimes, and by subduction occurring largely at sharp frontal density gradients.

The processes measured on this cruise included primary production, net community production (O_2:Ar), secondary production by bacteria and a representative species of copepod, grazing by microzooplankton and mesozooplankton, rates of viral lysis, dissolved iron and ligand effects on phytoplankton growth, carbon and nitrogen cycling between dissolved and particulate phases, and elemental export in both particulate and dissolved forms. The pelagic food web was characterized by state-of-the-art measurement methods, including omics approaches, for organisms ranging from viruses, prokaryotic and eukaryotic microbes, micro- and meso-zooplankton, to nektonic organisms (the latter as acoustic backscatter). Vertically stratified distributions of zooplankton were assessed by MOCNESS, complemented by in situ imagery from a UVP-HD mounted to the CTD-rosette. Most measurements were made in a Lagrangian reference frame while following discrete water parcels for 3-5 days at a time. These water parcels were selected to represent different stages in the temporal evolution of the Pt. Sur Filament: i.e., nearshore near the upwelling source and origin of the filament; further along the axis of the filament, as upwelled waters and entrained communities were advected offshore; and further to the south along the same filament, near its terminus, where export fluxes were expected to be elevated. The fourth water parcel was representative of California Current waters with which the Pt. Sur Filament

interacts. A Benthic Boundary Layer (BBL) study in two regions (3 stations near Pt. Sur and 9 stations north of or near Pt. Conception) was conducted to understand the relationship between coastal iron supply in nearshore sediments and the flux of iron into the coastal ocean via coastal filaments.

Our **Broader Impacts** activities included providing seagoing research opportunities and training for 16 graduate students, 5 undergraduate students and other volunteers, and 1 postdoctoral investigator; accommodating visiting assistant professors from the University of Ghana and the University of Lille (France); and communicating with the general public via an online blog created by graduate student Laura Lilly (https://cce.lternet.edu/blogs/201908/). We provided three **Science Chat** seminars at sea for all interested parties and a **Science Tour** was offered on the ship, providing a brief overview of different measurement methods and experiments in the shipboard laboratories and on deck, in order to acquaint all participants with the full range of CCE-LTER science activities at sea.

OVERVIEW OF THE SCIENCE PLAN

Preparations for this cruise began with deployment of a *Spray* ocean glider on 20 June 2019 (Jeff Sherman and Dan Rudnick, IDG, SIO), to characterize cross-shore fluxes on a line extending from Pt. Conception in the south to Pt. Piños at the southern end of Monterey Bay (Figs. 3, 4). The glider profiled from 500-0 m. Concurrently with this deployment, and prior to departure of the R/V *Atlantis* from MarFac on 5 August 2019, satellite and high frequency coastal radar (CODAR) images were generated daily to identify regions of filament formation. The remotely sensed variables analyzed included Chl-*a* (at 1.1 km and 300 m horizontal resolution, Mati Kahru, SIO); SST (Mati Kahru, SIO); Sea Surface Height and derived variables (Finite Size Lyapunov Exponents, Okubo-Weiss parameter; Alain de Verneil at NYU Abu Dhabi); and near-surface circulation inferred from CODAR (Ralf Goericke, SIO). Glider and remote sensing data were also examined daily at sea to guide site selection for Lagrangian Cycles.

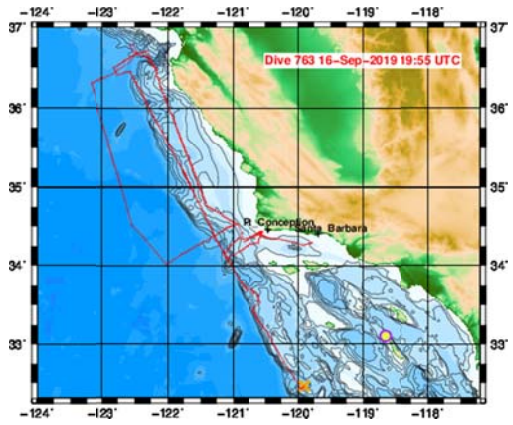


Fig 3: *Spray* glider (sn67) survey initiated prior to P1908 and continued afterward, to resolve cross-shore fluxes at different distances from the coast.

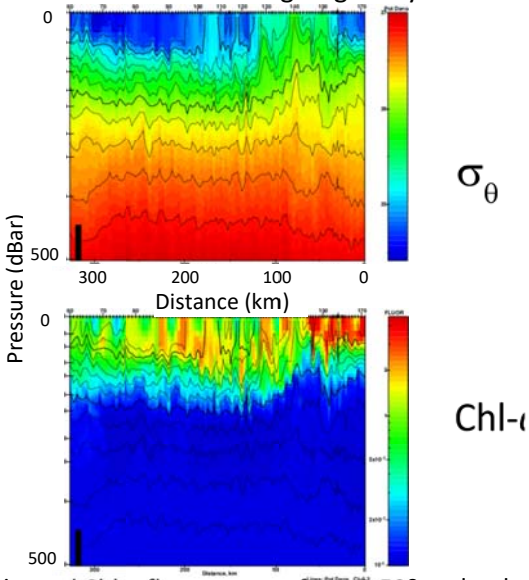


Fig 4: *Spray* vertical sections of density and Chl-*a* fluorescence, from 0-500 m depth, from the first glider line closest to the coast. Panels oriented from south (left) to north (right). Note relatively dense (cold, salty, recently upwelled water; shaded green) and higher Chl-*a* waters toward the northern end of the section. This dense water corresponds to the Pt. Sur Filament.

After departure of R/V *Atlantis* from Scripps' MARFAC on 5 August (delayed to 1400 because of low tides) we completed a series of over-the-side instrument tests (near 32° 51.3'N, 117° 39.3' W). We then steamed to the location of our first Seasoar survey, lowered the EK60 acoustic pole, conducted a pre-survey calibration CTD-rosette cast, and deployed Seasoar along three south-north lines extending from Pt. Conception to Pt. Piños, at successively greater distances from shore (Fig. 1 above). Seasoar profiled from ~300-6 m, in order to provide measurements needed to calculate cross-shore fluxes of mass, nitrate (using a Temperature-NO_3 proxy), and Particulate Organic Carbon (using a Beam Attenuation-POC proxy), between each pair of Seasoar lines. The sensors on Seasoar were: dual CTDs, a beam transmissometer, Chl-*a* fluorometer, and a Rinko III optode for dissolved oxygen. From this Seasoar survey, the glider measurements above, and remote sensing data, the **Pt. Sur Filament**, a major offshore-trending cool-water filament that originated off Pt. Sur, CA (Figs. 5, 6), became the primary focus of the P1908 cruise. During Seasoar surveys, extensive additional underway measurements were made as described below. Discrete samples were taken from the continuous underway seawater system for analysis of $^{234}Th/^{238}U$, particulate and dissolved C and N, phytoplankton pigments by HPLC, and dissolved nutrients.

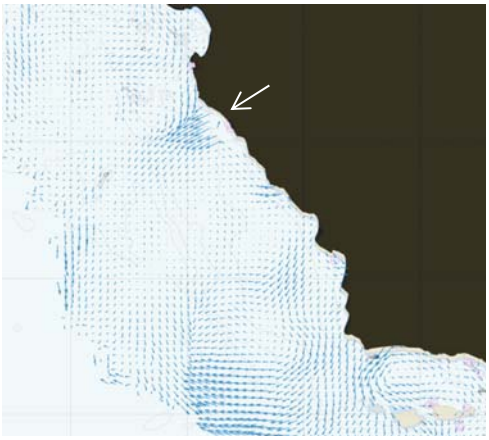


Fig. 5 (above). CODAR map of surface currents, 8 Aug. 2019, showing the Pt. Sur Filament.

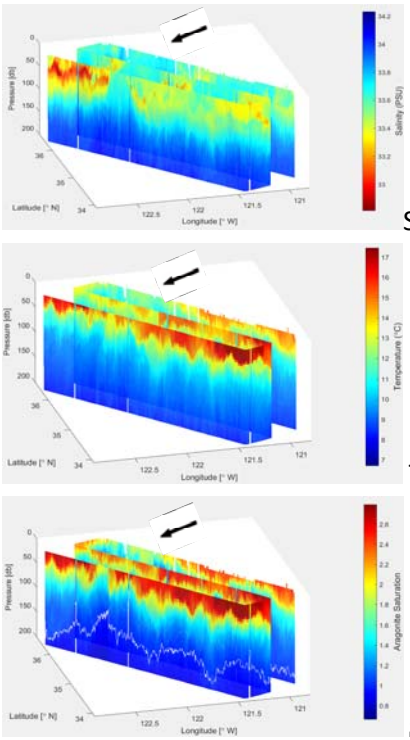


Fig. 6 (right). Seasoar 1 sections showing the high salinity, low temperature, reduced aragonite-saturation waters of the Pt. Sur Filament.

Following localization of the Pt. Sur Filament, the nearshore gradients and structure of the filament were resolved by a Moving Vessel Profiler (MVP) survey to 200 m depth with a rapid response CTD, Chl-*a* fluorometer, and Laser Optical Particle Counter (LOPC; e.g., Fig. 7). The MVP survey was followed by the first of 3 nighttime sampling Transects that sampled across the primary axis of the filament in 3 different locations. These Transects included a CTD-rosette cast to 300 m, vertical bongo net (from 100-0 m), and trace metal sampling with either a trace metal rosette that profiled to 150 m or a surface pole sample. (Bongo sampling was not done on Transect 1 because of insufficient time.)

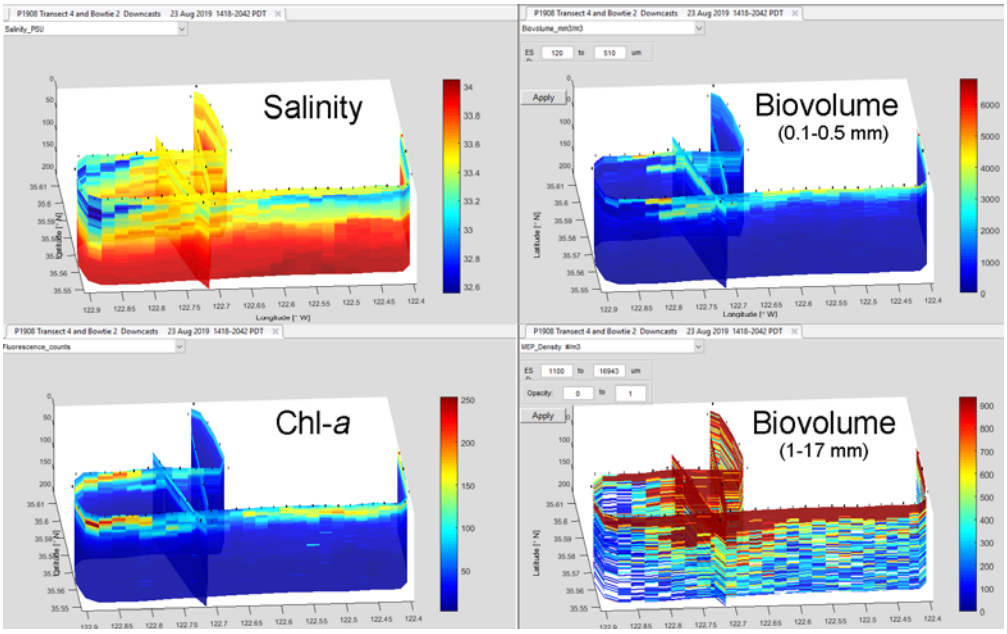


Fig. 7. MVP survey prior to Cycle 3, indicating strong frontal gradients in salinity, with corresponding changes in Chl-*a* and particle biovolume in two size fractions: (0.1-0.5 and 1-17 mm), determined by Laser Optical Particle Counter. (Depth scale is 0-200 m). M. Ohman

We then conducted a series of rate process measurements on four Lagrangian "Cycles" in water parcels selected to represent three states in the development of the Pt. Sur coastal filament (Figs. 8, 9), and a fourth Cycle in more offshore waters of the California Current with which such coastal filaments are thought to interact. As above, site selection for each Cycle entailed examining remote sensing data, followed by localization of each water parcel of interest by a preliminary MVP site survey. MVP surveys permitted regions of strong frontal gradients to be localized (e.g., Fig. 7) and avoided prior to deployment of drifting instruments. Following this approach, **Cycle 1** began in freshly upwelled waters ca. 11 km from shore; **Cycle 2** was in waters located ~60 km to the west of the starting point of Cycle 1, in partially aged upwelled waters; **Cycle 3** was in waters ~58 km south of the start part of Cycle 2, in post-bloom waters; **Cycle 4** began ~205 km west-southwest of the start point of Cycle 3, in lower salinity California Current waters. Prior to Cycles 2 and 3, as with Cycle 1, cross-filament Transect sampling was

Fig. 8. Trajectories of satellite-tracked drifters indicating the locations of 4 Lagrangian Cycles, beginning near Pt. Sur (Cycle 1). Black = path of Driftarray , red = path of sediment traps.

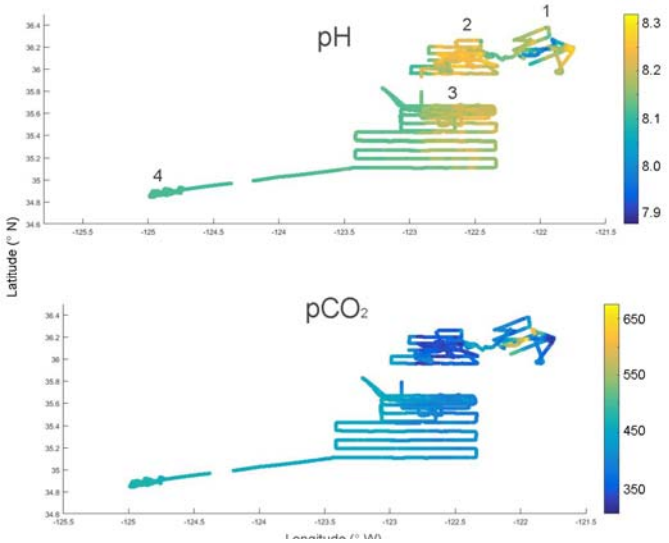


Fig. 9. Continuous underway measurements of pH and pCO_2, with locations of the 4 Lagrangian Cycles. Note the high pCO_2, low pH of the newly upwelled Cycle 1 waters, then the progressive drawdown of pCO_2 and increase of pH from Cycles 2 to 3. Cycle 4 (California Current) waters are close to equilibrium. Fig. by B. Botwe.

conducted, whereby waters across the core of the filament were sampled using a rapid CTD-rosette, vertical bongo net, and trace metal rosette or trace metal pole sampling. Each cross-filament Transect was conducted as rapidly as feasible, attempting to sample in nighttime hours (to the extent possible) in order to minimize diel variations attributable to phytoplankton physiological changes and zooplankton Diel Vertical Migration.

