Cruise Report

CCE 2007: Characterizing high-resolution diel variability of physical, chemical, and ecological dynamics in the Southern California Bight
California Current Ecosystem Long Term Ecological Research Site Student Cruise
R/V Sally Ride: 1 July – 3 July 2020

Compiled and submitted by Stephanie Matthews, Chief Scientist
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Cruise ID: CCE 2007 (Ship's Cruise ID SR2003)
Depart San Diego, CA: 1 July 2020 0700 PDT
Return San Diego, CA: 3 July 2020 1730 PDT
Vessel: *R/V Sally Ride*
Operator: Scripps Institution of Oceanography
Master: Captain Wesley Hill
Chief Scientist: Stephanie Matthews
SIO Resident Marine Technicians: Jeremiah Brower, Royhon Agostine

Contents

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Cruise Objectives

The primary scientific objective of this cruise was to collect information about diel variability in a single water parcel within the Southern California Bight. The goal of the cruise was to obtain high temporal resolution data on physical and chemical water properties and ecological dynamics, following a drifter deployed near CalCOFI Line 93.3, Station 40. The collected data are to be used to provide context on diel variability of ecosystem dynamics and to serve as calibration data for measurements taken once daily or once quarterly on CCE-LTER or CalCOFI cruises.

Science Plan

The California Current Ecosystem (CCE) is an eastern boundary upwelling system with high variability at scales ranging from interannual to sub-daily. The CCE has been extensively studied over the past seven decades. The California Cooperative Oceanic Fisheries Investigations program (CalCOFI) has sampled the central and southern portions of the California Current System (CCS) quarterly since 1949 on a fixed station grid, and the California Current Ecosystem Long-Term Ecological Research site (CCE-LTER) conducts biannual cruises consisting of quasi-Lagrangian 'cycles' tracking specific water parcels. One limitation of both CalCOFI and CCE-LTER is that most types of sampling occur only once per day, though observations are likely to vary throughout the diel cycle.

Diel cycling is well-established for many aspects of pelagic ecosystems. Diel variability exists in wind-forced mixing, production of reactive oxygen species through photooxidation, phytoplankton growth cycles, and zooplankton DVM. These physical and biological drivers of diel variability likely affect other aspects of the CCE, including dynamics of the air-sea microlayer, microbial community composition and activity, and organic and inorganic nutrient availability. High-resolution characterization of the full diel cycle in a single water parcel in the SCB would provide insight into whether and how much core CalCOFI and CCE-LTER chemical and biological measurements might vary depending on the time of day they are conducted. These core measurements will also be used to infer potential mechanisms linking diel cycling of biological and chemical parameters.

To characterize the diel cycle and integrate with ongoing measurements, this cruise was designed with CTD and trace metal sampling that aligns with standard CCE Process Cruise casts (0200 and 1100), dawn and dusk. Sea surface microlayer (SSML) sampling was planned to coincide with CTD casts. Continuous underway measurements were to be collected from instrumentation on the seawater flow-through system, including with the Advanced Laser Fluorometry system (ALF) and an Imaging Flow CytoBot (IFCB). Depth-stratified MOCNESS tows were planned for daytime and nighttime hours, for zooplankton DNA metabarcoding and for comparison with continuous EK80 acoustic data.

Science Operations

Surface temperature, salinity, oxygen, phytoplankton pigment composition, F_v/F_m, and CDOM were continuously collected from the shipboard flow-through system. Active acoustics were recorded continuously throughout the cruise with the shipboard EK80. The primary sampling activities on the cruise were regular CTD casts, trace metal sampling with GOFLO bottles and pole samples, and MOCNESS tows to capture depth-stratified zooplankton distributions. CTD and trace metal sampling followed a drifter which was deployed near CalCOFI Line 93.3 Station 40. Satellite images of sea surface temperature and chlorophyll were provided by Mati Kahru, daily plots of sea surface height and inferred u/v current velocities were provided by Alain de Verneil, and near-shore currents based on high frequency coastal radar were provided by Laura Lilly. These datasets helped inform the location of the deployment of a satellite-tracked drifter (provided by Mike Landry). Following deployment of the drifter, CTD casts were carried out at 2000, 0400, and 1100 each day. Trace metal sampling occurred immediately following each CTD cast. MOCNESS tows were completed each afternoon and night. We spent a total of 43 hours in the vicinity of the drifter, including MOCNESS tows which were carried out beyond the drifter location.

