# Incubation experiments to assess the physiological and molecular response of subsurface phytoplankton communities to a simulation of the Upwelling Conveyor Belt Cycle (UCBC) conducted in summer 2019 onboard the R/V Oceanus (OC1905b)

**Website**: https://www.bco-dmo.org/dataset/949788
**Data Type**: Cruise Results, experimental
**Version**: 1
**Version Date**: 2025-02-19

**Project**
» CAREER: An integrated molecular and physiological approach to examining the dynamics of upwelled phytoplankton in current and changing oceans (Upwelled Phytoplankton Dynamics)


| Contributors | Affiliation | Role |
|---|---|---|
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**Abstract**
The primary objective of this study was to assess the physiological and molecular response of subsurface phytoplankton communities to a simulation of the Upwelling Conveyor Belt Cycle (UCBC). To capture this phenomenon, we performed on-deck incubation experiments that spanned different time points representing the different stages of growth (initial deep-water community at T0, and stimulated growth phases at T1 and T2). We further subjected the incubations to various Fe-related treatments to test how Fe might play a role in determining their physiological and molecular response to upwelling. The first incubation was conducted from 27 May to 01 June 2019 in a wide continental shelf, and the second incubation was conducted from 02 June to 06 June 2019 in a narrow continental shelf. For each time point, the incubation was harvested and analyzed for chlorophyll, nutrients, particulate organic carbon and nitrogen, and dissolved and particulate Fe and Sc concentrations. 6-hour incubations using trace concentrations of stable isotopes of 13C and 15N were also conducted to assess uptake kinetics of dissolved inorganic carbon (DIC) and nitrate (NO3) in bulk-size fractionated phytoplankton communities. PUPCYCLE I (Phytoplankton response to the UPwelling CYCLE) took place in summer 2019 onboard the R/V Oceanus (OC1905b), led by Chief Scientist Adrian Marchetti.

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## Coverage

**Location**: California Current System
**Spatial Extent**: **N**:41.01471 **E**:-121.5429 **S**:35.92353 **W**:-124.4163
**Temporal Extent**: 2019-05-27 - 2019-06-04

**Methods & Sampling**

**For the Fe status incubations:**
Seawater was collected using trace-metal clean techniques from a depth of 90 meters (m) (corresponding to the 8.4 degree Celsius isotherm) for the wide shelf incubation and 80 m (corresponding to the 8.9 degree Celsius isotherm) for the narrow shelf incubation. Seawater from both sites was pumped directly into a positive pressure trace-metal clean plastic bubble created in the ship's laboratory into large, 50-gallon acid-washed high-density polyethylene (HDPE) drums to homogenize the seawater using a Wilden air-operated double-diaphragm pump made of polytetrafluoroethylene and acid-washed HDPE tubing. Preparation of the cubitainers was carried out prior to the cruise and included trace-metal clean techniques. Cubitainers were initially soaked in 2% Extran detergent for 7 days, then rinsed with deionized water four times and Milli-Q water three times prior to being soaked in 10% reagent grade hydrochloric acid for 2-3 days and rinsed with Milli-Q water. Subsequently, the cubitainers were soaked in 1% trace metal grade hydrochloric acid for 7 days and rinsed with Milli-Q water, then soaked in 0.1% trace metal grade acetic acid 3-4 days before final storage in low Fe water from Station P (50 degrees North,145 degrees West). Station P water had been collected and filtered from the 2018 EXPORTS North Pacific field campaign using trace metal clean techniques and stored in the dark at 4 degrees Celsius (°C) until use. In the bubble, these triplicate acid-cleaned 10-liter (L) low-density polyethylene cubitainers were filled and then incubated in large on-deck plexiglass incubators circulated with water chilled to the temperatures at which the subsurface samples were collected using Aqua Logic Delta Star® In-Line Water Chillers. Incubators were covered with neutral density screening to achieve 30% incident irradiance. To assess the effects of Fe addition or removal on the simulated upwelled plankton communities, samples were incubated with no amendment (control), amended with 5 nanomolar (nM) of FeCl2 (Fe treatment), or amended with 200 nM desferrioxamine B (DFB), a strong Fe chelator, which inhibits dissolved Fe uptake (DFB treatment). Three cubitainers were immediately harvested for the initial time- point (T0), also referred to as deep-water or DW. The remaining cubitainers were incubated for two additional time points for a total of 18 cubitainers per incubation. Cubitainers were harvested for various biological and chemical parameters (see below) following 48 hours (T1) for both incubation experiments, and following 120 hours in the wide shelf incubation and 96 hours in the narrow shelf incubation (T2).