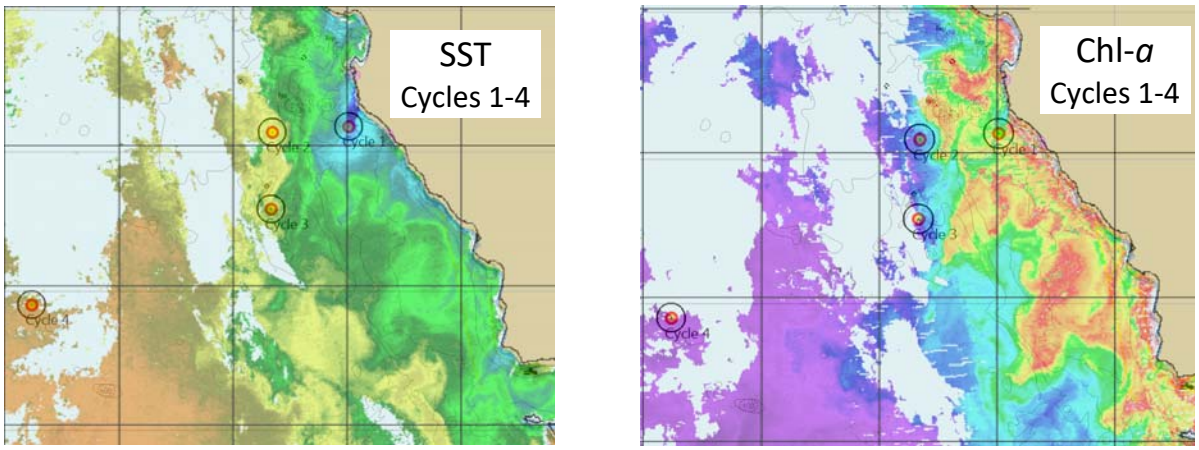


Fig. 10: Starting locations of Cycles 1-4, overlain on satellite images of SST (left) and Chl-*a* (right) for 8 Aug. 2019. Note that SST and Chl-*a* fields changed substantially over the 22 days of Cycle-based measurements and these single images are not representative of conditions observed during each Cycle. Images courtesy of Mati Kahru.

For each Cycle, Globalstar-tracked sediment traps and an in situ incubation Driftarray were used to follow water parcels over repeated day/night measurements in order to quantify the temporal evolution of rate processes and plankton community composition. Both sediment traps and Driftarrays employed a holey sock drogue centered at 15 m depth and telemetered positions ashore via Iridium every 10 min. All other measurements were made in these same water parcels in close proximity to the Driftarray (ca. 100-150 m away), or centered on the Driftarray (in the case of towed nets like the bongo and MOCNESS). Incubation bottles were suspended from the Driftarray at six light depths spanning the euphotic zone in order to determine specific growth rates of phytoplankton and specific grazing rates of microzooplankton (using seawater dilution experiments), virus-induced mortality of phytoplankton, in situ rates of ^{14}C-based primary production, Fe-limitation, and New Production from $^{15}NO_3$ uptake. Additional measurements/samples at the drifter locations included Fe limitation and ligand production incubations; vertical profiles of trace metals sampled with a trace metal clean rosette; ^{14}C-based primary production; ^{3}H-leucine-based bacterial production; analysis of stable isotopes of N, C, and O; reactivity of DOC and DON; ^{234}Th:^{238}U disequilibrium; microbial diversity assessed by 16S and 18S ribosomal subunit genes; bacterial production by ^{3}H-leucine incorporation; phytoplankton pigments by HPLC; size-fractionated Chl-*a*; POC and PON; picoplankton samples for flow cytometry; microplankton samples for epifluorescence microscopy; mesozooplankton biomass and grazing (via gut fluorescence) in five size fractions from bongo tows; mesozooplankton community composition from bongo tows and shore-

based Zooscan; copepod egg production rates for the dominant species of calanoid copepod; mesozooplankton vertical distributions via MOCNESS samples for DNA metabarcoding and Zooscan; and vertical profiles of macronutrients and standard hydrographic variables. In addition, continuous underway measurements were made on the ship's uncontaminated seawater system, including phytoplankton pigments, variable fluorescence (F_v/F_m), and CDOM, all using an Advanced Laser Fluorescence Analyzer (ALFA; Chekalyuk and Hafez. 2008. LOM: 6:591); phytoplankton pigments by HPLC; O_2:Ar ratios as a measure of net community production (M. Stukel lab, for S. Kranz); continuous pCO_2 and pH (for Taylor Wirth, T. Martz lab); standard ship-provided measurements of ocean surface properties and meteorological variables; ADCP-derived currents at 75 kHz and later at 300 kHz (only from 8 Aug., 1545); and EK60 acoustic backscatter at four frequencies (38, 70, 120, 200 kHz). In situ plankton images were acquired on all CTD-rosette casts using a high definition Underwater Vision Profiler (UVP5-HD). Measurements are described in greater detail below.

In addition to core measurements at the four Lagrangian Cycles, K. Barbeau's group conducted a Benthic Boundary Layer (BBL) survey at 3 stations on the continental shelf near Pt. Sur and at 9 stations north of or near Pt. Conception (Fig. 11). This study tested the hypothesis that dissolved iron is elevated in the Benthic Boundary Layer (BBL) above continental shelf sediments, a likely source of dissolved iron in coastal filaments.

Fig. 11. Locations of Benthic Boundary Layer stations near Pt. Sur and in the vicinity of Pt. Conception-Pt. Arguello (Kathy Barbeau group).

A novel *Zooglider* was deployed at 1700 on 13 Aug. at Cycle 1. It was then piloted by Jeff Sherman (onshore) across the Pt. Sur Filament multiple times to Cycle 2, then recovered 14 days later (1100 on 27 Aug.).

Fig. 12. ***Zooglider*** track (green dots, each representing an individual dive), superimposed on Driftarray (black) and sediment trap (red) tracks from Cycles 1-3. (Mark Ohman & Sven Gastauer)

This was a highly successful cruise. All of our science objectives were fully met. The assistance of the Captain, SSSGs, bosun, crew, and SIO electronic technicians were instrumental in maintaining a close schedule of round-the-clock operations. Science personnel were entirely responsible for Event Logger entries, which had not been the case on previous cruises. Some R/V *Atlantis* standard operating procedures needed to be modified, e.g., the ship's crew operated CTD and MOCNESS winches, in order to ensure that vertical profiling was done continuously and without interruption caused by winch control changeover. However, the ship's design for a magnetic cradle to attach the EK60 acoustic pole to the hull of *Atlantis* was unsatisfactory and is not recommended. The cradle moved vertically and, on occasion, briefly detached from the hull in moderate seas.

Brief Chronology of Cruise P1908

(see Daily Activity Schedule at the end of this document, and Event Log for details and accurate times)

5 Aug. 2019 (1400 PDT)	Depart MarFac (departure delayed for high tide)
5 Aug. (1700)	Test station (32° 51.3', 117° 39.3' W)
6 Aug. (1600)	EK60 pole deployment and ship speed tests
6 Aug. (1700)	Seasoar calibration CTD cast
6 Aug. (2000) - 9 Aug. (1430)	**SEASOAR #1**
9 Aug. (1630)	Seasoar calibration CTD cast
10 Aug. (0700-1900)	MVP Pt. Sur Survey
10 Aug. (2100) - 11 Aug. (1030)	**TRANSECT 1** (CTD – Trace Metal)
11 Aug. (1300-1830)	**BBL** stations near Pt. Sur
11 Aug. (1900-2130)	MVP Bowtie 1
12 Aug. (1800-2030)	MVP Transect 2
12 Aug. (2130)	Deploy sediment trap, **BEGIN CYCLE 1**
13 Aug. (1700)	Deploy *ZOOGLIDER*
17 Aug. (0600)	Deploy drifter at Driftarray recovery location
17 Aug. (0700)	Recover sediment trap, **END CYCLE 1**
17 Aug. (0930-1930)	Underway survey; last portion as MVP Transect 3
17 Aug. (1930) - 18 Aug. (0530)	**TRANSECT 2** (CTD – Trace Metal – Bongo)
18 Aug. (0700-1900)	Underway survey
18 Aug. (1930)	Recover drifter
18 Aug. (2000)	Deploy sediment trap, **BEGIN CYCLE 2**
23 Aug. (0530)	Recover sediment trap, **END CYCLE 2**
23 Aug. (0730-2100)	Underway survey; last portion MVP Bowtie 2
23 Aug. (2330)	Deploy sediment trap, **BEGIN CYCLE 3**
26 Aug. (0600)	Recover sediment trap, **END CYCLE 3**
26 Aug. (0730-1600)	Pre-Transect 3 survey; last portion MVP Transect 5
26 Aug. (1730) - 27 Aug. (0630)	**TRANSECT 3** (CTD – Trace Metal – Bongo)
27 Aug. (1100)	Recover *ZOOGLIDER*; Annular survey
27 Aug. (1315) - 29 Aug. (1330)	**SEASOAR #2**
29 Aug. (2230-2340)	MVP Bowtie 3
30 Aug. (0000)	Deploy sediment trap, BEGIN CYCLE 4
2 Sept. (0530)	Recover sediment trap, END CYCLE 4
2 Sept. (2300) - 3 Sept. (1900)	**SEASOAR #3**
3 Sept. (2200) - 4 Sept. (0030)	CCE2 mooring calibration casts; Annular survey
4 Sept. (0800) - 5 Sept. (0200)	**BBL** stations north and south of Pt. Conception
5 Sept. (0300)	Santa Barbara Basin sampling; CTD and TM rosette
6 Sept. (0730)	Arrive MarFac

GROUP REPORTS

SeaSoar - (Operations directed by Carl Mattson; many others participated)

The SeaSoar was equipped with a Rinko 3 dissolved oxygen sensor, Chl-*a* fluorometer, beam transmissometer, and dual temperature, conductivity, and pressure sensors. Three SeaSoar surveys were conducted. Seasoar #1 consisted of 3 south-north legs running from Pt. Conception to Pt. Piños, CA (Fig. 1 above). This survey was used to identify the location, vertical structure, and offshore extent of the target filament within the California Current Ecosystem, prior to beginning Lagrangian Cycle 1. After completion of Cycle 3, the SeaSoar #2 survey with east-west orientation was completed in the vicinity of the Cycle 3 mixing zone, where Pt. Sur Filament waters appeared to be interacting with the surrounding water. The westward extent of Seasoar #2 also clearly resolved the low salinity/relatively warm water front delineating the boundary of the California Current. Seasoar #3 reoccupied the inshore-most line occupied by Seasoar #1, in order to record changes in the cross-shore features toward the end of the cruise. After the cruise, the SeaSoar surveys will be used to calculate cross-shore fluxes and to help constrain physical models.

Hydrography, Primary Production – Goericke Group (Ralf Goericke, Megan Roadman, Shonna Dovel, and volunteers Zev Brook and Eric Lawrence)

Hydrography: More than 80 CTD casts were carried out every 8 to 12 hours while the drifter was in the water. The package (SBE 9Plus) had instruments for temperature (SBE 3), conductivity (SBE 4), oxygen (SBE43 and Rinko3), chlorophyll fluorescence and turbidity (FluoroWetlab ECO_AFL_FL), light attenuation by particles (Wetlabs C-Star), and photosynthetically active radiation (Licor PAR sensor). Samples were collected from the CTD at about 8 depths per cast for concentrations of algal nutrients (nitrate, nitrite, silicic acid, phosphate, and ammonia; filtered using either an Acropak filter [most 0200 casts] or a 0.8 µm polycarbonate filter, and frozen at -20° C), salinity, Chl-*a* (determined fluorometrically aboard the ship in 90% acetone following 24+ h extraction), Particulate Organic Carbon and Nitrogen (frozen at -20° C), and taxon-specific pigments by HPLC (filters frozen in liquid N_2). All particulate samples were filtered onto GFF filters, precombusted in the case of POC/PON. The temperature-salinity diagram allows the identification of water masses and the tracking of changes of water masses between Cycles. The TS diagrams for all P1908 cycles are shown in Fig. 13. Waters encountered during Cycle 1

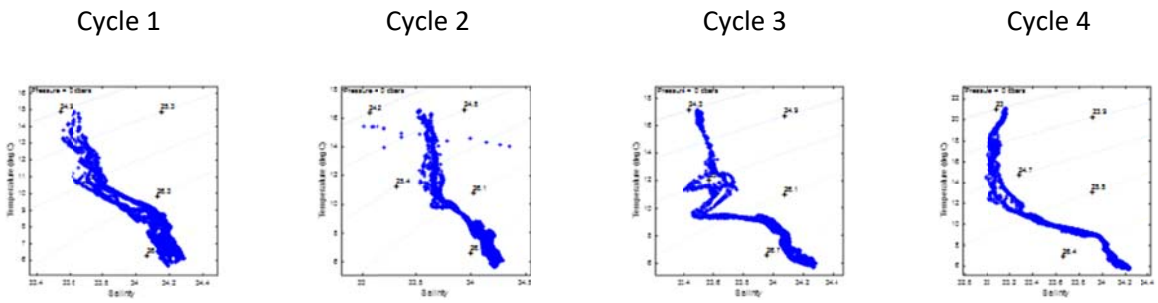


Fig. 13: TS diagrams for P1908 Cycles 1 - 4, illustrating the water mass variability during the Cycles.

were variable. The surface layer warmed over the course of the Cycle; at depth we see significant variability as well, suggesting that we sampled different water parcels during our CTD casts. TS-diagrams for the other Cycles suggest that we faithfully tracked a surface layer but encountered different water masses at depth; in the case of Cycles 2 and 3, water probably derived from the California Current.

Acoustic Doppler Current Profilers (ADCP) were used to measure currents along our cruise track. The 300 kHz instrument is used to profile the near-surface layer and the 75 kHz narrow band instrument deeper sections. Currents measured during Transect 1 off Pt. Sur showed strong flows within the filament southward and northward along the coast. The depth of the southward flow raises the question if this is entirely driven by surface winds.

pCO_2 – pH Measurements: We also monitored a SuperCO2 System (Sunburst Sensors) operated for the Martz lab (SIO). The instrument measures pCO_2 and pH on water from the ship's underway system. Measurements during Seasoar 1 (Fig. 14) show how the ocean is 'exhaling' CO_2 in the upwelling areas where surface seawater pCO_2 was up to 200 ppm higher than atmospheric pCO_2. The recently upwelled water has a lower pH than surrounding waters as expected for waters of the deep ocean (at-sea pH values are uncalibrated).