The science party navigated limitations on instrument availability, minimal personnel, and difficulty with shipboard and STS-supplied equipment. Despite these challenges, this cruise successfully obtained physical, chemical, and microbial samples at three evenly spaced timepoints over the diel cycle. Collection of EK80 data was successful. The two vertically stratified MOCNESS tows will be useful for diel comparison of zooplankton and micronekton, and individual micronekton specimens were collected from the other two tows that, while not vertically stratified, will be useful for analysis of oceanic food webs.

Operations Issues

CCE 2007 was the first cruise on the *R/V Sally Ride* following a 3-month UNOLS-wide stand-down. All science equipment had to be delivered to the ship prior to pre-cruise isolation, and access to the ship was restricted to essential personnel who were sailing on the cruise. The number of people in the science party was severely limited to facilitate social distancing while onboard. All sea surface microlayer sampling was removed from the schedule as the necessary equipment was not available due to the COVID-19 pandemic. The IFCB instrument (flow-through imaging) was also unavailable.

There were some software difficulties due to the UNOLS stand-down, including failure of the ship-board event logger and a malfunction in the underway software that stopped underway oxygen from being collected for the first 30 hours of the cruise. The stepping mechanism on the MOCNESS failed during the first tow, resulting in depth-integrated sampling. The ship's trawl winch had an electronics fault during the second MOCNESS tow, causing a 2hr delay. The error was cleared, but the winch continued to have faults throughout the third and fourth MOCNESS tows, resulting in cancellation of the fourth MOCNESS tow. The delays due to the winch malfunction caused the 0200 CTD to be shifted to 0400. Because on-board personnel were limited, it was impossible to accomplish both 0400 and 0600 CTD sampling. We adjusted our CTD and trace metal sampling schedule to

reflect 3 samples per day and successfully obtained two replicates at each timepoint (2000, 0400, and 1100).

During recovery of the satellite-tracked drifter and drogue, the wire became wrapped around the ship's starboard rudder. The drogue and float were brought on board and the wire was cut, but a length of wire remained caught on the rudder. Attempts to dislodge the wire using weights and small boat operations were unsuccessful. The captain obtained permission to send down a freediver who dislodged the wire by hand. After recovering the divers, we calculated the projected location of the drifter based on its velocity in the previous 6 hours. We conducted the final CTD and trace metal sampling at that predicted location.

Group Reports

CTD Sampling

The CTD Rosette team successfully completed seven casts on a diel time scale with sampling at six depths between the surface and 515 meters depth. The CTD package included the following sensors: temperature (SN 6140, SN 2059), conductivity (SN 3207, SN 1919), pressure (SN0914), PAR (SN QSP235070629), oxygen (SBE, SN 1071), and nitrogen (ISUS), as well as a fluorometer (Wetlabs, SN FLRTD-1156), transmissometer (Wetlabs, SN CST-1874DR), and altimeter (SN PSA960D). The initial cast was at 1430 following drifter deployment. Subsequent casts occurred daily at 2000, 0400, and 1100 for the next two consecutive days. Seawater samples were taken from 6 depths on each CTD cast typically targeting surface waters, the deep chlorophyll maximum (DCM), water both above and below the DCM, 170m, and 515m. The samples collected during this student cruise aim to support the core LTER research themes of movement of organic and inorganic matter and the potentially resulting microbial ecosystem disturbance patterns. The results of the analyses completed by individuals in their respective labs will be shared throughout the participants of the cruise and will be publicly available through Datazoo.