**For the seed population incubations:**
Seawater was collected using trace-metal clean techniques at 15 m depth for the surface incubations and at 90 m for the subsurface incubations (corresponding to the 8.4 °C isotherm). Seawater was pumped directly into a positive pressure trace metal clean plastic bubble created in the ship's laboratory into large, 50-gallon acid-washed high-density polyethylene (HDPE) drums to homogenize the seawater using a Wilden air-operated double-diaphragm pump made of polytetrafluoroethylene (PTFE) and acid-washed HDPE tubing. Preparation of the cubitainers was carried out prior to the cruise and included trace-metal clean techniques (Crawford et al., 2003): 10 L cubitainers were initially soaked in 2% Extran detergent for 7 days, then rinsed with deionized water four times and Milli-Q water three times prior to being soaked in 10% reagent grade hydrochloric acid for 2-3 days and rinsed with Milli-Q water. Subsequently, the cubitainers were soaked in 1% trace metal grade hydrochloric acid for 7 days and rinsed with Milli-Q water, then soaked in 0.1% trace metal grade acetic acid 3-4 days before final storage in low-Fe water from Ocean Station Papa (St. P). The St. P water had been collected and filtered from the 2018 EXPORTS North Pacific (50 °N, 145 °W) field campaign using trace metal clean techniques and stored in the dark at 4 °C until use. In the bubble, these triplicate acid-cleaned 10 L low-density polyethylene (LDPE) cubitainers were filled and then incubated in large on-deck plexiglass incubators circulated with water chilled to the temperatures at which the subsurface samples were collected using Aqua Logic Delta Star® In-Line Water Chillers. Incubators were covered with neutral density screening to achieve 30% incident irradiance. For the experimental design, a portion of the surface and subsurface collections was directly collected and denoted as the initial (T0) surface and subsurface communities, respectively. The resulting incubations (triplicates) were characterized by either the surface waters (SW) or the subsurface waters (DW) incubated for 96 hours (T1). Another portion (triplicates) was subjected to mixture with filtered waters from the respective subsurface or surface communities, such that the 96 hour incubations consisted of an equal mixture of filtered-subsurface waters and surface waters, denoted as FDW/SW (filtered deep water/surface water), an equal mixture of filtered-surface waters and subsurface waters, denoted as FSW/DW (filtered surface water/deep water), and an equal mixture of both unfiltered surface and subsurface waters, denoted as mixed (surface water/deep water). No additional macronutrients or micronutrients were added to any of the incubations. Cubitainers were harvested for various biological and chemical parameters (see below) in the initial time point and following 96 hours of incubation.

**Physiological Measurements:**
For chlorophyll a measurements, 250 milliliters (mL) of seawater was gravity filtered through 5-micrometer (µm) Isopore membrane filters (47-millimeters (mm)) and subsequently vacuum filtered onto GF/F (25 mm) filters under 100 mmHg of vacuum pressure. Filters were then rinsed with 0.45 µm filtered seawater and immediately stored at -20 °C until onshore analysis in the lab. Chlorophyll a extraction was performed using a

90% acetone solution at -20 °C for 24 hours and measured on a 10-AU fluorometer (Turner Designs, San Jose, CA) using the acidification method.

Dissolved inorganic nutrients (nitrate + nitrite, phosphate, and silicic acid) were measured by filtering 30 mL of water through a 0.2 µm filter, using acid-washed syringes into an acid-cleaned polypropylene FalconTM tube. Dissolved nutrient concentrations were analyzed using an OI Analytical Flow Solutions IV auto analyzer by Wetland Biogeochemistry Analytical Services at Louisiana State University. Concentrations of nitrate measured from the discrete samples were used for the calculation of absolute nitrate uptake rates.