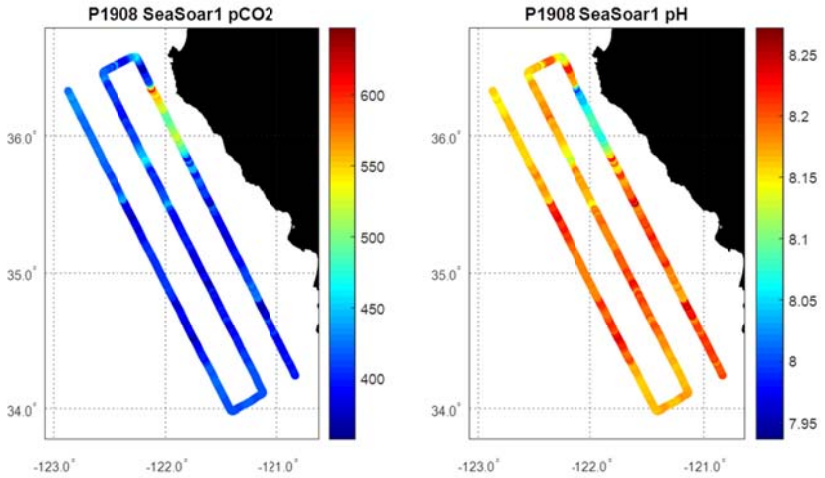


Fig. 14. Seasoar 1 off Central and Southern California: (A) pCO_2 concentrations in surface water (ppm) and (B) pH.

Phytoplankton Biomass: Chl-*a* as a proxy for phytoplankton biomass was determined by measuring the fluorescence of 90% acetone extracts following filtration on GFF filters. The depth distributions of Chl a (Fig. 15) for Cycles 1 and 2 are typical for phytoplankton blooms, i.e. surface maxima of Chl-*a*, increasing with time during Cycle 1 and decreasing with time during Cycle 2. Patterns for Cycle 3 suggest declining phytoplankton biomass in the surface layer or, during Cycle 4 constant levels of biomass at equilibrium with grazers as expected from the waters of the California Current. The large variability of Chl-*a* at the Chl maximum may reflect the advection of different waters at depth to our sampling point.

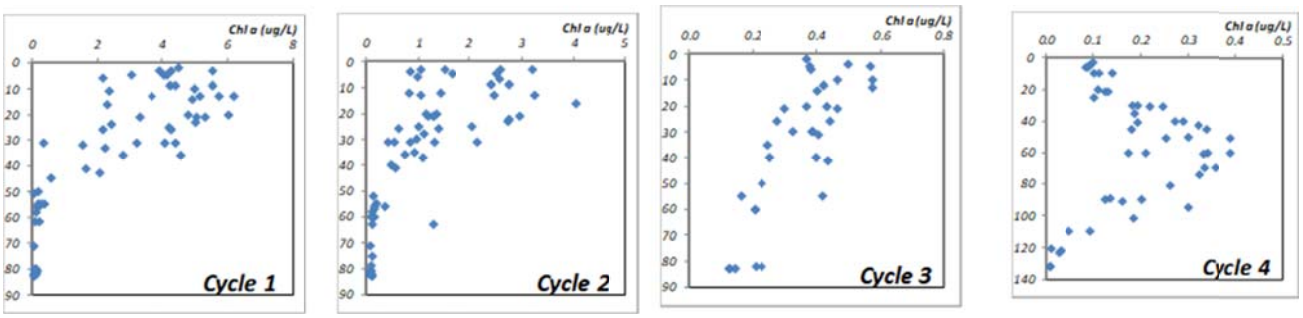


Fig. 15. Chl-*a* depth profiles for Cycles 1 - 4. Note different scales on x- and y-axes.

Phytoplankton Community Structure: We collected samples for the shore-based analysis of phytoplankton taxon-specific pigments pigments by HPLC from most casts.
Chl-*a* size fractionations were carried out on samples from the mixed layer or the deep chlorophyll maximum (DCM). Dramatic differences were found between Cycles (Table 1). Time series of biomass in different size fractions (Fig. 16A) and their relative contribution to the total (Fig. 16B) for Cycle 2 illustrate that the > 20 µm and 8 -20 µm size fractions were the primary drivers of changing size distribution during this Cycle. These patterns are typical for the CCS.

Table 1: Chlorophyll size fractionation, using water from the 0200 CTD casts from the mixed layer (ML) or the noon CTD casts from the Deep Chl Maximum (DCM; if present). Number of experiments (N), Chl-*a* concentration (TChl-*a*), and % of TChl-*a* < 1 µm, 1 -3 µm, 3 -8 µm, 8 -20 µm and > 20 µm size fractions.

Cycle	Location	Depth	N	TChl a	< 1µm	1-3µm	3-8µm	8-20µm	> 20µm
-	-	(m)	-	(µg /L)	(%)	(%)	(%)	(%)	(%)
1	ML	5	9	4 ± 1.12	19 ± 8	9 ± 5	13 ± 4	11 ± 5	48 ± 11
1	DCM			-	-	-	-	-	-
2	ML	5	9	1.67 ± 0.71	14 ± 10	8 ± 5	9 ± 5	20 ± 6	49 ± 11
2	DCM			-	-	-	-	-	-
3	ML	5	5	0.42 ± 0.1	54 ± 6	20 ± 2	12 ± 3	7 ± 2	7 ± 4
3	DCM			-	-	-	-	-	-
4	ML	5	4	0.09 ± 0	63 ± 6	20 ± 5	8 ± 1	5 ± 2	4 ±1.5
4	DCM	55	3	0.30 ± 0.02	60 ± 4	22 ± 3	11 ± 2	4 ± 0	4 ±1.2

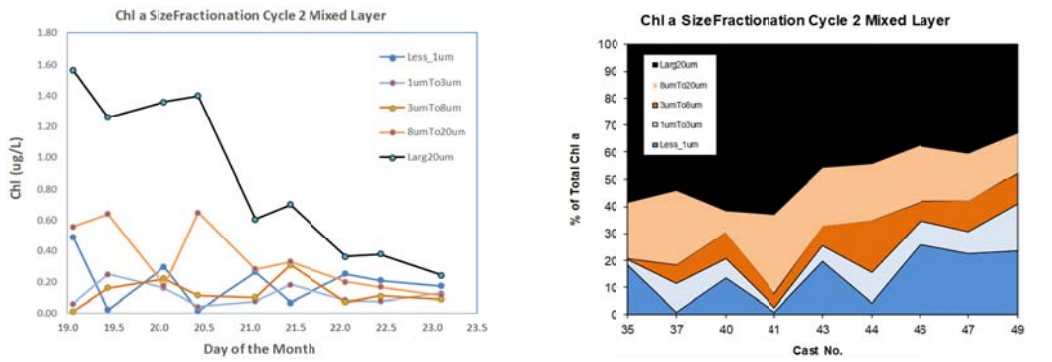


Fig. 16: The (A) Chl-*a* biomass and (B) percentage contribution to total biomass of different size classes of phytoplankton during Cycle 2.

Primary Production: Rates of primary production were determined from the incorporation of ^{14}C into Particulate Carbon and Dissolved Organic Carbon, the former defined by particles retained on GFF filters and the latter by the filtrate through 13 mm Millex PVDF Durapore 0.45 μm syringe filters. Incubations were done in situ for 24 hours on the Driftarray at 6 light depths. ^{14}C filters and DOC filtrates were acidified, scintillation cocktail added, and then were counted after return to SIO.

An Advanced Laser Fluorescence Analyzer (ALFA) system was used to characterize phytoplankton biomass, pigment community structure, photosynthetic capacity (Fv/Fm), and colored Dissolved Organic Matter from the ship's underway system. Patterns observed during Seasoar 1 show low phytoplankton biomass and associated photosynthetic capacity in the recently upwelled water off Pt. Sur. In contrast, high phytoplankton biomass and photosynthetic capacity was found in the slightly older upwelled water off the central coast. Oceanic *Synechococcus* were present in the southern section of the pattern, in waters we believe to be derived from mixing of California Current and coastal waters.

Net Community Production - (Mike Stukel group, for Sven Krantz [in absentia])

We quantified O_2:Ar Net Community Production (NCP) from the ship's flowthrough system. The system was deployed throughout the cruise to quantify diel variability in NCP during Lagrangian experiments and to determine spatial patterns of NCP during Transects and SeaSoar Surveys. The system provided continuous data with approximately one minute temporal resolution with only a few brief down periods.

Trace Metal Studies – Barbeau/Allen Group (Kathy Barbeau, Kiefer Forsch, Max Fenton; from the Allen lab: Rob Lampe and Tyler Coale)

Iron is a critical micronutrient that limits phytoplankton growth in wide-ranging areas of the ocean. The California Current upwelling region has been described as a mosaic of iron limitation with regions and

events that range from iron replete, to iron co-limitation, to iron-limited. We seek to understand how iron supply shapes the composition of the phytoplankton community, and related impacts on biogeochemistry. The Barbeau group has also taken on biogenic silica sampling, as previous cruises have shown that silica dynamics in this region are strongly impacted by the iron stress status of the diatom community.

Sampling Activities - We 47 trace metal casts, primarily with the trace metal rosette but also including three GO Flo casts to sample the Benthic Boundary Layer around Point Sur. Iron profiles have been obtained at all Cycles (to 150 m at Cycles 1, 2, 3 and to 300 m at Cycle 4). Multiple profiles to 150 m and surface pole samples were taken during cross-filament Transects 1, 2, and 3. A total of 18 iron-related experiments (see below for details on some experiments) were conducted at Cycles 1, 2, 3, and 4, and on the Transects, both on-board and on the in-situ Driftarray. Biogenic Si sample profiles were taken daily at all Cycles, at about every other station on Transects, and from iron addition incubation experiments. A 9-station Benthic Boundary Layer sampling pattern along-shelf was completed at the end of the cruise, where a standard CTD-rosette cast was followed by a GO Flo cast at each station.

***In situ* array iron addition/removal incubations -** At each Cycle, we exposed natural phytoplankton communities from the near-surface or deep chlorophyll maximum to iron addition (+5 nM $FeCl_3$) or iron removal (+100 nM the iron chelator desferrioxamine B) and incubated them for 24 hours in their ambient environment on the *in situ* quasi-Lagrangian Driftarray. Evaluation of the mRNA from these incubations will allow us to evaluate the phytoplankton communities' responses to changes in iron bioavailability under near-natural conditions. These experiments were also conducted on the 2014 and 2017 CCE-LTER process cruises, allowing us to compare across years.

Trace metal clean pCO_2 incubations - The Allen and Barbeau labs were funded to investigate the impact of increased atmospheric CO_2 concentrations on phytoplankton communities found in the California Current Ecosystem. This research stems from the recent discovery made through an Allen/Barbeau collaboration of a carbonate-dependent iron acquisition protein (phytotransferrin) that is utilized by eukaryotic phytoplankton. Aboard the P1908 Process Cruise, members of the Allen and Barbeau labs have tested the hypothesis that iron limitation of primary production in the CCE may be exacerbated by increasing atmospheric CO_2 via the corresponding decline in carbonate concentration and inhibition of phytotransferrin-mediated iron uptake. We conducted trace metal clean incubations of natural phytoplankton communities under a range of pCO_2 during each Cycle. At initial (T_0) and two subsequent timepoints for each experiment, iron uptake rates of both uncomplexed ferric iron and siderophore-bound iron were measured and samples were collected for both mRNA and protein abundances, as well as dissolved iron, iron speciation, macronutrients, chlorophyll concentrations, and POC/PON. Combined, these data will allow us to assess the effects of ocean acidification on the bioavailability of distinct pools of iron and evaluate the cellular responses of the phytoplankton communities on a molecular level.

N Cycling – Aluwihare Group (Sara Rivera, Ralph Torres, Lihini Aluwihare [in absentia])

(1) Suspended Particulate Organic Matter (POM) and stable isotopes
Samples were collected on 47mm GF/F filters to measure particulate organic carbon (POC) and particulate organic nitrogen (PON) concentrations. The ^{15}N and ^{13}C content of suspended POM, as measured by isotope ratio mass spectrometry coupled to a CHN analyzer, will also be determined. Samples were collected from 10:30 am CTD casts for Cycles 1 – 4, at every station during Transects 2 and 3, at all 9 stations of the second BBL transect, and the Santa Barbara Basin CTD cast. Volumes of 4L were drawn from the CTD Niskin bottles using Masterflex tubing into carboys (rinsed 3x) covered with black plastic bags to prevent influences due to light. Samples were drawn by vacuum pump at a high rate to reduce time that the samples sat at room temperature (isolated within 1.5 hours of collection), and the filters were stored at -80° C.

(2) $^{15}NO_3$
Samples were collected into 60ml HDPE bottles from a 47mm GF/F filter holder attached directly to the Niskin bottle's nozzle and immediately frozen at -80° C (within 30 min of collection). These samples were taken to measure the ^{15}N and ^{18}O composition of nitrate in the seawater. Samples were collected from 10:30 am CTD casts for Cycles 1 – 4, at every station during Transects 2 and 3, at all 9 stations of the second BBL transect, and at the Santa Barbara Basin CTD cast.

(3) TOC/DOC
Samples were collected into 40mL pre-combusted clear borosilicate vials to later measure either the total or dissolved organic carbon concentrations. The primary intent from the TOC/DOC measure is to quantify one of the largest reactive organic reservoirs in the ocean. Samples for TOC and DOC were collected from 10:30am CTD casts for Cycles 1 – 4, at every station during Transects, all 9 stations of the second BBL transect, and at the Santa Barbara Basin CTD cast. 40mL volumes for DOC were collected from a 47mm GF/F filter holder attached directly to the Niskin bottle's nozzle. 40mL volumes for TOC were collected directly from the Niskin bottle nozzle. Samples were immediately acidified to a pH of 2 using trace metal grade acid upon collection (within 30 min).

(4) FDOM
Samples were collected into 40mL pre-combusted amber borosilicate vials to later measure the fluorescent properties of DOM. Samples for FDOM were collected from 10:30am CTD casts for Cycles 1 - 4 and at every station during Transects 1 and 2, and at the Santa Barbara Basin CTD cast. 40mL volumes were collected from a 47mm GF/F filter holder attached directly to the Niskin bottle's nozzle. Samples were immediately placed in the refrigerator upon collection (within 30 min).

Metabolites - Aluwihare Group (Ralph Torres, Lihini Aluwihare [in absentia])
To analyze marine community metabolomes, we enriched seawater samples for metabolites and separated them from salts using solid phase extraction (PPL cartridges) and stored the cartridges at -20°C until further processing ashore. Samples for marine community metabolomes were collected from 10:30 am CTD casts for Cycles 1 – 4, every station during transects, all 9 stations of the second BBL

transect, and the Santa Barbara Basin CTD cast. Ashore we will elute metabolites with methanol from the cartridges and analyze them via Liquid Chromatography Tandem Mass Spectrometry (LC-MS/MS).