Microbial Community: Sarah Schwenck (Allen Lab)

For each depth, 4L of seawater was filtered onto 0.2µm Sterivex filters in duplicate using a peristaltic pump. Excess water was removed from each filter using a syringe and the ends were sealed with putty on one end and a screw-on cap on the other. Each filter was flash frozen using liquid nitrogen and stored at -80°C. Back in the lab, RNA will be extracted from each filter and sequenced via amplicon sequencing and metatranscriptomics to analyze microbial community composition.

Organic Matter: Ralph Riley Torres (Aluwihare Lab)

The sampling I completed on behalf of my research goals, the CCE-LTER program and the Aluwihare Lab will be analyzed for total organic carbon (TOC), dissolved organic carbon (DOC), fluorescent dissolved organic matter (fDOM), colored dissolved organic matter (cDOM), particulate organic carbon and nitrogen (POC and PON) with isotopic analysis, bacterial abundance, inorganic macronutrients and environmental metabolomics analysis through solid phase extraction (PPL) to characterize organic compounds. The results of these analyses will be used to assess changes in the structure of the chemical community throughout the period of the cruise with a focus on diel variability. The surface data collected

from the CTD Rosette casts will be used in conjunction with samples taken from incubations to assess microbial-associated and photochemical oxidative transformations of dissolved organic matter. In conjunction with sensor data and 16S sequencing obtained during this cruise, I will address the research question of how well do nutrient and organic matter pools correlate with biotic and abiotic factors.

Phosphorus: Jamee Adams (Diaz Lab)

During SR2003, I successfully obtained total particulate phosphorus (TPP), total dissolved phosphorus (TDP), soluble reactive phosphorus (SRP), biologically available phosphorus (BAP), and flow cytometry samples (for both phytoplankton and bacteria) from all depths on all CTD casts performed onboard. These data will be used to assess how nutrient and organic matter pools change over the course of a day. Total phosphorus pool data in this region is not routinely collected, so these samples serve as baseline values for CCE-LTER work going forward.

I also collected data on alkaline phosphatase activity in the region from natural and nutrient amended small scale onboard incubations. Amended incubations were spiked with both inorganic and organic nitrogen and phosphorus substrates to assess how and if these substrates impact DOP hydrolysis. DOP hydrolysis measurements from the onboard incubations will be used to help inform the bioavailability of the organic phosphorus pool in the region, which as of now remains unknown.

Metalloenzymes: Viktoria Steck (Diaz Lab)

Phosphorus is a vital nutrient of life, and essential for the proliferation and productivity of marine microorganisms. In certain regions of the global ocean, however, easily accessible orthophosphate is a biologically limiting nutrient that constrains marine primary production. In these areas, marine plankton produce various metalloenzymes to acquire phosphorus instead from the less accessible pool of dissolved organic phosphorus (DOP). The activity of these enzymes is dependent on the trace metal ions (for example iron and zinc) in the surrounding seawater, which populate the enzymatic active site and give rise to its biochemical function. In bottle incubation experiments, we spiked field samples of planktonic communities within the CCE with these metals. After two days, we measured the effect of metal amendments on the activity of APs in our samples, which translates to the ability of marine microbes to satisfy their nutritional phosphorus demand by using DOP.

Trace Metal Sampling

A total of 7 stations were sampled for Fe geochemical variables using acid-cleaned 12L GO-Flo bottles (General Oceanics) suspended on a clean hydroline (Amsteel) and triggered with acid-cleaned Teflon messengers designed by Ken Bruland. Corresponding surface samples were taken with the trace metal “pole” in which cleaned bottles were secured at the end of the 25’ fiberglass pole and filled over the starboard side, while the ship moved at a nominal 0.5-1 knots. This sampling effort coincided with concurrent CTD stations. Once on board, GO-Flo bottle tops and bottoms were covered with plastic and placed on a wooden rack located within the trace metal clean shipboard plastic “bubble”, kept under positive-pressure by HEPA-filtered air. Samples for dFe analysis were pressure-filtered through 0.2 m Acropak 200 capsule filters (VWR International), fed by filtered air,

into low-density polyethylene bottles (Nalgene) and acidified to pH 1.7 to 1.8 using HCl (optima grade, Fischer Scientific). These sampling methods were conducted following established trace-metal clean methods to the standards of the GEOTRACES program to avoid metal contamination. Whole seawater was directly sampled from the GO-Flo bottle and acidified to pH 1.8 to be stored for >6 months for total dissolvable Fe (TdFe). Macronutrients for both pole and GO-Flo water were sampled.

