Note: This cruise plan was created in January 2020, prior to a 3-month UNOLS stand-down and implementation of COVID-19 pandemic protocols. In June 2020 prior to sailing, this plan was scaled back to reflect equipment availability, limited science party size, and on-board social distancing.

Characterizing high-resolution diel variability of physical, chemical, and ecological dynamics in the Southern California Bight

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20. TBD (graduate or undergraduate helper, potentially REU student)
21. MOCNESS Technician

Proposed Chief Scientist:
Stephanie Sommer, Chief Scientist
Quinn Montgomery, Co-Chief Scientist and Personnel Head
Kiefer Forsch, Chemicals

Intended Destination:
CalCOFI Line 93.3, Station 40 (32.51304 N, -118.21386 W)

Background and overarching science question:

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 provides context for other research and monitoring programs. One such program is the California Current Ecosystem Long-Term Ecological Research site (CCE-LTER), an experimental research program which conducts biannual cruises consisting of quasi-Lagrangian 'cycles' that track specific water parcels in order to examine submesoscale physical variability and chemical and biological processes (e.g., changes to nutrient availability and uptake, organism growth rates, particulate matter sinking rates). The combination of consistent temporal and spatial sampling by CalCOFI and measurements of water parcel evolution by CCE-LTER provide complementary views of the long-term 'mean' state, interannual trends, and short-term rates (i.e., uptake, growth) and chemical and biological interactions in the CCS.

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. On CalCOFI cruises, sampling is carried out as soon as the ship arrives at a station, regardless of the time of day. The opposite occurs on CCE-LTER process cruises: most types of measurement are conducted at the same time of day to maximize comparability between cycles and cruises, and we have no consistent information about how they may vary throughout a 24-hour period (e.g., samples for metabolomics and metagenomics are only collected on the 11 a.m. CTD cast, and we have no information on how they might be different at the 2 a.m. cast). High-resolution time series of some physical and biogeochemical properties (temperature, salinity, oxygen, nitrate, pH, and chlorophyll fluorescence) are available from two CCE moorings in the offshore core California Current and nearshore upwelling regions off Point Conception, CA. However, these moorings are not representative of the more protected waters of the Southern California Bight (SCB), and do not provide information on specialized chemical sampling (i.e., phosphorus, iron), microbial community characterization, or zooplankton species comparisons between the midwater and surface.

Diel cycling is well-established for many aspects of pelagic ecosystems (e.g., wind-forced mixing, production of reactive oxygen species through photooxidation, phytoplankton growth cycles, and zooplankton DVM). These physical and biological drivers are likely to have knock-on effects on 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 at a single CalCOFI station 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. We propose a cruise with high resolution sampling (approximately every 6 hours) at a single CalCOFI station (Line 93.3, Station 40), with the primary goal of

collecting information about diel variability in the SCB. This will provide needed context on the stability of ecosystem dynamics, and would be a valuable dataset given the broader time series data available both at this location and throughout the CCS.

We propose to address the following questions on this cruise:

> *Q1:* Do iron, nutrient and organic matter pools significantly change over the course of a day? If so, do changes in the surface iron pool correlate with biotic and abiotic factors? Do changes in organic matter pools correlate with changes in bacterial community composition or activity?
>
> *Q2:* How does sampling time of day impact rates of photochemistry, photosynthesis, and levels of reactive oxygen species?
>
> *Q3:* How does predation pressure by planktivorous fish on mesozooplankton differ between the mesopelagic and epipelagic regions? Does vertical variability in predation pressure vary between day and night? Additionally, how does food chain length and trophic position of midwater predators change between strong and weak upwelling regimes?

Outline of proposed activities:

Shipboard Flow-through Measurements:

In addition to the provided underway salinity and temperatures measurements, a fluorometer and an Imaging Flow Cytobot (IFCB) will be attached to the shipboard flow through system. Additional samples for 16S and 18S rRNA will be taken off the flow-through system to compare phytoplankton composition measurements between IFCB and 'omics.

CTD and 'Omics work:

Sampling will be conducted at six depths from surface to 515m, similar to the sampling scheme on recent CCE-LTER processes cruises and CalCOFI cruises, 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, inorganic nutrients (nitrate, phosphate), chlorophyll *a*, phaeopigments, soluble reactive phosphorus, dissolved organic phosphorus (DOP), particulate organic phosphorus (POP), and microbial community rRNA/DNA. Samples will also be collected at the same six depths for metabolomics analysis through solid phase extraction (PPL), for future LC-MS/MS and GC-MS analysis to characterize organic compounds. Metabolomics analysis will be coupled

to sampling for 16S and 18S rRNA analysis to assess changes in structure of both chemical and biological communities. Solid phase extraction (PPL) will additionally be used to characterize DOP compounds. Small scale on-board incubations from the same six depths will be done to determine if DOP hydrolysis is limited by availability of metals. The organic phosphorus work is new to the general CCE-LTER suite of measurements made during the 11 A.M. CTD cast. Data collected from the CTD casts will support the core LTER research themes of movement of organic and inorganic matter and the potentially resulting microbial ecosystem disturbance patterns. Additionally, it will support the CCE-LTER specific hypothesis that localized (microbial) food web changes in response to changes in nutrient supply (organic matter).