Bacterial Biomass and Production – Aluwihare and Azam Groups (John Irving, Sara Rivera)
Samples for bacterial biomass were collected from 10:30 am CTD casts for Cycles 1 – 4, at every station during Transects, all 9 stations of the second BBL transect, and the Santa Barbara Basin CTD cast. To measure bacterial cell abundance and size at each depth cryovials were filled with 3 mL seawater, fixed with 120 µL of 25% glutaraldehyde, flash frozen in liquid nitrogen, and stored at -80°C. On shore, the cryovials will be thawed, filtered onto 0.2-µm pore polycarbonate filters, stained with DAPI, and examined microscopically. Bacterial cell abundance and size will be measured.

Samples for bacterial production rate were collected from 10:30 am CTD casts for Cycles 1 – 4, at every other station during Transects, and all 9 stations of the second BBL transect. To estimate rates of bacterial protein synthesis, seawater was incubated with approximately 20 nM ^{3}H-leucine for one hour at 9°C in triplicate with one control killed with final concentration 5% TCA. After the incubation was complete, all samples were killed with an addition of 100% TCA for a final concentration of 5% TCA. Samples were then pre-processed at sea by the centrifugation method. The dried pellets after the 80% EtOH wash were frozen and stored at -20°C. On shore, the pellets will be defrosted, scintillation cocktail added, and the tube assayed by liquid scintillation counter. The BBL samples were frozen and stored at -20°C; they will be fully processed using the centrifugation method on shore. Disintegrations per minute are converted to protein synthesis rates. This calculation is normalized by the corresponding cell abundances.

Microbial Community Composition - Allen and Aluwihare Group (Sara Rivera, Sarah Schwenck, Alice Levesque)
Samples for bacterial biomass and production were collected from 10:30 am CTD casts for Cycles 1 – 4, every station during transects, all 9 stations of the second BBL transect, and the Santa Barbara Basin CTD cast. For each sample, 2 L of seawater were filtered through a 0.22 µm Sterivex filter using a peristaltic pump. Excess water from the Sterivex filters was removed using a syringe; the filters were then sealed with putty, flash frozen with liquid nitrogen, and stored at -80°C. On shore, the RNA from the filters will be extracted, converted to cDNA, and sequenced for 16S, 18S V4, and 18S V9. The sequence data will be analyzed to determine the microbial community composition.

Viral dilution experiments – (Sarah Schwenck, Alice Levesque, with additional help from Shonna Dovel and Mike Stukel)

Viral dilution experiments were conducted in conjunction with full dilution experiments prepared by Mike Stukel to investigate the role of viral- induced mortality of the microbial community relative to grazer-induced mortality. These experiments were set up once at each Cycle, where each Cycle tracked a different section of a coastal upwelling filament as it moved further offshore.

Water for each experiment was collected on two evening CTD casts on the first day of each Cycle from the mixed layer, generally at ~10 m. From the first cast (1800), water was brought into the lab and filtered sequentially through first a 0.1µm Acropak filter and then a 50kDa tangential flow filter (TFF) to achieve virus-free water. This virus-free water was then used to fill bottles in triplicate for treatments of 20%, 40%, 70%, and 100% whole seawater (WSW) that would be sampled after 24 hours. In addition, single bottles of each treatment were prepared to be sampled at T0, triplicate bottles of the 20%, 40%, and 100% WSW treatments were prepared for sampling at T48, and six bottles of 100% WSW were prepared to investigate the impacts of nutrient addition to be sampled after 24 hours (triplicate with no nutrients addition, and triplicates of a 10% nutrient addition).

The second CTD cast (2000) was used to collect all of the whole seawater used for the experiments as well as the 0.1µm filtrate used to create the dilutions for the grazer experiment. Whole seawater was added to each bottle via a continuously-filling carboy attached to the CTD. Each bottle was filled to the brim without overflowing and then gently inverted to mix. Samples for flow cytometry were then taken from each bottle and nitrate and phosphate were added. The bottles were mixed once more and then placed into on-deck incubators for either 24 or 48 hours.

Following the appropriate incubation time, samples were taken from each bottle for flow cytometry, chlorophyll-*a*, viral counts, single cell work, nutrients, dissolved organic carbon, and -omics analysis including 16S, 18S, metatranscriptomics, and viral libraries from concentrates. The samples for chlorophyll and flow cytometry were processed with the help of Shonna Dovel.
Viral Counts: Triplicates of 4mL of water were preserved in 0.02% glutaraldehyde, incubated for 15 minutes, and then flash frozen in liquid nitrogen.
Single Cell: 2mL of water was centrifuged for 10 minutes at 3000 RPM. The supernatant was then poured off and the pellet flash frozen in liquid nitrogen.
Dissolved Organic Carbon: 40mL of water was filtered through a pre-combusted GFF filter into TOC vials, acidified with HCl, and stored in the dark at room temperature.
Nutrients: 20mL of water was filtered through a 0.2µm polycarbonate filter into scintillation vials and stored at -20°C.

Omics: The remaining volume in each bottle was filtered onto a 0.22µm Sterivex filter. A syringe was used to remove any remaining liquid in each filter and then the top end of each Sterivex was capped, and the bottom end sealed with Hematoseal. The filter was then flash frozen in liquid nitrogen and stored at -80°C. Ashore, RNA will be extracted from these filters for community composition analyses via 16S and 18S as well as for metatranscriptomic work.
Viral Concentrates: The filtrate produced from the Sterivex filters was concentrated down from ~2L to ~60mL via TFF, preserved with glycerol and stored at -20°C.

Microbial Community Biomass, New Production, Growth and Grazing – Stukel Group (Mike Stukel, Tom Kelly, Natalie Yingling, John Irving, Christian Fender)

Our goal for this portion of our work was to quantify phytoplankton growth rates and the protistan grazing rates. In addition to these primary goals, we also deployed an in situ array to track water parcels during Lagrangian experiments. We measured O_2:Ar net community production (NCP) and, on the Driftarray, $^{15}NO_3^-$ uptake, as well as phytoplankton growth and grazing in seawater dilution experiments. $^{15}NO_3^-$ uptake was measured during 24-hour *in situ* incubations conducted on our experimental array at 6 light depths on each day of our Lagrangian Cycles. This yielded a total of 78 samples that will be analyzed ashore. We also conducted deck $^{15}NO_3^-$ uptake experiments to quantify diel patterns of nitrate uptake and determine whether nitrate uptake was underestimated during 24-hour incubations. A total of four diel experiments were conducted, yielding an additional 32 nitrate uptake measurements.

We conducted two-point microzooplankton grazing dilution experiments. These experiments were conducted daily at six depths spanning the euphotic zone on the in situ array during our Lagrangian experiments. We conducted a total of 80 two-point dilution experiments. Samples from each of these experiments were taken for bulk chlorophyll-*a*, flow cytometry, and High Pressure Liquid Chromatography (HPLC). We found that phytoplankton growth rates typically exceeded protistan grazing rates in the surface ocean by a substantial amount. This excess growth was potentially available to mesozooplankton grazers. In addition, we conducted four full (i.e., five treatment) dilution experiments in deckboard incubators. The purpose of these experiments was to test the assumption of linearity in the two-point dilution experiments and to support viral dilution experiment measurements.

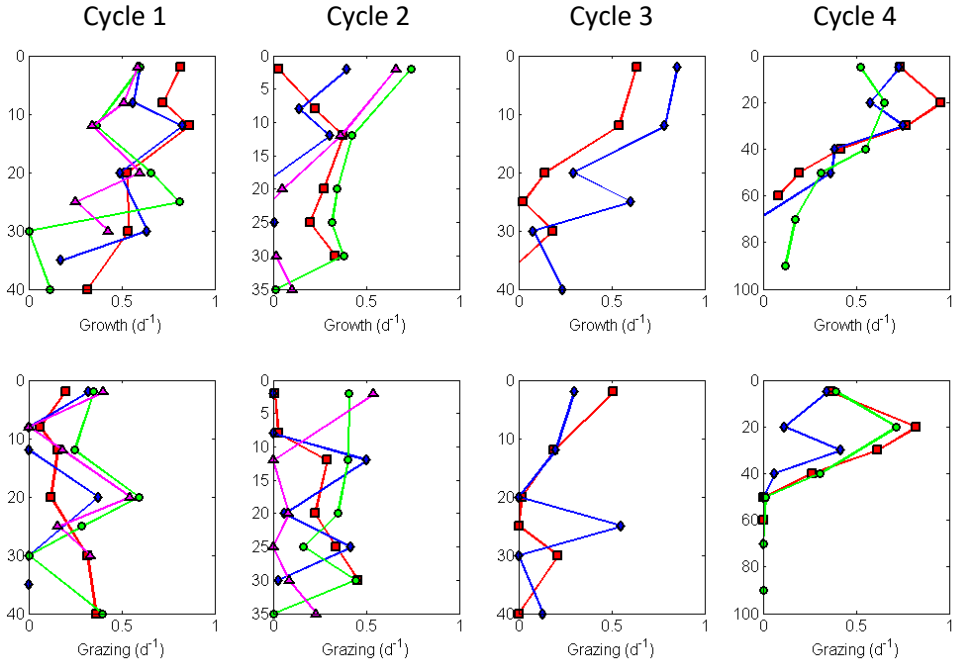


Fig. 17. Phytoplankton specific growth rate (upper panels) and specific grazing rate due to microzooplankon (lower panels) on each of our Lagrangian Cycles. Colors represent an individual day's experiments. Y-axis is depth (m).

Mesozooplankton – Ohman Group (Mark Ohman, Laura Lilly, Stephanie Sommer, Pierre Chabert, Julie Barrios, Benjamin Botwe, Jacob Evans, Natasha Morgan-Witts, Inès Mangolte, Alex Fledderjohn, Eric Lawrence)

***Moving Vessel Profiler (MVP)*:** A free-fall Moving Vessel Profiler (MVP) was deployed to characterize horizontal gradients in hydrographic and plankton properties and guide site selection for experimental Cycles (Fig. 7 above). The MVP sensors included a Laser Optical Particle Counter (LOPC, SN 11432), Wetlabs FLRT Chl-*a* fluorometer (SN 247), and AML Micro fast response CTD (initially SN 7209, changed to SN 7677 on 20 Aug. 2019). A total of 446 MVP casts were completed. Five MVP transects and 3 Bowtie surveys were completed, sampling either just before or after each Cycle and before or after CTD-Bongo-TM Transects 1, 2, and 3. In addition, at Cycle 4 where distinct daytime layers of pyrosomes were detected, a brief annular survey (diameter 350 m) of 11 MVP casts to 150 m in diameter was conducted between 1700-1740 on 30 Aug. in order to localize the pyrosome layers at depth. The larger pyrosome colonies formed a distinct layer at 55-65 m depth, closely overlapping the primary Chl-*a* fluorescence maximum.

Vertically stratified MOCNESS sampling: (Stephanie Sommer, Laura Lilly, Inès Mangolte, Natasha Morgan-Witts, Alex Fledderjohn, Eric Lawrence, Ben Osei Botwe, Pierre Chabert, Julie Barrios, Jake Evans):

Sampling coverage:
A total of 24 MOCNESS tows were completed: N=7 at Cycles 1 and 2, N=4 at Cycle 3, and N=6 at Cycle 4.

- *MOCNESS to 450m:* Cycles 1, 2, 3, 4 – Tows at 1300 and 2230 on days 1-2 of each Cycle (green LED strobe lights **OFF** for all 450 m tows)
- *MOCNESS to 1,000m:* Cycles 1, 2, 3, 4 – Tows at 1300 and 2230 on day 3 or 4 of each Cycle (green LED strobe lights **ON** for all 1,000 m tows)

Methods
Zooplankton samples were collected using a ten-net MOCNESS with 202 µm mesh nets and 1m^2 mouth opening. Samples were preserved in either 5% formaldehyde buffered with sodium tetraborate for morphological identification, Zooscan analysis, and biomass estimates ('Formalin'), or 95% non-denatured ethyl alcohol treated with 5 mM ammonium hydroxide for DNA analysis ('ethanol').

For standard MOCNESS (the first 4 tows of each Cycle, except for Cycle 3), sequential nets sampled from 450m to the surface at a ship speed of 2kts, with a nominal 45^o wire angle. Depth strata were: 0-25m, 25-50m, 50-100m, 100-150m, 150-200m, 200-250m, 250-300m, 300-350m, 350-450m. Each net from the first daytime and nighttime tow of each Cycle was washed down, and the entire sample split quantitatively with a Folsom splitter into two aliquots, which were preserved in Formalin and ethanol, respectively. The second daytime and nighttime tows of each Cycle were preserved in Formalin (with the exception of Cycle 3, which was an abbreviated Cycle with only one set of 450m MOCNESS samples).

The MOCNESS tows on day three of each Cycle (or day 2 of Cycle 3) sampled to 1,000 m with depth strata as follows: 0-50m, 50-100m, 100-200m, 200-300m, 300-400m, 400-500m, 500-600m, 600-800m, 800-1000m. The samples from the cod ends were immediately transported in seawater to a -20^{o} C constant temperature room to minimize sample degradation prior to preservation. These non-quantitative samples were split into two aliquots which were preserved in Formalin and ethanol. The nets were then washed down and any remaining organisms from the net wash were preserved as a separate Formalin sample.

One additional MOCNESS tow was completed at the end of Cycle 2, with depths sampled: 0-100m, 100-200m, 200-300m, 300-400m, 400-500m, 500-600m, 600-700m, 700-800m, 800-1000m. These samples were immediately transported in seawater to a -20^{o} C constant temperature room, then split into two aliquots. One aliquot was stored at 4^{o} C and sorted immediately for phaeodarians and other rhizarians (Tristan Biard and Stephanie Sommer), and the second aliquot was frozen in liquid nitrogen for analysis ashore.