Samples for dissolved iron (dFe) were collected from each cubitainer within a trace-metal clean, positive pressure plastic bubble by filtering through pre-cleaned 0.2 µm pore size polyethersulfone membrane Acropak-200® capsule filters into LDPE bottles that had been rigorously cleaned as described in the GEOTRACES cookbook. Sample bottles were rinsed three times with sample before filling. Samples were acidified at sea to pH ~1.7 with optima HCl (2 mL of 12 M HCl per liter of seawater) and were analyzed after the cruise. Briefly, this method involves pre-concentration onto Nobias-chelate PA1 resin followed by analysis with a High-Resolution Inductively Coupled Plasma Mass Spectrometer. For quality control, a few samples were rerun with a flow injection analysis method. This method involves pre-concentration on toyopearl resin followed by in-line spectrophotometric analysis.

To assess the isotope uptake of DIC and NO3, a 618 mL polycarbonate bottle was filled to the top with incubation samples from each cubitainer. The subsamples were collected for dissolved inorganic carbon (DIC) and nitrate uptake rates at each respective time point, and immediately spiked with both NaH13CO3 and Na15NO3 at approximately 10% of the estimated ambient DIC concentrations and measured nitrate concentrations in a trace metal clean (TMC) space located on the ship (see below). Since there were no underway measurements of DIC, an expected ambient concentration of 2000 micromoles per liter (µmol L-1) was derived from literature values for both incubation sites. Nitrate concentrations of the deep-water and surface water in both incubation sites were measured using the Submersible Ultraviolet Nitrate Analyzer (SUNA), which quantifies dissolved nitrate concentrations by illuminating the water sample with UV and using the absorbance values to estimate nitrate concentrations from a multi-variable linear regression based on the MBARI method. After spiking with respective trace concentrations of both stable isotopes of DIC and nitrate, samples were returned to the incubator for six hours. All rate measurement incubations were initiated at approximately the same time of day (i.e., close to dawn). Following incubation, seawater was immediately filtered where cells greater than 5 µm were gravity filtered onto 5 µm Isopore membrane filters (47 mm) and then washed onto a pre-combusted (450 °C for 5 hours) GF/F filters (0.7 µm nominal porosity) by vacuum filtration using 0.2 µm filtered seawater and preserved at -20 °C. Cells smaller than 5 µm passed through the initial 5 µm Isopore membrane filters and were collected on pre-combusted GF/F filters and preserved at -20 °C. Prior to analysis, filters were dried at 60 °C for 24 hours, encapsulated in tin and pelletized. Particulate organic carbon (POC), particulate organic nitrogen (PON), and atom percentages of 13C and 15N were subsequently quantified using an isotope ratio mass spectrometer (EA-IRMS) at the UC Davis Stable Isotope Facility. For each sample, POC and PON concentrations (µmol L-1) were calculated by dividing the measured POC/PON mass (micrograms (µg)) by the respective atomic mass of carbon and nitrogen over the volume filtered (0.62 L).

For the wide shelf incubation, samples were spiked with 200 µmol L-1 of NaH13CO3 and 1 µmol L-1 of Na15NO3 according to estimated ambient DIC concentrations of 2000 µmol L-1 and measured surface nitrate concentrations of 10 µmol L-1. For the narrow shelf incubation, samples were spiked with 200 µmol L-1 of NaH13CO3 for all samples and 1.5 µmol L-1 of Na15NO3 for the deep-water triplicate samples. This amount was amended according to estimated ambient DIC concentrations of 2000 µmol L-1 and measured nitrate concentrations of 15 µmol L-1 in the deep-water. Absolute uptake rates of dissolved inorganic carbon and nitrate (ρ, DIC or NO3 taken up per unit time) were derived from the constant transport model. The 13C fraction was first calculated by dividing the measured 13C atom percentage in each sample by the natural 13C atom percentage (1.087%), over the difference between the percentage of 13C over total C in the sample and the natural 13C atom percentage. The 13C biomass was then derived by multiplying the 13C fraction by the calculated POC concentration for each sample, and 13C absolute uptake rate was measured as the 13C biomass over the incubation time (6 hours). The same calculations were applied to assess the 15N absolute uptake rates, but with the respective natural atom percentage of 15N (0.367%). Biomass-normalized uptake rates (V, DIC or NO3 taken up per unit POC or PON, respectively, per unit time) were derived from the specific uptake model, and was assessed by dividing the absolute uptake rates of DIC or NO3 by the measured POC and PON concentrations (µmol L-1), respectively. Correction for ammonium regeneration during the incubation period was not performed.