Diel Variability: Maxwell Fenton & Kiefer Forsch (Barbeau Lab)

Trace metal time series have traditionally relied on stationary platforms or re-occupied stations to infer the biotic and abiotic factors which control temporal and spatial variability in the ocean. In the California Current System (CCS), frequent dynamical features (e.g. internal waves, eddies) are observed on moorings, as the passing features' signature is recorded. These features and their effect on the ecosystem are the focus of CCE-LTER program. Acknowledging the inherent spatial variability within the CCS, our Lagrangian approach focuses our interpretation to the effect of temporal variability. Of particular importance to the study of iron (Fe) in the euphotic zone, is the effect of biological uptake and regeneration, and photochemical transformation. A previous study (Hayes et al. 2020)**, which followed a water parcel for multiple days in the North Pacific gyre, sampling every 12 hours, found that at the ocean surface (<5m), no diel variability was found for Fe, yet day to day changes were resolved. We examine, with higher temporal resolution (every ~6 hours), the variability of Fe in the southern CCS in the surface (<2m) and at a pronounced deep chlorophyll maximum (DCM).

We do not have any initial results at the moment for Fe geochemistry, but a description of the water parcel and variability we observed onboard follows. Upon arrival to the study site (reference CalCOFI station 93.40), we found a well-stratified water column, with a pronounced and narrow DCM (~33-34m depth) sitting ~10m above the depth of the nitracline (40m). Over the course of sampling, the DCM shoaled to 27-28m during the night, and deepened during the day. The depth of the nitracline, indicated by the voltage gradient on the ISUS sensor, did not change during this study. The tight window (~27-34m) for which the DCM existed suggests strong control on the depth of the DCM. The magnitude of the DCM was 4-5.5 mg/L Chlorophyll-a throughout the cruise and did not show any significant diel variation. The ISUS traces will be calibrated with measurements of nitrate on water samples. Following the recovery of the surface drifter, the location of the water parcel was projected based on prior geo-locations and time-elapsed.

Analyses of Fe variables are ongoing using our in-house flow-injection with chemiluminescence technique.

**Hayes, C. T., Fitzsimmons, J. N., Jensen, L. T., Lanning, N. T., Hatta, M., McGee, D., & Boyle, E. A. (2020). A Lagrangian view of trace elements and isotopes in the North Pacific. Journal of Geophysical Research: Oceans, 125, e2019JC015862. https://doi.org/10.1029/2019JC015862

Sensor development: Maxwell Fenton (Barbeau Lab)

The next step in obtaining high resolution trace metal datasets is the creation of technologies which could provide continuous, in-situ measurements of dissolved metals in seawater. To this end, an in-situ iron sensor employing an Fe3+ ion-selective chalcogenide glass electrode is being developed. This sensor would be outfitted for use in shipboard or

pier-based flow through systems and could potentially be integrated into autonomous drifters or floats. A secondary objective of CCE2007 was the collection of a large volume of clean surface water for sensor calibration and matrix-matched in-house standards. This low-Fe water will be used to assess the accuracy of the ion-selective electrode measurements of dFe by comparison to independent laboratory measurements of dFe by flow-injection chemiluminescence analysis, and measurements of free iron and iron-binding ligand concentrations by cathodic stripping voltammetry. An effective, deployable iron-sensor would revolutionize the ability of marine chemists to obtain valuable dFe datasets over longer temporal scales and larger areas of the CCS.