Fig. 18. Live Phaeodarian sorted from a MOCNESS live tow (Tristan Biard). Scale bar = 0.5 mm

***Mesozooplankton biomass and grazing rates*:** (Laura Lilly, Stephanie Sommer, Pierre Chabert, Julie Barrios, Benjamin Botwe, Jacob Evans, Natasha Morgan-Witts, Ines Mangolte, Alex Fledderjohn, Eric Lawrence)

Sample/measurement coverage:

- *Oblique Bongos:* Cycles 1, 2, 3, 4 – Tows at 0930 and 2130 for the first 3 days of each Cycle (N = 22)
- *Vertical Bongos:* Transects 2 (Stations 1-7), 3 (Stations 1-9) (N = 16)

Methods

Zooplankton samples were collected using a two-net Bongo with 202 µm mesh nets, 71 cm mouth openings, and PVC cod end cups. For oblique Bongos (conducted during Cycles), nets were deployed from the surface to 300 m wire out (mwo) at 50 meters/min at a 45^{o} nominal wire angle. Nets were towed at 300 mwo for 30 seconds, then hauled back to the surface at 20 m/min at a nominal 45^{o} wire angle. The port net sample (which had a flowmeter attached across the net opening) was immediately placed in a bucket and anesthetized with carbonated water. The net was rinsed fully, and the rinse sample was also placed in the bucket. That bucket was immediately taken to the lab and split into three parts using a Folsom splitter:

- **Gut contents** – ¼ was filtered into a plastic cup with 202 µm mesh bottom and immediately frozen in liquid nitrogen to preserve zooplankton for future gut content analysis using molecular probes

- **Gut fluorescence** – 3/8 was size-fractionated through a five-filter sieve (5 mm, 2 mm, 1 mm, 0.505 mm, and 0.202 mm), and each size-fraction was transferred to a 0.202 mm filter, placed in a petri dish, and frozen in liquid nitrogen to be analyzed for gut fluorescence by fluorometry
- **Biomass** – 3/8 was size-fractionated through a five-filter sieve (5 mm, 2 mm, 1 mm, 0.505 mm, and 0.202 mm), rinsed with isotonic ammonium formate, and each size-fraction transferred to a pre-weighed 0.202 mm filter, placed in a petri dish, and frozen in liquid nitrogen. Filters will be weighed on land, and the tare weight subtracted to give a measure of biomass of each size-fraction.

The second bongo cod end was placed in a bucket (but not anesthetized), along with its net rinse. That sample was placed in a pint or quart jar with seawater and 5% Formalin buffered with sodium tetaborate, and preserved for future species identification.

For vertical Bongos (conducted during Transects), the frame was bolted so that net openings could not pivot, then the cod ends snapped onto a horizontal spreader bar. Nets were lowered vertically from the surface to 100 mwo at 30 m/min with a nominal 0° wire angle. Nets were held at 100 mwo for 20 seconds, then hauled back to the surface at 0° wire angle at 50 m/min. Samples were processed the same as for oblique tows except that gut fluorescence and biomass samples were preserved whole (i.e., no size-fractionation).

Fig. 19. Zooplankton samples – from cross-filament Transect 2. Jars are arranged from Station 1 (west, left) to Station 7 (east, right). Stations 2-4 were in the filament core, as evidenced by dense, dark green samples. Station 7 has a large pyrosome colony.

Copepod egg production experiments **-** (Laura Lilly, Stephanie Matthews, Mark Ohman)

This study quantified egg production rates (EPR) and hatching success of the copepod *Calanus pacificus* along the Pt. Sur filament and in contrasting waters offshore. Egg-laying rate and hatching success are metrics of population growth potential, and can be used as a proxy measure of secondary production for one species. This study focused on EPR in 3 different stages of filament evolution (i.e., newly-upwelled, more mature, offshore-mixing) and a fourth comparison location in lower productivity California Current waters.

People involved at sea: Laura Lilly, Stephanie Matthews, Sven Gastauer, Mark Ohman

- *Bongo tows:* Laura Lilly, Sven Gastauer, Mark Ohman,
- *Copepod sorting:* Stephanie Matthews, Mark Ohman
- *Egg/nauplii counting:* Laura Lilly

Sample/measurement coverage: Cycles 1, 2, 3, 4 – Tows 1, 2, 3 (first three mornings of each Cycle). N.B.: Cycle 3 only had two Tows.

Methods: Live copepods were collected at 0830 every morning using a Bongo net with two 333 µm mesh nets and sealed cod end cups (to protect animals from water flow). The net was lowered to 300 mwo at 50 m min^{-1}, maintained for 3 min at depth, then recovered at 20 m min^{-1}. Upon recovery animals were promptly diluted in 3.8 L jars of seawater collected at >200 m depth and maintained at 13.5° C. Samples were immediately sorted and adult female *Calanus pacificus* removed and placed in individual 20 mL petri dishes filled with seawater from the chlorophyll maximum layer (which ranged from 0-30 m depth). Copepods were incubated in the dark at 13.5°C for 24 h, and were checked twice (at 12 and 24 h) for egg production, at which time the chlorophyll maximum seawater was replenished. If females produced eggs, they were removed; eggs were counted and placed in the incubator for an additional 36 hours to assess hatching success. After the 24 hour incubation, females were preserved in seawater with 5% Formalin for prosome length measurements ashore.

We measured moderately high average egg production at Cycle 1, in newly upwelled filament waters (Fig. 20). Cycle 2 (more mature filament waters) had the highest average egg production. Cycle 3, in the mixing and aged filament, had very low egg production, particularly on Day 2. Cycle 4, in low-productivity pelagic waters not part of the filament, had healthy adult female copepods but zero egg production.

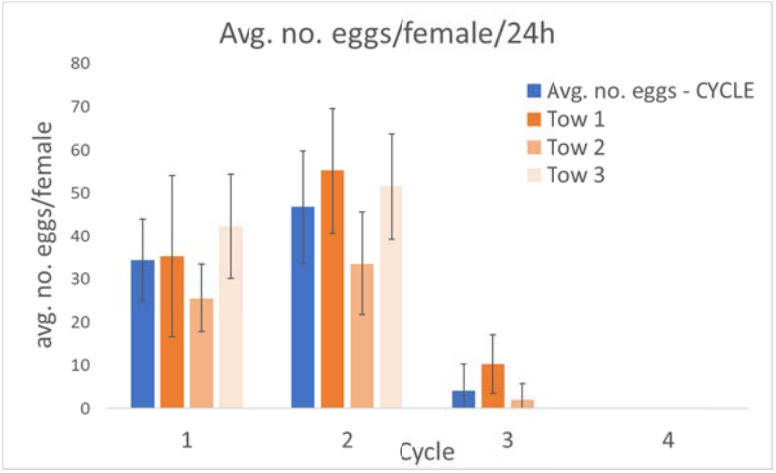


Fig. 20. Egg production rates of females of *Calanus pacificus* by Cycle (blue = Cycle average; orange shades = each individual tow). Cycle 3 only had two tows. Cycle 4 had three tows but zero egg production at each tow.

EK60 multi-frequency sonar: (Sven Gastauer)

Acoustic equipment setup

Four Simrad echosounders operated at 38, 70, 120 and 200 kHz (Table 1) were positioned in a pod at the lower end of a steel pole (with extension) attached to the port side of the R/V *Atlantis*. The pole had a submerged V-fin and was held in lateral position by a stainless-steel cradle attached to the ship's hull magnetically, and stayed with 2 pairs of steel cables running fore and aft. The lower pair of cables was faired.

Table 2. Echosounder survey settings

Model	ES**38**-12	ES**70**-7C	ES**120**-7C	ES**200**-7C
Serial #	0	163	403	377
Pulse Duration [ms]	1.024	1.024	1.024	1.024
Power [W]	1000	750	250	120
Mode	CW/Fast Ramping	CW / Fast Ramping	CW / Fast Ramping	CW / Fast Ramping

Vibrations of the pole of differing intensity were visible throughout the survey. The depth of the pod below the water surface was roughly 2 m. The ship's speed was limited to 8-8.5 kts when the pole was submerged. The magnetic attachment device proved unsatisfactory because it moved up and down on the hull, and in some sea states briefly separated from the hull.

Synchronization of acoustic equipment

All Simrad echosounders were set to ping at the same time (i.e., not sequentially). Other acoustic equipment, such as ADCP's, other echosounders, multibeam systems or sonars can cause interference that are visible in the data as 1 ping x few samples long 'spikes' (impulsive noise; see Ryan et al. 2015 for details, **Error! Reference source not found.**). To avoid these noise patterns, acoustic equipment should be synchronized if possible. Other acoustic equipment in use during the cruise included a narrowband ADCP at 75 kHz, a narrowband ADCP at 300 kHz, as well as a Knudsen 12 kHz echosounder.

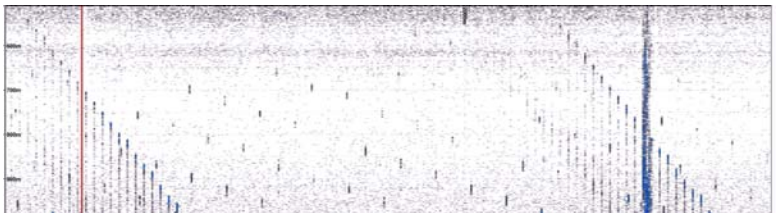


Fig. 21. Typical impulsive noise structure measured on P1908

The 75 kHz ADCP was synched using a serial connection from the EK60 auxiliary port to the triggering port on the ADCP. In the EK80 software, under settings, Installation, Synchronization, the Synchronization Mode was set to Master with a synchronization delay of 100 ms and Serial Port 1 as Synchronization Port. In the ADCP software, trigger in, out were set to 300, 300.

The 300 kHz ADCP that was initially not intended to be used during the cruise could not be synchronized. After the 75 kHz ADCP was found to provide inadequate near-surface coverage, the 300 kHz ADCP was used throughout. This might cause some limited impulsive noise issues, which should be removed during post-processing.

The Knudsen 12 kHz could not be synchronized and its use causes clear noise spikes. The use of this echosounder was limited to situations where continuous bottom depth was necessary, such as during Seasoar or MVP transects.

Whenever noise spikes are removed during post-processing, detected spikes should be replaced by an empty data cell, rather than being 'smoothed' through a mean or median of the surrounding pings, which causes the introduction of 'false' data. Impulsive noise can be detected by comparison of a given range of samples with a sliding window average of a number of surrounding samples.

Acoustic calibration

The EK60 38, 70 and 120 kHz were calibrated on 18 July 2019 at the NOAA SWFSC facilities, using standard sphere operations as outlined in the ICES CRR Calibration of Acoustic Instruments (Demer *et al.*, 2015). First attempts to calibrate the 200 kHz failed due to a faulty extension cable. Impedance values were out of the expected range (reading 1.5 Ohm for quadrant 4) while resistance values for each pin were within reason. Cutting the cable short by a few inches and re-terminating it resolved the issue and a successful calibration was performed on 19 July.

- Calibration was performed using Simrad EK80 software.
- All beams were updated at the end of the calibration.
- Diagnostic plots were computed using ESP3 v.1.3.0 (Ladroit, 2017) following the routines of the original TS Cal Matlab script developed by Gavin MacCauley (NIWA, IMR).

Calibration results are summarized in Table 3.

Table 3. Calibration results prior to the cruise for the Simrad EK60 operated at 38, 70, 120 kHz and the EK80 operated at 200 kHz in CW mode, using standard survey settings.

Parameter	**ES38-12 Serial No: 0**	**ES70-7C Serial No: 163**	**ES120-7C Serial No: 403**	**ES200-7C Serial No: 377**
Frequency	38000	70000	120000	200000
Gain	21.83	26.47	25.75	26.87
Beam Width Alongship	12.45	6.75	6.77	6.72
Beam Width Athwartship	12.50	6.74	6.79	6.78
Angle Offset Alongship	0.09	0.05	-0.05	-0.04
Angle Offset Athwartship	-0.19	0.13	0.03	0.07

SaCorrection	-0.5544	-0.3628	-0.2771	0.0230
Equivalent Beam Angle	-15.50	-20.70	-20.70	-20.70
Impedance	75.00	75.00	75.00	75.00
Phase	0.00	0.00	0.00	0.00
TS RMS Error	*0.0677*	*0.0493*	*0.0692*	*0.0948*

It is recommended that a post-cruise calibration be completed, to test the stability of the echosounders.

Data recording

Acoustic data were recorded continuously, unless the vessel was transitioning between stations at speeds above 9 kts. Acoustic data were recorded using Simrad EK60 and EK80 echosounders, as detailed in Table 1. Ping rate (P.R.) was generally kept at around 1 Hz unless either a ghost bottom was visible (P.R. was slowed down by 0.1 s increments until ghost bottom disappeared and reset to 1 s after the feature causing the ghost bottom was passed) or when in shallow waters, ping rate was increased to obtain the best possible data resolution (P.R. = 0.750 s).

Data were saved directly to an external hard disc and backed up at least every 48 hours. File size was restricted to 25 MB to simplify post-processing. 38 kHz data were recorded down to 1000 m, 70 kHz to 600 m, 120 kHz to 300 m and 200 kHz to 200 m. For the first two days all data were recorded to 1000 m. Initially the 200 kHz EK80 in CW mode was recoding data in full resolution, causing very large amounts of data. From 20 August onwards, this was set to Power/angle samples (reduced file size). It is recommended that the replayed data be used for post-processing to simplify data management.

On two occasions the 38 kHz lost connection without any obvious reason, requiring a hard reset of the 38 kHz GPT. On both occasions this coincided with the deployment of the Seasoar or MVP, albeit probably unrelated. In the first occurrence data were lost for ca. half an hour and for ca. one hour on the second occurrence.

Data quality

In very good weather conditions (calm, virtually no wind), the data quality appears to be fine. Once some swell (<2 m) build up, data quality degraded quickly, with lost pings caused by bubble sweep down. This was always most notable on the 38 kHz, then the 70 kHz, followed by the 120 kHz and the 200 kHz, which is attributable to the positioning of the transducers on the pod. For some days, where weather conditions were not ideal, up to 50 % and more of the pings were lost, rendering the data useless. It is recommended that where possible, a vessel with a dropped keel, as recommended by the ICES Acoustic Survey standards should be used. If this is not an option, then a vessel with a hull mounted or a towed body system is preferred. If a pole setup is being used, it should be positioned in a more stable position on the vessel (fixed attachment) and the transducers should be placed at least 4 m below the water surface to avoid complete signal attenuation in sub-ideal weather conditions.

Opportunistic Recordings

Illustration of acoustic recordings – First BBL survey

The echogram below shows the first Benthic Boundary Layer (BBL) survey, with the continental shelf clearly visible. This also illustrates the layered structure of the water column and some fish schools in the water column or close to the bottom.

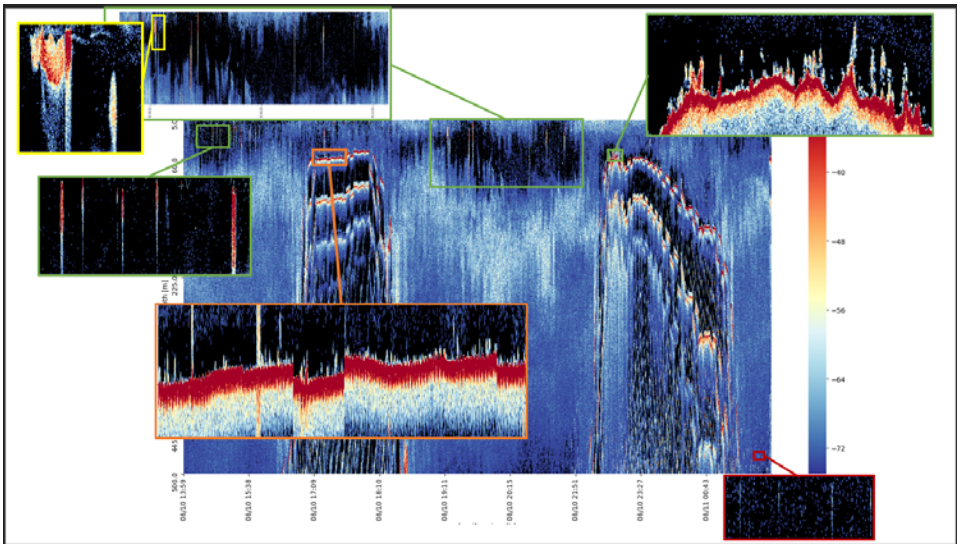


Fig. 12. Acoustic recordings at 38 kHz of the BBL survey: Red box: impulsive noise signals; Orange box: seafloor; Green boxes: Fish schools close to the bottom or in the water column; Yellow box: detailed view of a water column fish school

Acoustic recordings of whales

Occasionally, when whales were passing by the vessel, they would appear as strong traces on the echograms as well if they swam beneath the vessel, as illustrated below.