MOCNESS work:

Net sampling will be done using a MOCNESS-10 with a $10m^2$ mouth opening, or if unavailable, using a MOCNESS-1 with a $1m^2$ mouth opening. These tows will target large mesozooplankton and small nekton. Samples will be taken in five depth strata ranging from 0-600m to characterize changes in community composition and vertical distributions of biomass over a diel cycle. A subset of the collected animals will be preserved for stable isotope analysis in order to characterize food web structure based on trophic levels, which will be compared with samples previously collected during a non-upwelling regime. The remainder of the collected animals will be used for species-specific predator prey analysis, using molecular probes for gut content analysis. Temporal changes in community composition will be correlated with CTD collected data, including dissolved nutrient concentrations, temperature, and salinity. The analysis of food web structure will support CCE-LTER's goal of investigating *in situ* food web changes based on altered stratification and nutrient supply.

Active acoustic work:

The shipboard echosounder (EK80) will obtain continuous underway backscatter to characterize temporal changes in diel vertical migration (DVM) amplitude. Mean volume backscatter and dB differencing will be used to detect structural differences in the vertical structure and extract DVM patterns of different functional groups. Routine net samples will corroborate acoustically detected patterns in relative biomass and composition. Acoustic data will be correlated with PAR, dissolved oxygen, and CTD data to link physical gradients to vertical organism distribution. High-resolution surface measurements of microbial communities, metabolites, and chlorophyll will also be linked to nightly surface acoustic backscatter to detect any correlations or fine-tuned changes in DVM amplitude or surface biomass. Acoustic backscatter within one diel cycle can offer a greater resolution to vertical structure at this particular site, adding to the greater repository of CCE-LTER acoustic data that encompasses larger spatial and temporal scales. Acoustic equipment will be calibrated during the cruise or recent calibration information will be applied. The collected high resolution broadband acoustic data bears the potential to further methods allowing to resolve the size and orientation of scattering organisms.

Trace metal work:

A trace metal clean pump manifold will be used to sample the surface layer (~5m) for dissolved, total dissolvable, and particulate trace metals. The focus will be on characterizing the physicochemical speciation of the iron pool and the degree to which it varies over the course of one day. In order to accomplish this work, a teflon tube attached to a 20' fiberglass arm will extend away from the ship while seawater is pumped directly into sample bottles and processed in a hygienic "bubble." To minimize contamination from the ship's hull and stationary sampling activities (namely, CTD), seawater will be pumped while the ship moves at <0.5 knots. These samples will be analyzed using in-house technologies (flow-injection analysis, electrochemistry), with potential further work measuring other bioessential transition metals. Additionally, a large volume of trace-metal clean water will be collected for future use in sensor development and in-house standards.

Aerosol work:

Samples from the sea surface micro layer (SSML) and sea spray aerosol collection from the bow mast will be collected using quartz filters for comparison with bulk seawater from the CTD rosette system. Metabolomics analysis through solid phase extraction, LC-MS/MS and GC-MS will be conducted in order to characterize organic compounds. These analyses will be coupled with amplicon sequencing to characterize and compare to microbial community composition.

Grad student objectives:

Shailja Gangrade: Characterize local variability in DVM dynamics and vertical structure of plankton assemblages and vertical migrators. This will benefit future thesis work regarding organism spatial distribution across dissolved oxygen gradients and submesoscale features.

Kiefer Forsch and Max Fenton: Quantify the variability in the surface iron pool over a diel cycle. Collect large volumes of trace metal clean seawater for calibration of novel Fe(III) sensor.

Julia Chavarry: Define differences in midwater community composition and food web structure in response to seasonal upwelling, using a compilation of data from this cruise and data from a previous class cruise.

Jamee Adams: Quantify phosphorus pool in the region (soluble reactive P, total DOP, and POP), characterize DOP compounds (solid phase extraction), and determine if DOP hydrolysis is limited by availability of metals (on board incubation(s)).

Stephanie Sommer: Collect data on co-occurence of large mesozooplankton (>0.5mm) and planktivorous fish to test whether vertical changes in predation pressure drive zooplankton DVM behavior. Additionally, professional development and chief scientist training opportunity.