MOCNESS Deployments

We conducted four MOCNESS tows, each to 1000m depth, using a $1m^2$-opening MOCNESS outfitted with 10 nets of 202micrometer mesh. Two tows were daytime (approximately 1300-1600 local time), and two were nighttime (2200-0200). The goals of the tows were to: 1) sample vertical gradients in mesozooplankton and mesopelagic fish communities, and 2) measure how much those communities varied between day and night. The MOCNESS package included sensors for temperature (SN 4060), pressure (SN 381), conductivity (SN 2569), oxygen (SBE, SN 1508), and PAR (SN QCP 2350 70627), as well as an SCF fluorometer (SN SCF-2748), transmissometer (SN CST-1873DR), flowmeter, and a light strobe system (strobe parameters: 1000ms interval, 40ms pulse width, 50% intensity).

Three of the tows suffered mechanical challenges that limited our sampling to varying degrees. On the first daytime tow (Tow #1), only the first net (Net 1) successfully closed, at 1000 m depth. All subsequent net trips failed due fracture of the plastic spider connecting the stepping motor to the net release shaft. After that tow, we replaced the net tripping mechanism with the motor and net release shaft from the 10 m^2 MOCNESS. On Tow #2, all nets closed successfully, but the ship's winch suffered an electronics fault at about 540m net depth. Due to this winch trouble, we had a prolonged sampling period for that net. After the winch was temporarily fixed, we continued the tow, with no subsequent major winch dropouts. Tow #3 proceeded smoothly. Tow #4 had winch problems at 100 m net depth on the descent, so the captain canceled the tow and we hauled back to avoid equipment damage.

Zooplankton: Stephanie Matthews & Laura Lilly (Ohman Lab)

The first MOCNESS tow produced one integrated downward sample (Net 0, 0-1080m) and one integrated upward sample (Net 1, 1000-0m). The integrated samples were given to Julia Chavarry for preservation of fish, jellies, and size fractioned biomass samples. We preserved the net washes of nets 2-9 in formalin to analyze the extent of water column contamination of closed nets during the tow. The second MOCNESS tow resulted in 8 depth stratified samples, as the cod end and base of net 4 was lost during the tow. Nets 3 and 5 were non-quantitative, as they were towed at depth for 10-90 minutes. After all the fish were removed, each net was split and preserved as follows: 50% in ethanol, 25% in formalin, and 25% given to Julia Chavarry to freeze for biomass. We preserved the net washes (100%) separately in formalin. The third MOCNESS tow was successful, with only minor pauses in winch speed. All the fish were preserved separately, then we split each net once and preserved 50% in ethanol for DNA metabarcoding and 50% in formalin and with the net wash preserved separately in formalin. The Net 0 contents were given to Julia Chavarry. One

ethanol sample from Tow #3 was broken during flipping. The fourth and final MOCNESS tow was cancelled at 100m, and the full integrated 0-100m sample given to Julia Chavarry for processing of fish and other micronekton.

Micronekton: Julia Chavarry (Choy Lab)

In total, 284 individual specimens of micronekton and zooplankton were collected from the MOCNESS tows, comprising 99 samples. Micronekton and gelatinous animals were separated into similar size classes and pooled to create samples, then preserved in the onboard -80 freezer. Zooplankton were preserved on 200m Nitex mesh filters, rinsed with ammonium formate, and then preserved in the onboard -80 freezer. When possible, zooplankton were size fractionated into three groups using stacked sieves: >5mm, 1-5mm, and 0.2-1mm. For the first tow, a 1/16 split of size fractionated zooplankton was preserved from one of the nets. The fish and a subset of the gelatinous animals were preserved from both nets. For the second tow, a ¼ split of zooplankton was preserved from five nets, as well as the fish and a subset of the gelatinous animals from all available nets. No zooplankton were preserved from the third tow; however, the fish and a subset of gelatinous animals were successfully preserved from all available nets. A 1/32 split of size fractionated zooplankton was preserved from the last tow, as well as the fish and a subset of the gelatinous animals. These samples will be used in a variety of analyses to better describe the CCE pelagic food web, potentially including stable isotope analysis, investigation for the presence of microplastics, and determination of mercury concentration.