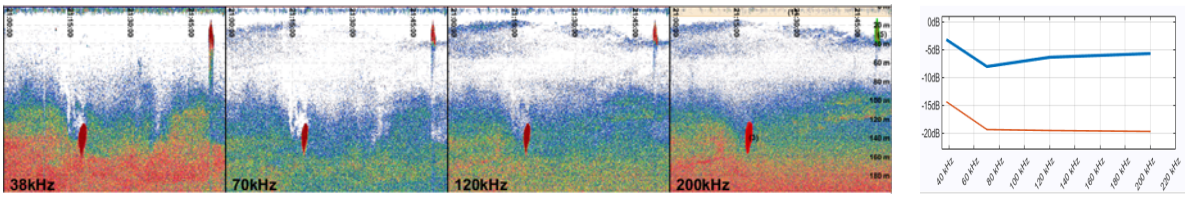


Fig. 23. Whale detected on the echosounders on the Sv echogram at four frequencies and the TS frequency response of the signatures

Pyrosomes

From the beginning of Cycle 3 pyrosomes (probably *Pyrosoma atlanticum*) were visible at the sea surface during nighttime. This occurrence led to a brief investigation into the colonies' distributions and material properties. Throughout 3 days a constant layer was observed at around 25 – 75 m depth in the daytime, with a stable TS frequency response (illustrated in Figs. 24 and 25). At ~ 1600 on 19 Aug., two dedicated double oblique bongo tows (down to ~70 m) were completed to sample the layer. At the same time, the acoustic pulse length was modified to receive higher resolution data for single target

detection. At ~ 1700 on 30 Aug (at Cycle 4) a short MVP (with an LOPC sensor) and acoustic mini-survey were completed (26). Qualitative comparison between the MVP and the acoustics revealed similar findings with the highest concentrations of organisms at around 50 – 70 m. What might appear to be a single structure layer at first sight, proved to be a multi-structure layer, clearly visible when comparing the different frequencies (**Error! Reference source not found.**).

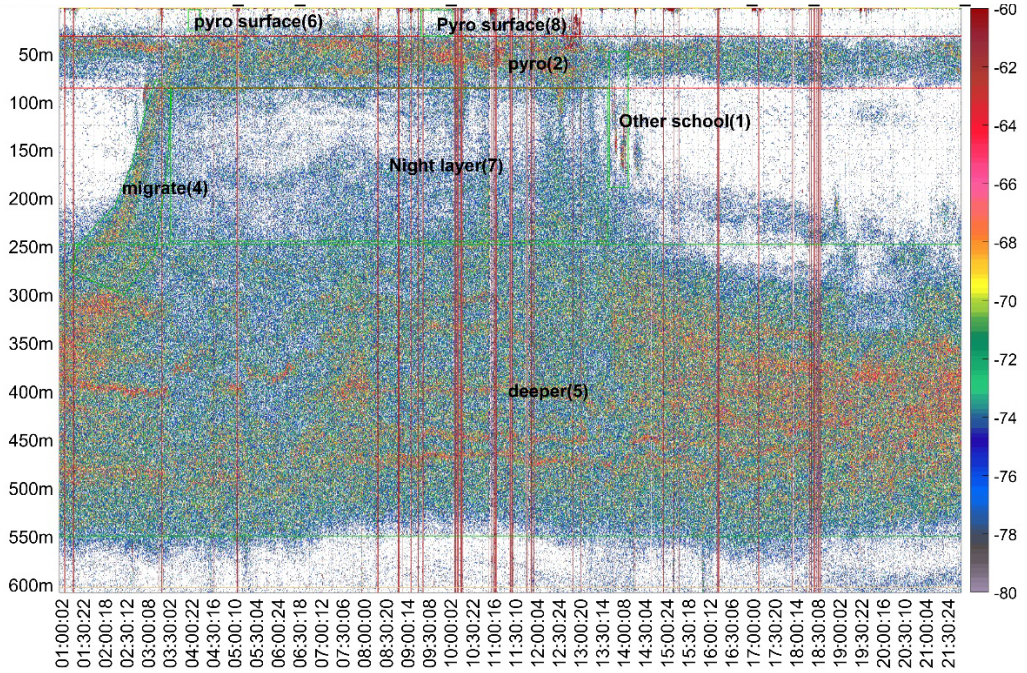


Fig. 22. 20.5 hours of acoustic recordings at 38 kHz prior to the acoustic - MVP survey for pyrosomes. This illustrates a clearly visible Diel Vertical Migration of some of the organisms (upwards migration – migrate (4)), a stationary pyrosome layer, strongest between 25 and 70 m (pyro (2)), a night layer between the two vertical migration phases (Night layer (7)), a deeper stationary layer at 250 – 550 m (deeper (5)) and a fish school (other school 1). Red vertical lines indicate lost pings.

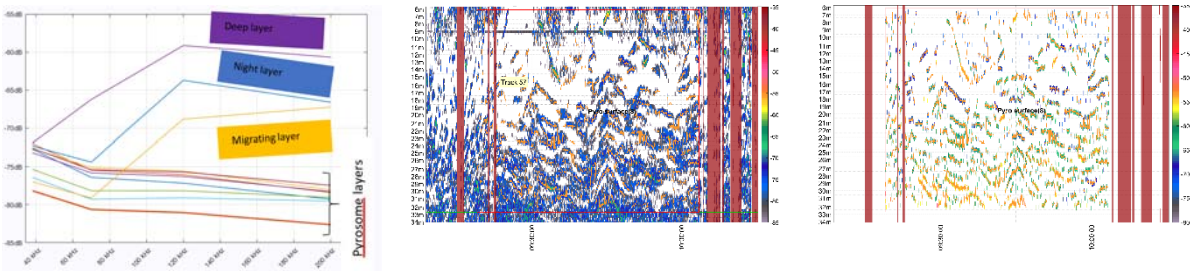


Fig. 23. a) TS frequency response for the different layers shown in the figure above, b) Acoustic traces of pyrosomes as observed near the surface, c) Single target detections of pyrosomes close to the surface with an indication of the movement tracks of individual pyrosomes (yellow lines). Red vertical lines are ping drop outs.

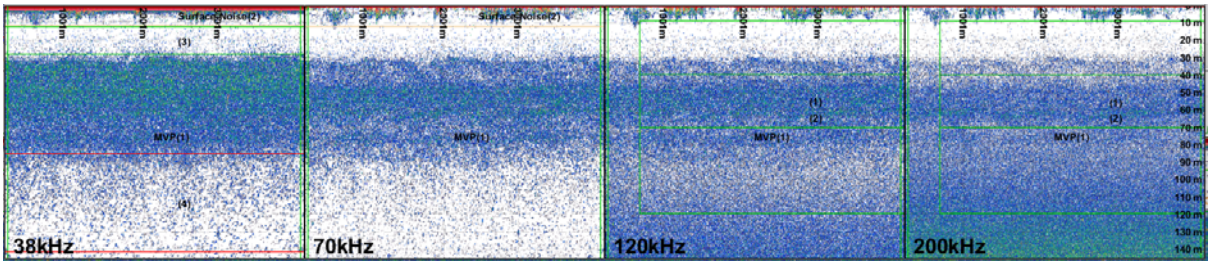


Fig. 24. Acoustic -MVP mini survey as observed on the 4 frequencies

In order to improve target strength estimates of pyrosomes, we conducted a set of density and soundspeed contrast experiments ast sea. For this purpose ambient seawater was enriched with NaCl, to create more dense water solutions. Entire pyrosome colonies as well as ~1.0-1.5 cm^2 squares of live zooids were carefully placed into solutions of different density and it was noted whether they rose or sank (**Error! Reference source not found.**). This allowed the estimation of density and soundspeed contrasts, as important input values to acoustic scattering models (Fig. 27). For the purpose of these experiments, dedicated ring-net tows were taken at the surface, with minimal tow durations (3-6 minutes), large non-filtering cod end reservoirs, and gentle handling of the pyrosome colonies, to ensure the best possible condition.

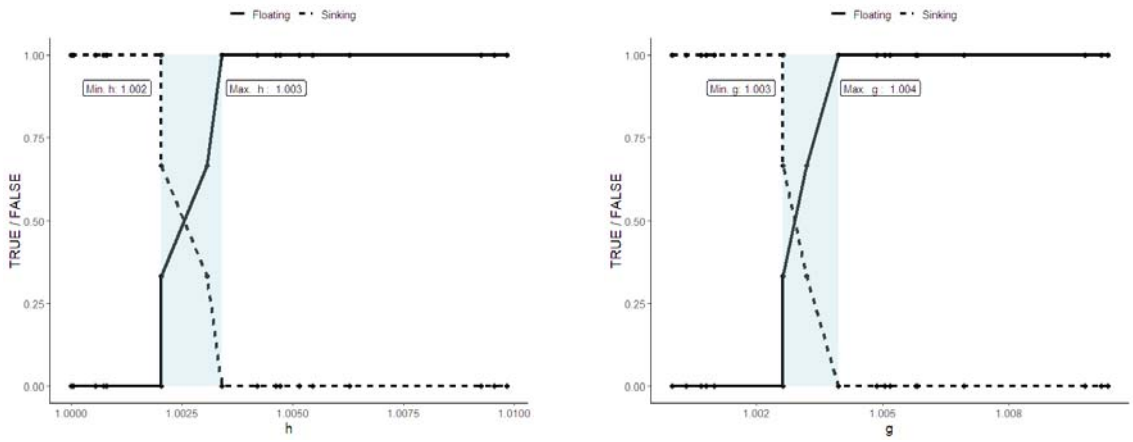


Fig. 27. Proportion of sinking vs floating pyrosomes at different sound speed - h (a) and density - g (b) contrasts

Underwater Vision Profiler (UVP5) – (Tristan Biard)

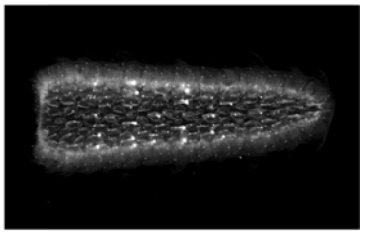


Fig. 28. Pyrosome colony, imaged by UVP5 at Cycle 4. Tristan Biard.

Instrument and configuration

UVP5-HD, serial number sn201; Image volume = 1.14 L. Pixel size is 88 x 88 µm. Instrument borrowed from Emmanuel Boss and Lee Karp-Boss, Univ. of Maine.

UVP data (LPM and Plankton)

A total of 77 casts (including 9 from the final BBL survey and one from the Santa Barbara Basin) were performed, generally to a standard depth of 1,000m. All casts were processed on board ship using *ZooProcess* software to extract vignettes of large particles/plankton. Preliminary validation has been performed on selected casts and revealed the dominant zooplankton groups typically observed in CCE process cruises. Table 4 below summarizes the different types of casts, which recorded vignettes of organisms and marine snow, as well as enumerating Large Particulate Matter (LPM.

Table 4. Summary of UVP5-HD casts made on P1908.

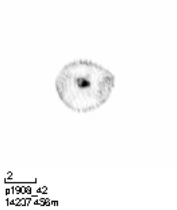
Type	Casts (n)	Standard depth (m)	Vignettes (total)	Validation
Test casts	3	300, 600, 1,000	17,403	100%
Transect 1	6*	300	17,456*	0%
BBL (1)	3*	--	4,386*	0%
Cycle 1	11	1,000 (two 200m + one 2,000m)	149,451	94%
Transect 2	7	300	125,858	0%
Cycle 2	11	1,000 (one 200m + one 2,000m)	365,689	0%
Cycle 3	6	1,000 (two 200m + one 2,000m)	122,165	21%
Transect 3	9	300	120,561	0%
UVP/Zooglider	2	250	6,140	0%
Cycle 4	9	1,000 (two 200m + one 2,000m)	51,460	79%
BBL (2)	9	--	--	--
	76		**980,569**	

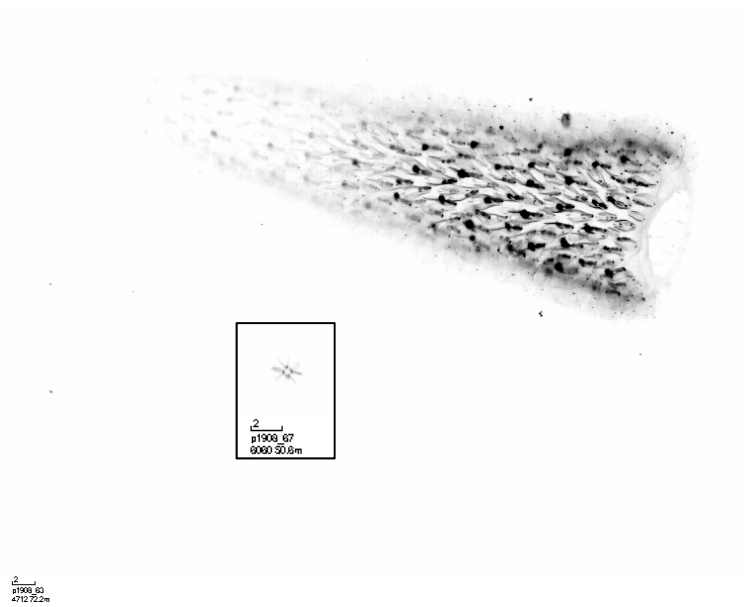
** Due to an instrument malfunction (one of two lights not working) these casts are highly dubious regarding the accuracy of the UVP. The consequences are: uncertain abundance profiles and particle size spectra.*

Fig. 29. Notable facts (preliminary) from UVP5 observations

Cycle 1 - UVP vignettes from Cycle 1 contained a large number (n ~ 350) of (anchovy?) fecal pellets consistently observed over the course of the Cycle. These pellets were imaged from the surface down to the deepest location reached by the rosette. The first 50 vignettes were imaged within the first 150m while more than 200 vignettes were recorded at depths greater than 500 m.