Lucia Cancelada and Tyler Price: Research will benefit both students' thesis projects related to ocean and surface interactions between marine life and atmospheric chemical composition.

Ralph Riley Torres: Further ascertain dominant chemical structures within dissolved organic nitrogen (DON) and examine daily changes in the DON pool and with respect to inorganic nutrient availability and microbial community composition.

Sarah Schwenck: Obtain diel microbial community composition samples that can be utilized as a comparison to pre-existing long-term samples from the CalCOFI NCOG program, particularly those from the annual summer cruises (generally in July).

Quinn Montgomery: Quantify photosynthetic biomass and characterize changes in nearshore surface phytoplankton community structure both in transit to and from station and over the 48-hour period on station.

Outline of schedule:

Date	Time	Scheduled events	Location
June 31		Ship loading	
July 1	7:00	Science party on board	
	8:00	Depart MARFAC	
	14:00	Arrive CalCOFI 93.3 40	32.51304, -118.21386
	14:00	CTD #1 (to 600m)	On station
	15:00	Iron (pole sample)	Underway, leaving station
	15:30	Pump water for trace metal team	On station
	17:00	SSML sampling protocol test	On station
	19:30	SSML sampling	On station
	20:00	CTD #2 (to 600m)	On station
	21:00	Iron (pole sample)	Underway, leaving station
	21:30	MOCNESS	Start ~2nm away, steam through station
	1:30	SSML sampling	On station
July 2	2:00	CTD #3 (to 600m)	On station
	3:00	Iron (pole sample)	Underway, leaving station
	3:30	MOCNESS	Start ~2nm away, steam through station
	7:00	SSML sampling	On station
	0800	CTD #4 (to 600m)	On station
	9:00	Iron (pole sample)	Underway, leaving station
	10:30	SSML sampling	On station
	11:00	CTD #5 (to 600m)	On station
	13:00	Iron (pole sample)	On station
	13:30	MOCNESS	Underway, leaving station
	19:30	SSML sampling	On station
	20:00	CTD #6 (to 600m)	On station
	21:00	Iron (pole sample)	Underway, leaving station
	21:30	MOCNESS	Start ~2nm away, steam through station
July 3	1:30	SSML sampling	On station
	2:00	CTD #7 (to 600m)	On station
	3:00	Iron (pole sample)	Underway, leaving station

	3:30	MOCNESS	Start ~2nm away, steam through station
	7:00	SSML sampling	On station
	0800	CTD #8 (to 600m)	On station
	9:00	Iron (pole sample)	Underway, leaving station
	9:30	SSML sampling	On station
	10:00	CTD #9 (to 600m)	On station
	11:00	Iron (pole sample)	Underway, leaving station
	11:00	Depart for MARFAC	
	16:00	Arrive MARFAC	

Instrumentation requested:

- 24 bottle rosette
- Shipboard EK80
- PAR, Oxygen sensor (if not already equipped on CTD package)
- IFCB (potentially, supplied by Barton lab)
- Flow through fluorometer (if not supplied by ship)
- Hygienic bubble (set up in forward wet lab, constructed by Barbeau lab)
- $10m^2$ MOCNESS (SIO/MarFac) (or $1m^2$ MOCNESS if not available)
- Microscope (from Ohman lab)
- Peristaltic pump (from Diaz lab)
- Plate reader (from Diaz Lab)

Teams:
Teams are designed to have enough members for two 12 hour shifts to allow for adequate sleep.

'Omics:
- Sarah Schwenck (lead)
- Tyler Price

Active Acoustics:
- Shailja Gangrade (lead)
- Sven Gastauer

10m^2 MOCNESS:
- Julia Chavarry (lead)
- Shailja Gangrade
- Laura Lilly
- Stephanie Sommer
- Sven Gastauer

  +3

Aerosols:
- Daniel Petras (lead)
- Tyler Price
- Lucia Cancelada

Trace Metal:
- Kiefer Forsch (lead)
- Max Fenton

CTD:
- Ralph Riley Torres (operations lead)
- Jamee Adams (water budget lead)
- Quinn Montgomery
- Sarah Schwenck
- Daniel Petras
- Tyler Price
- Lucia Cancelada
- Alice Levesque
- +1

Water Budget (assumed 24 Niskin rosette):

Depths:
0m
10m
DCM
DCM + 10m
170m
515m

Budget per depth:
5L 'omics (16S and 18S rRNA) in duplicate
5L POC single sample
~1L DOC/ TOC/ FDOM/ FCM/ nutrients/ incubation
3L Metabolites: PPL in duplicate (includes surface sample for Daniel)
9L Organic phosphorus compounds: PPL in triplicate
3L Chl
4L DOP

~30 L total