Underway Measurements

Flowthrough system: Quinn Montgomery & Stephanie Matthews

Standard shipboard sensors collected continuous underway measurements of sea surface salinity, temperature, and oxygen throughout the cruise from the uncontaminated flowthrough system. Oxygen data were not recorded for the first 30hrs of the cruise due to a software malfunction. The ALF (Advanced Laser Fluorometer) system recorded phytoplankton pigment composition, F_v/F_m, and CDOM via the flowthrough system (ALF assistance provided by Ralf Goericke, CalCOFI). The shipboard pCO_2 system was not functioning, and we did not have the personnel to operate the CalCOFI pCO_2 system (installed for the subsequent cruise on the *R/V Sally Ride*). The flowthrough system was also used for experimental ship-board incubations to test metalloenzyme uptake of phosphorous.

Active Acoustics: Sven Gastauer & Shailja Gangrade (in absentia, summarized by S. Matthews)

Neither member of the acoustics team was able to join the cruise, but active acoustic data were collected with remote assistance from Sven Gastauer. Data were collected continuously with the shipboard EK80 for future analysis of midwater animals and comparison with net-collected animals. The EK80 system sampled at 18kHz, 38 kHz, 70 kHz, 120 kHz, and 200kHz with 1000ms intervals. The system was synchronized with the ADCP while the ADCP was active. The ADCP was primarily used during transit to inform deployment of the drifter and to check surface currents 10-15 minutes prior to net deployment. The multibeam depth sounder (Teledyne) was turned off to avoid interference with the EK80, as it could not be synced with the Konsberg systems.

Schedule (Actual)

Time start	Activity
1-Jul-2020 07:00	Depart MARFAC
1-Jul-2020 07:00	Transit to CalCOFI 93.3 40
1-Jul-2020 13:00	Deploy drifter
1-Jul-2020 13:00	Drifter check, CTD test, TM deck runthrough
1-Jul-2020 14:30	CTD #1
1-Jul-2020 15:00	TM sampling (Go-Flo bottle, pole sample)
1-Jul-2020 15:30	MOCNESS #1
1-Jul-2020 20:00	CTD #2
1-Jul-2020 20:30	TM sampling (Go-Flo bottle, pole sample)
1-Jul-2020 22:30	MOCNESS #2
2-Jul-2020 04:00	CTD #3
2-Jul-2020 04:30	TM sampling (Go-Flo bottle, pole sample)
2-Jul-2020 05:00	TM surface pump
2-Jul-2020 11:00	CTD #4
2-Jul-2020 11:30	TM sampling (Go-Flo bottle, pole sample)
2-Jul-2020 13:00	MOCNESS #3
2-Jul-2020 20:00	CTD #5
2-Jul-2020 20:30	TM sampling (Go-Flo bottle, pole sample)
2-Jul-2020 21:30	MOCNESS #4
3-Jul-2020 04:00	CTD #6
3-Jul-2020 04:30	TM sampling (Go-Flo bottle, pole sample)
3-Jul-2020 08:00	Recover drifter
3-Jul-2020 11:00	CTD #7
3-Jul-2020 11:30	TM sampling (Go-Flo bottle, pole sample)
3-Jul-2020 12:00	Transit to MARFAC
3-Jul-2020 17:30	Arrive MARFAC