Cycle 3 - Preliminary analysis of this Cycle suggests 1) the presence of copepod populations (674 vignettes) in concentrations larger than usual, and 2) high abundances of protists belonging to the family Aulosphaeridae.





Cycle 4 - This Cycle was clearly characterized by the presence of large pyrosome colonies in the upper 100m from day 1 to day 3 (morning). The preferred depth varied from daytime to nighttime, with a clear distribution within the upper 30 m at night, and a daytime location at ~70m. Likely “juvenile” pyrosome colonies were also observed alongside “adult” colonies.

Zooglider (Mark Ohman and Sven Gastauer)

An autonomous *Zooglider* (Fig. 30, Ohman et al. 2018. LOM doi 10.1002/lom3.10301) was deployed at sea for 14 days, to assess frontal gradients in plankton communities and hydrographic properties across the Pt. Sur Filament. Measurements were made in a series of 110 *Zooglider* dives from 400-0 m, in which optical images of zooplankton and marine snow were recorded by Zoocam, acoustic backscatter measured at 200 and 1000 kHz (by Zonar), and CTD and Chl-*a* fluorescence also recorded. *Zooglider* was deployed from the R/V *Atlantis* at 1700 on 13 Aug. 2019 at Cycle 1, then recovered at 1100 on 27 Aug. 2019 by small boat just west of the location of Cycle 2. At the time of *Zooglider* recovery, a brief Annular Survey was made around the *Zooglider* location to record acoustic backscatter at 200 kHz from the shipboard EK60 for comparison with Zonar measurements. Two CTD-rosette profiles were made to compare UVP5-HD profiles of plankton with Zoocam profiles. At the second CTD cast, water samples were taken for Chl-*a* analyses. It proved to be highly advantageous to be able to make autonomous *Zooglider* measurements in a geographically separate part of the Pt. Sur Filament than analyzed concurrently by shipboard measurements. Upon both deployment and recovery, *Zooglider* attracted the attention of seabirds (notably black-footed albatross), as well as Pacific white-sided dolphins upon deployment (Fig. 31).

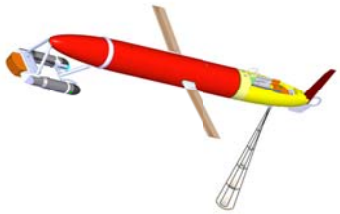


Fig. 30. *Zooglider* (Ohman et al. 2018)

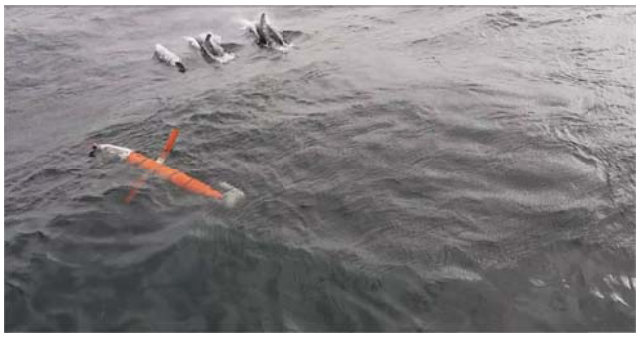


Fig. 31. *Zooglider* immediately after deployment at Cycle 1 (S. Gastauer)

Export Production - Stukel group (Mike Stukel, Tom Kelly, Natalie Yingling, John Irving, Christian Fender)

Our goal for these measurements was to quantify the balance between New and Export production along and across the Pt. Sur Filament as water was advected offshore.

We deployed sediment traps during each of 4 Lagrangian Cycles. Vertex-style sediment trap cross-pieces (8:1 aspect ratio, with a baffle on top with similar 8:1 aspect ratio) were typically placed slightly

below the base of the euphotic zone (50 – 85 m) and at depths of 120 m, 175 m, and 445 m (445 m depth trap was not utilized on Cycle 1). To quantify the spatial variability and extent of carbon flux, we used ^{238}U-^{234}Th deficiency measurements. ^{238}U-^{234}Th deficiency was measured at 12 depths on two profiles during each of our Lagrangian Cycles for comparison with the sediment trap results (96 samples). It was also measured at 8 depths at each station during three Transects across the filament region (176 samples). We also measured surface ^{238}U-^{234}Th deficiency in samples taken during SeaSoar and MVP spatial surveys through the study region at the beginning and end of the cruise (117 samples). Preliminary results show enhanced export in the filament relative to offshore waters (Fig. .

We subsampled sediment traps for a multitude of measurements including: C and N, particulate Si, δ^{13}C and δ^{15}N, C:^{234}Th ratios, Chl-*a* and phaeopigments, trace metals, organic molecules, microscopy, genomics, and transcriptomics (transcriptomics sediment trap tubes deployed with RNA Later in tubes to preserve RNA contained in organisms on sinking particles). We also deployed tubes containing polyacrylamide gel at the 150 m depth to preserve aggregates and other sinking particles in their in situ shapes for microscopic analysis. We used "Labyrinth of Doom" traps deployed at 105 m depth to differentiate vertically-migrating mesozooplankton that swam into the traps from dead sinking mesozooplankton. Initial results (based on pigments and preliminary microscopic analyses) suggest that fecal pellets (produced primarily by euphausiids and/or copepods) were the primary source of sinking particles in the Pt. Sur Filament. Planktivorous fish fecal pellets (likely anchovy) were also an important component of vertical flux during Cycle 1. Total pigment flux was elevated in the coastal region at Cycle 1, somewhat lower and similar at Cycles 2 and 3, which were still within the filament, and substantially lower in Cycle 4 (conducted in California Current waters; see Fig. 33A). Phaeopigment-to-Chlorophyll ratios were fairly similar across Cycles and typically increased with depth, while total pigment flux decreased with depth (Fig. 33).

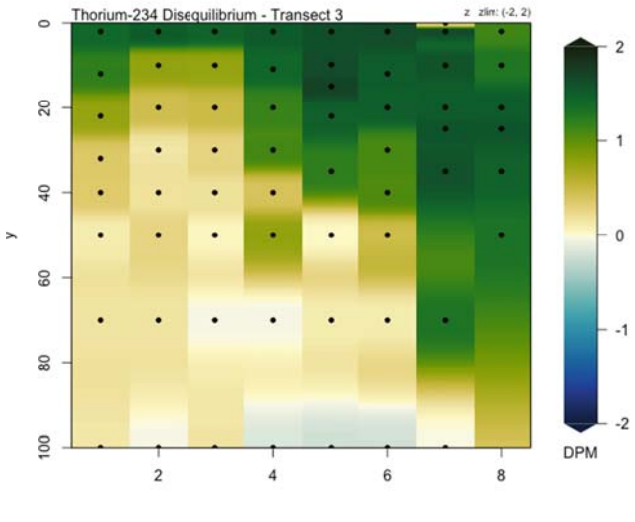


Fig. 32. Vertical section of ^{238}U-^{234}Th disequilibrium across Transect 3. Y-axis is depth (m).

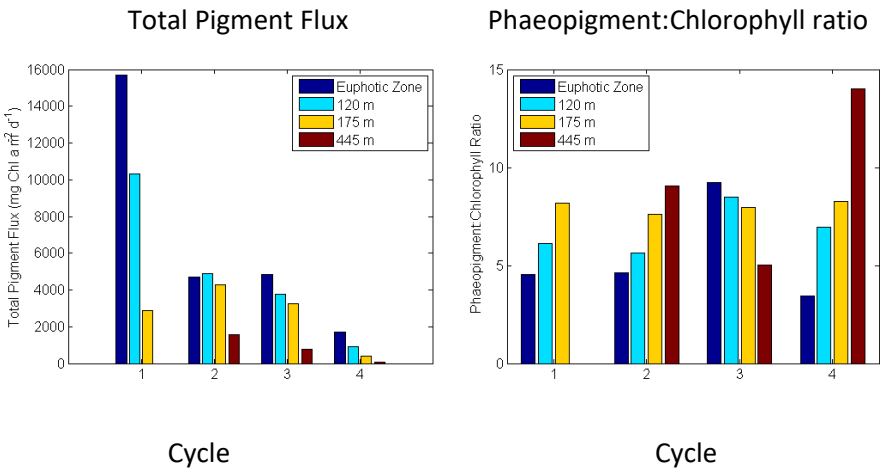


Fig. 33. Pigment flux recorded in sediment traps. Colors indicate different trap depths (euphotic zone to 445 m).

INFORMATION MANAGEMENT (James Conners)

CCE IM set up an event logger to provide a listing of each research activity, with assigned event numbers, date, time, and latitude/longitude. A glossary of activity names incorporated as a configuration file serves as a controlled vocabulary list. Unlike on previous cruises, the bridge on the R/V *Atlantis* did not agree to participate in logging events, hence a logging laptop was not set up there and all events needed to be recorded by the science party. Event log cleaning will be done post-cruise, including checking for consistency and missing events, in order to facilitate post-cruise coordination of datasets. Cruise data will be served on CCE's DataZoo.

EDUCATION, OUTREACH, AND CAPACITY BUILDING (EOCB)

Our **EOCB** activities included providing seagoing research opportunities and training for 16 graduate students, 5 undergraduate students and other volunteers, 1 postdoctoral investigator; accommodating visiting assistant professors from the University of Ghana (Accra, Ghana) and the University of Lille (France); and communicating with the general public via an online blog created by graduate student Laura Lilly (https://cce.lternet.edu/blogs/201908/). The blog presents, in accessible language, accounts of our science and life at sea.

Three **Science Chat** seminars were provided at sea by the science party for all interested:

20 Aug. – Sven Gastauer: "*Ocean Bioacoustics*"

29 Aug. – Pierre Chabert: "*Temporal Variability in Cross-shore Fluxes in the California Current Ecosystem"*

2 Sept. – Kiefer Forsch and Sara Rivera*: "Searching for Life's Essential Ingredient in the Benthic Boundary Layer (BBL)"*

In addition, on 3 Sept. a **Science Tour** was offered on the ship, providing a brief overview of different measurement methods and experiments in the shipboard laboratories and on deck. Thus tour was intended to acquaint all participants with the full range of CCE-LTER science activities at sea, including the science party and ship's crew.

CCE-P1908 DAILY ACTIVITY SCHEDULE

(5 August – 6 September 2019) ***R/V Atlantis***

Listed are intended times; consult Event Log for actual times.

5 August (Mon.)

1400 Depart MARFAC (departure delayed for high tide)
1700 TEST STATION (32° 51.3', 117° 39.3' W)
CTD test cast
Trace Metal rosette test
Bongo test
MOCNESS test
~2300 Transit to EK60 pole deployment location

6 August (Tues.)

1300 MVP (Moving Vessel Profiler) test
1600 EK60 pole deployment (34° 02' N, 120° 40' W); ship speed tests
1700 Transit to waypoint (34° 13.7' N, 120° 49.5' W) for start of Seasoar
1800 Calibration casts for Seasoar
CTD cast to 1,000 m (wdp)
Trace Metal cast to 1,000m (wdp)
2000 Deploy Seasoar
(Seasoar survey will continue without stopping for ~ 3 days)

7 August (Wed.)

Seasoar survey (~ 507 nm)
(w/ continuous measurements of EK60, pH/pCO_2, O_2:Ar, ALFA, meteorological and standard ocean variables, w/ point samples for Thorium, HPLC, Chl-a, POC/PON, nutrients)

waypoint		
1	34° 13.7' N	120° 49.5' W
2	36° 34.7' N	122° 16.1' W
3	36° 27.3' N	122° 34.4' W
4	34° 06.3' N	121° 07.3' W
5	33° 58.8' N	121° 25.1' W
6	36° 19.8' N	122° 52.7' W

8 August (Thurs.) Seasoar survey

9 August (Fri.) Complete Seasoar Survey

1430 - Recover Seasoar
1630 - CTD calibration cast
Trace Metal cast (bottle conditioning)
1830 - MVP trials 2
2130 - Recover MVP and steam toward Pt. Sur

10 August (Sat.)

0700 - Start MVP Pt. Sur survey (~ 75 nm)

Waypoints:

001	36° 03.2' N	122° 03.6' W
002	36° 11.8' N	121° 45.1' W
003	36° 14.4' N	121° 51.4' W
004	36° 07.3' N	122° 06.6' W
005	36° 11.5' N	122° 09.5' W
006	36° 17.8' N	121° 55.8' W
007	36° 23.1' N	121° 56.3' W
008	36° 15.7' N	122° 12.3' W

1900 - Recover MVP and steam to first transect location

2100 - **TRANSECT 1 (CTD-TM-Bongo)**:

1	36° 10.5' N	122° 12.3' W -	CTD, Trace Metal, bongo
2	36° 10.6' N	122° 06.9' W -	CTD
3	36° 10.8' N	122° 01.5' W -	CTD, Trace Metal
4	36° 11.0' N	121° 56.1' W -	CTD
5	36° 11.2' N	121° 50.8' W -	CTD, Trace Metal
6	36° 11.4' N	121° 45.4' W -	CTD, Trace Metal

11 August (Sun.)

0800 Complete TRANSECT 1 **(CTD-TM-Bongo)**

0900 (or just after completion of Transect 1) – Steam outside 12 nm for water generation and pump tanks, if needed

1300 Benthic Boundary Layer stations (N = 3), w/ CTD and Trace Metal rosette

BBL1	36° 19.2' N	121° 56.3' W
BBL2	36° 16.3' N	121° 54.7' W
BBL3	36° 13.7' N	121° 49.7' W

1900 MVP survey – Bowtie 1

2100 Steam beyond 12 nm to generate freshwater

12 August (Mon.)

1600 Steam to location for MVP survey

1800 MVP Transect 2

2200 Deploy sediment trap, **Begin Cycle 1** (position depends on MVP survey)

13 August (Tues.) – Cycle 1, Day 1

0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy Driftarray #1
0500 CTD, for Thorium
0600 Trace Metal cast
0830 Bongo live tows, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
1100 CTD, for microbiology, dissolved organics
1230 MOCNESS – Day #1 (start 2 nm downwind of Driftarray)
1500 Steam to location for Zooglider deployment (position tbd; inshore of Driftarray)
1600 Zooglider deployment
1700 Return to Driftarray location
1800 CTD, viral dilution experiments
2000 CTD, full dilution experiments (shallow CTD)
2130 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
2230 MOCNESS – Night #1 (start 2 nm downwind of Driftarray)

14 August (Wed.) – Cycle 1, Day 2

0130 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover Driftarray #1/Deploy Driftarray #2
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1230 MOCNESS – Day #2 (start 2 nm downwind of Driftarray)
1615 MVP tests
1900 CTD, experiments
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
2230 MOCNESS – Night #2 (start 2 nm downwind of Driftarray)

15 August (Thurs.) – Cycle 1, Day 3

0130 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover Driftarray #2/Deploy Driftarray #3
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1300 Deep MOCNESS (start 2 nm downwind of Driftarray)
1900 CTD, experiments

2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
2230 MOCNESS – Night #3 (start 2 nm downwind of Driftarray)

16 August (Fri.) – Cycle 1, Day 4
0130 CTD, sampling & *in situ* experiments
0430 Recover Driftarray #3/ Deploy Driftarray #4
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1300 MacLane pump (Stukel)
1600 MIMS pump profile (Stukel)
1730 Deep CTD (2,000 m); remove PAR and ISUS
2100 Deep MOCNESS (start 4 nm downwind of Driftarray)

17 August (Sat.) – END Cycle 1
0230 CTD
0430 Recover Driftarray #4
0500 Deploy Drifter at Driftarray recovery location
0530 Steam to Sediment trap location
0700 Recover sediment trap, **END CYCLE 1**
0930 Underway survey; Last part w/ MVP: Pre-Cycle 2 survey @ 8 kts SOG

36° 15.7' N	122° 37.1' W	
36° 15.5' N	122° 27.2' W	
36° 11.9' N	122° 27.2' W	
36° 12.2' N	122° 51.1' W	
36° 08.6' N	122° 51.2' W	
36° 08.4' N	122° 27.4' W	(3 nm before next waypoint, slow to 3 kts and deploy MVP)
36° 04.8' N	122° 27.4' W	
36° 05.0' N	122° 51.2' W	**+ MVP** TRANSECT 3 (1530-1910)

1930 **TRANSECT 2 (CTD-TM-Bongo)** Across Filament (approximately 9 hr)
(7 stations sampled rapidly with CTD, Trace Metal, Bongo)

St1	36° 05.0' N	122° 51.2' W	- CTD, Trace Metal rosette, Bongo
St2	36° 05.0' N	122° 46.1' W	- CTD, Bongo, Trace metal pole
St3	36° 04.9' N	122° 42.2' W	- CTD, Bongo, Trace metal pole
St4	36° 04.9' N	122° 38.2' W	- CTD, Bongo, Trace metal pole
St5	36° 04.8' N	122° 34.2' W	- CTD, Trace Metal rosette, Bongo
St6	36° 04.8' N	122° 30.3' W	- CTD, Bongo, Trace metal pole
St7	36° 04.7' N	122° 26.3' W	- CTD, Trace Metal rosette, Bongo

18 August (Sun.)

0500 End **TRANSECT 2**

0700 Underway Survey @ 8 kts SOG (can pump tanks once underway)
75 and 300 kHz ADCPs need to be active

Begin	1	35° 57.6' N	122° 20.1' W
	2	35° 57.7' N	122° 59.3' W
	3	36° 01.4' N	122° 59.3' W
End	4	36° 01.4' N	122° 20.5' W

1900 Steam to location of Drifter
1930 Recover Drifter
2000 Deploy Sediment Trap, Begin **CYCLE 2**
2130 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Sediment Trap)
2230 MOCNESS – Night #1 (start 2 nm downwind of Sediment Trap)

19 August (Mon.) – Cycle 2, Day 1

0130 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy Driftarray #1
0500 CTD, for Thorium
0600 Trace Metal cast
0830 Bongo live tows, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
1030 CTD, for microbiology, dissolved organics
1300 MOCNESS – Day #1 (start 2 nm downwind of Driftarray)
1700 Bongo (Gastauer)
1800 CTD, viral dilution experiments
2000 CTD, full dilution experiments (shallow CTD)
2130 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
2230 MOCNESS – Night #2 (start 2 nm downwind of Driftarray)

20 August (Tues.) – Cycle 2, Day 2

0130 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover Driftarray #1/Deploy Driftarray #2
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #2 (start 2 nm downwind of Driftarray)
1800 CTD, experiments
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)

21 August (Wed.) – Cycle 2, Day 3

0130 CTD, sampling & *in situ* experiments
0430 Recover Driftarray #2/Deploy Driftarray #3
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 Deep CTD (2,000 m); remove ISUS and PAR, microbiology, dissolved organics
1330 MacLane pump (Stukel)
1600 MacLane profile (Stukel)
1900 CTD, experiments
2100 Deep MOCNESS – Night #3 (start 4 nm downwind of Driftarray) – Rhizaria and metabolic enzymes

22 August (Thurs.) – Cycle 2, Day 4

0130 CTD, sampling & *in situ* experiments
0430 Recover Driftarray #3/ Deploy Driftarray #4
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1300 Deep MOCNESS – Day #3 (start 4 nm downwind of Driftarray)
1830 Deep CTD (2,000 m); remove ISUS and PAR
2200 Deep MOCNESS – Night #4 (start 4 nm downwind of Driftarray)

23 August (Fri.) – END Cycle 2

0230 CTD
0430 Recover Driftarray #4
0500 Steam to Sediment trap location
0530 Recover sediment trap, **END CYCLE 2**
0730 Underway survey (latter portion incl. MVP) to Cycle 3 location
(can pump tanks when we begin steaming)

Underway survey at 8.5 kts SOG

S0	36° 00.3' N	122° 45.9' W	
S1	36° 00.1' N	122° 54.5' W	
S2	35° 36.8' N	122° 54.6' W	
S3	35° 36.9' N	122° 23.9' W	
S4	35° 33.3' N	122° 23.7' W	(slow to 3 kts to deploy MVP, 1.5 nm before S4)
S5	35° 33.2' N	122° 54.5' W	
S6	35° 33.2' N	122° 54.5' W	(continue to beginning of Bowtie survey without stopping)

1800 **Bowtie 2 survey (MVP) at 8 kts SOG**

001	35° 34.7' N	122° 45.7' W	
002	35° 34.7' N	122° 38.8' W	
003	35° 37.5' N	122° 42.4' W	
004	35° 31.9' N	122° 42.4' W	
001	35° 34.7' N	122° 45.7' W	(end Bowtie 2 Survey at initial station)

2100 Steam to Cycle 3 position (tbd, in vicinity of Bowtie Survey)
2130 ~~Bongo tow~~ (cancelled, to pump tanks outside Davidson Seamount zone)
2230 Deploy sediment trap – **BEGIN CYCLE 3**

24 August (Sat.) – Cycle 3, Day 1, BEGIN CYCLE 3
0130 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy Driftarray #1
0500 CTD, for Thorium
0600 Trace Metal cast
0700 Pump tanks (outside Davidson Seamount zone)
0830 Bongo live tows, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
1030 Deep CTD (2,000 m); remove ISUS and PAR; for microbiology, dissolved organics
1330 MOCNESS – Day #1 (start 2 nm downwind of Driftarray)
1600 Pump tanks (outside Davidson Seamount zone)
1800 CTD, viral dilution experiments
2000 CTD, full dilution experiments (shallow CTD)
2130 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
2230 MOCNESS – Night #1 (start 2 nm downwind of Driftarray)

25 August (Sun.) – Cycle 3, Day 2
0130 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover Driftarray #1/Deploy Driftarray #2
0600 Trace Metal cast
0700 Dispose galley waste; pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1230 Deep MOCNESS – Day #2 (start 4 nm downwind of Driftarray)
1630 Dispose galley waste; pump tanks (> 1.5 nm downwind of Driftarray)
2000 CTD, experiments
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
2230 Deep MOCNESS – Night #2 (start 4 nm downwind of Driftarray)

26 August (Mon.) – Cycle 3, END

0230 CTD

0430 Recover Driftarray #2

0530 Recover Sediment trap – **End CYCLE 3**

0730 Steam south (outside Davidson Seamount zone) to pump tanks, then complete Pre-Transect 3 survey, 8 kts SOG

1	35° 35.5' N	122° 39.2' W	(or latest position of sediment trap)
2	35° 26.5' N	122° 39.2' W	
3	35° 26.5' N	123° 03.9' W	(slow to 3 kts to deploy MVP 1.5 nm before WP4)
4	35° 38.0' N	123° 03.9' W	
5	35° 38.0' N	122° 23.8' W	

1730 Start **TRANSECT 3 (CTD-TM-Bongo)** (9 stations from east to west)

Sequence: CTD-rosette, Trace Metal rosette or pole sampling, Vertical Bongo.

Important to complete each station and move to next as expeditiously as possible.

Station positions tbd after pre-Transect 3 survey is completed.

TRANSECT 3 - P1908

1	35° 38.0' N	122° 27.7' W	- CTD, TM Rosette, Vert. Bongo
2	35° 38.0' N	122° 31.1' W	- CTD, Vert. Bongo, TM pole
3	35° 38.0' N	122° 34.7' W	- CTD, Vert. Bongo, TM pole
4	35° 38.0' N	122° 38.4' W	- CTD, TM Rosette, Vert. Bongo
5	35° 38.0' N	122° 42.4' W	- CTD, TM Rosette (?) OR TM pole, Vert. Bongo
6	35° 38.0' N	122° 46.5' W	- CTD, Vert. Bongo, TM pole
7	35° 38.0' N	122° 50.7' W	- CTD, Vert. Bongo, TM pole
8	35° 38.0' N	122° 55.3' W	- CTD, TM Rosette, Vert. Bongo
9	35° 38.0' N	122° 59.9' W	- CTD, TM Rosette, Vert. Bongo

27 August (Tues.)

0600 End TRANSECT 3

0715 Steam to Zooglider location

0930 2 CTD casts

1030 Small boat deployment to recover Zooglider

1100 Annular survey around ZG

1315 Deploy **SEASOAR** 2 (approx. 48 hour survey; waypoints tbd)

001	35° 40.0' N	123° 04.3' W
002	35° 39.9' N	122° 20.6' W
003	35° 35.3' N	122° 20.6' W
004	35° 35.3' N	123° 04.3' W
005	35° 30.5' N	123° 04.3' W
006	35° 30.5' N	122° 20.5' W
007	35° 25.7' N	122° 20.5' W
008	35° 25.7' N	123° 24.9' W
009	35° 21.2' N	123° 24.9' W
010	35° 20.9' N	122° 20.5' W
011	35° 16.2' N	122° 20.5' W
012	35° 16.2' N	123° 24.9' W
013	35° 11.5' N	123° 24.9' W
014	35° 11.5' N	122° 20.5' W
015	35° 06.7' N	122° 20.5' W
016	35° 06.7' N	123° 24.9' W

28 August (Wed.)
SEASOAR 2

29 August (Thurs.)
1330 Recover SEASOAR 2
1500 Steam to CYCLE 4 location (approx. 35° 01' N, 124° 31.1' W)
2230 MVP survey – BOWTIE 3
Total distance 13.7 NMi

001	34° 54.8' N	124° 42.9' W
002	34° 54.2' N	124° 47.9' W
003	34° 52.6' N	124° 45.1' W
004	34° 56.4' N	124° 45.8' W
005	34° 54.8' N	124° 42.9' W

2400 Deploy sediment trap – **BEGIN CYCLE 4**

30 August (Fri.) – Cycle 4, DAY 1
0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Deploy Driftarray #1
0500 CTD, for Thorium
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tows, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
1030 Deep CTD (2,000 m); remove ISUS and PAR
1300 MOCNESS – Day #1 (start 2 nm downwind of Driftarray)
1600 Trace Metal cast
1700 MVP pyrosome survey
1800 CTD, viral dilution experiments
2000 CTD, full dilution experiments (shallow CTD)
2130 Bongo, zooplankton net tow, gut fluor. (start 0.5 nm downwind of Driftarray)
2230 MOCNESS – Night #1 (start 2 nm downwind of Driftarray)

31 August (Sat.) – Cycle 4, DAY 2
0200 CTD, sampling & *in situ* experiments
0300 Trace Metal cast
0430 Recover Driftarray #1/Deploy Driftarray #2
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1300 MOCNESS – Day #2 (start 2 nm downwind of Driftarray)
1800 CTD, experiments
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
2220 Ring net, pyrosomes
2230 MOCNESS – Night #2 (start 2 nm downwind of Driftarray)

1 September (Sun.) – Cycle 4, Day 3

0230 CTD, sampling & *in situ* experiments
0430 Recover Driftarray #2/Deploy Driftarray #3
0600 Trace Metal cast
0700 Pump tanks (> 1.5 nm downwind of Driftarray)
0830 Bongo live tow, zooplankton experiments (start 0.5 nm downwind of Driftarray)
0930 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
1030 CTD, microbiology, dissolved organics
1300 Deep MOCNESS - Day #3 (start 4 nm downwind of Driftarray)
1700 MacLane pump (Stukel)
2000 CTD, experiments
2115 Ring net, pyrosomes
2130 Bongo, zooplankton net tow, gut fluor (start 0.5 nm downwind of Driftarray)
2230 Deep MOCNESS – Night #3 (start 4 nm downwind of Driftarray)

2 September (Mon.) – Cycle 4, Day 3

0300 CTD
0430 Recover Driftarray #3
0530 Recover Sediment Trap, **END CYCLE 4**
0730 Raise acoustic pole
0830 Steam to start of SEASOAR 3 (36° 34.7' N, 122° 16.1' W) @ 12 kts SOG
2200 Arrive start of SEASOAR; lower pole
2300 Deploy SEASOAR 3

3 September (Tues.)

1930 End SEASOAR #3 and recover SEASOAR
2100 Steam to CCE2 mooring (34° 18.60' N, 120° 48.86' W – position will be updated)
2200 Circular survey around CCE2 mooring, ~300 m radius (calibration for pH/pCO2)
2300 CTD cast ~300 m downwind of CCE2 mooring
2400 CTD cast ~300 m upwind of CCE2 mooring

4 September (Wed.)

0100 Raise acoustic pole
0200 Steam to BBL Sta. 1
0800 **Benthic Boundary Layer (BBL)** study - CTD rosette, followed by Go-Flo casts

0800	BBL sta. 1	Cambria	35º	34.728’	121º	10.096’
0945	BBL sta. 2	Pt. Estero	35º	28.507’	121º	03.411’
1130	BBL sta. 3	Morro Bay	35º	21.621’	120º	55.541’
1515	BBL sta. 4	Shell Beach	35º	05.090’	120º	46.250’
1700	BBL sta. 5	Vandenberg	34º	52.860’	120º	44.170’
1845	BBL sta. 6	Santa Ynez	34º	41.530’	120º	42.560’
2030	BBL sta. 7	Pt Arguello	34º	33.857’	120º	41.065’
2215	BBL sta. 8	Line 80 sta. 51	34º	27.735’	120º	31.250’
2400	BBL sta. 9	Gato	34º	25.351’	120º	24.443’

1330-1345 MVP casts, > 400 m water

5 September (Thurs.)
0100 Transit to Santa Barbara Basin (34º 16.49' N, 120º 1.5' W)
0300 CTD cast
0400 Trace Metal cast
0500 Transit to Pt. Loma

6 September (Fri.)
0630 Meet pilot at sea buoy
0730 Arrive MarFac