Map of Sampling Locations

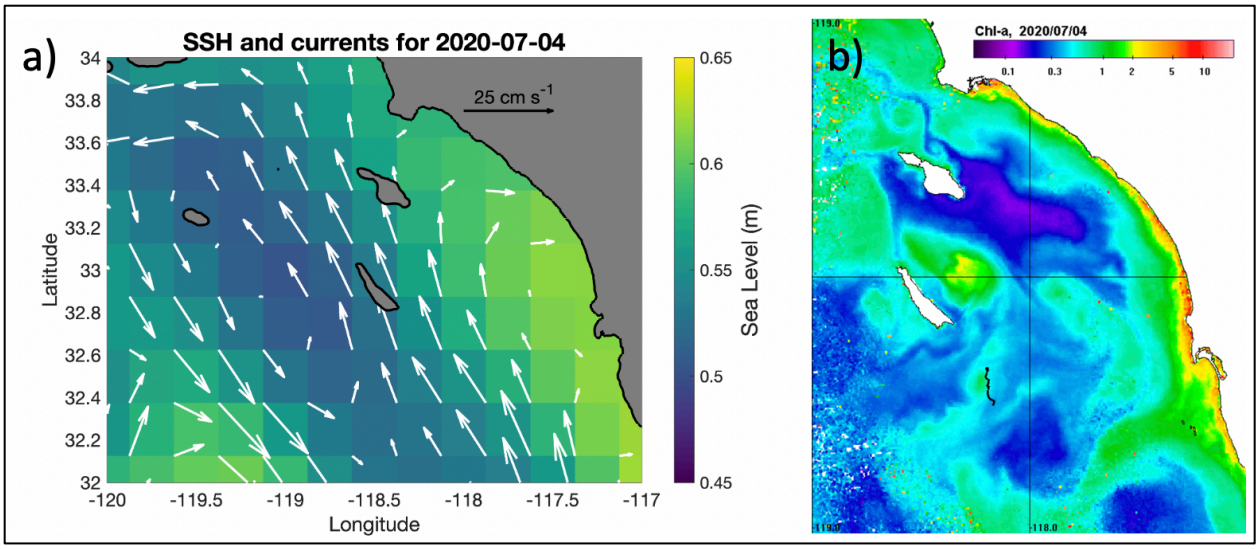

Figure 1. A) SSH and inferred u/v velocities on 4 July 2020 for the region of the cruise. SSH and currents were temporally stable throughout the cruise. SSH image courtesy of Alain de Verneil. B) In black, the track of the satellite-tracked drifter that was deployed near CalCOFI 93.3 40. The drifter was deployed at the southernmost point on the track at 1300 on 1 July and drifted north until recovery at 0800 on 3 July. The satellite image of chlorophyll is from 4 July as there was heavy cloud cover during the cruise. San Clemente Island is to the northwest of the drifter track, and San Diego Bay can be seen directly to the east of the track. Chla-a image courtesy of Mati Kahru.

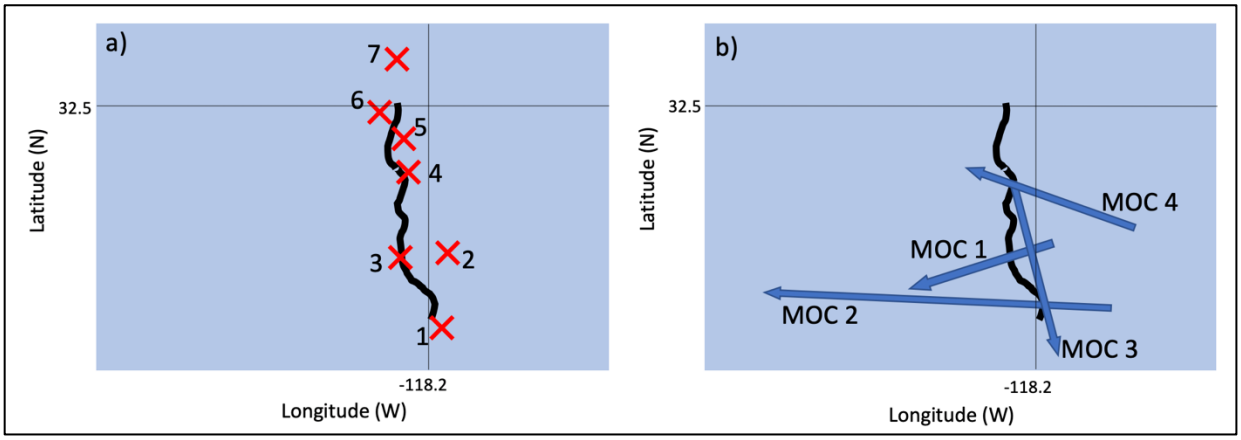

Figure 2. Sampling locations relative to the drifter track from Fig 1a (in black). A) CTD and trace metal sampling locations are marked with red Xs and numbered sequentially. B) MOCNESS tows are marked with blue arrows and are labelled sequentially, independently from CTD casts. Arrows indicate the direction of the tow.