**Data Processing Description**

GraphPad Prism was used to plot both the environmental and physiological data.

**BCO-DMO Processing Description**

- Imported original file "PUPCYCLE_compiled_results_Q_experiments.csv" into the BCO-DMO system.
- Renamed fields to comply with BCO-DMO naming conventions.
- Converted dates to YYYY-MM-DD format.
- Saved the final file as "949788_v1_pupcycle_2019_incubation_experiments.csv".

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## Parameters

| Parameter | Description | Units |
|---|---|---|
| Experiment | Name of experiment: Wide shelf_Fe status, Wide shelf_seed populations, Narrow shelf_Fe status, Narrow shelf_seed populations. | unitless |
| Time_Point | Time point; how long the particular sample incubated for. For Fe status incubations - T0: initial conditions before the incubation; T1: 48 hours after incubation; T2: 120 hours after incubation for wide shelf, 96 hours after incubation for narrow shelf. For seed population incubations - T0: initial conditions in the surface water SW before incubation; T1: 96 hours after incubation for wide shelf, 72 hours after incubation for narrow shelf. | unitless |
| Hours | Time point in hours; how long the particular sample incubated for. | hours |
| Treatment | Description of the treatment (in triplicates) for the particular sample. DW: initial deep water/subsurface water; Ctrl: no amendments added to incubation; Fe: 5 nM FeCl2 amended; DFB: 200 nM desferrioxamine B (DFB) amended; SW: initial surface water; Filtered DW/SW - half filtered subsurface water mixed with half unfiltered surface water; Filtered SW/DW - half filtered surface water mixed with half unfiltered subsurface water; SWDW - unfiltered surface water mixed with unfiltered subsurface water. | unitless |
| Replicate | There were three replicates for each treatment. This parameter serves to disambiguate them. | unitless |
| Sample_Name | Sample ID (marked as Q numbers) used to represent each sample. | unitless |

| | | |
|---|---|---|
| Date | Date of sample collection. | unitless |
| Latitude | Latitudinal coordinates of the sample site. (North = positive values). | decimal degrees |
| Longitude | Longitudinal coordinates of the sample site. (West = negative values). | decimal degrees |
| NO3 | Nitrate concentration. | micromolar (uM) |
| PO4 | Phosphate concentration. | micromolar (uM) |
| SiOH4 | Silicate concentration. | micromolar (uM) |
| chl_a_gt_5um | Chl a >5um: chlorophyll concentration for the greater than 5 micrometers size fraction. | micrograms per liter (ug/L) |
| chl_a_GFF | Chl a GFF [>0.7um]: chlorophyll concentration for the greater than 0.7 micrometers size fraction. | micrograms per liter (ug/L) |
| chl_a_Total | Chl a Total: chlorophyll concentrations for both cell size-fractions. | micrograms per liter (ug/L) |
| Fv_Fm | Fv/Fm: photosynthetic efficiency measured for each sample. | unitless |
| Sigma | Sigma: Photosystem II cross-sectional area. | unitless |
| PON_gt_5um | PON >5um: particulate organic nitrogen concentration for the greater than 5 micrometers size fraction. | micromoles per liter (umol/L) |
| PON_GFF | PON GFF [>0.7um]: particulate organic nitrogen concentration for the greater than 0.7 micrometers size fraction. | micromoles per liter (umol/L) |
| PON_Total | PON Total: particulate organic nitrogen concentrations for both cell size-fractions. | micromoles per liter (umol/L) |
| POC_gt_5um | POC >5um: particulate organic carbon concentration for the greater than 5 micrometers size fraction. | micromoles per liter (umol/L) |

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|---|---|---|
| POC_GFF | POC GFF [>0.7um]: particulate organic carbon concentration for the greater than 0.7 micrometers size fraction. | micromoles per liter (umol/L) |
| POC_Total | POC Total: particulate organic carbon concentrations for both cell size-fractions. | micromoles per liter (umol/L) |
| N_Uptake_gt_5um | N Uptake >5um: absolute nitrate uptake rates for the greater than 5 micrometers size fraction. | micromoles per liter per day (umol/L/day) |
| N_Uptake_GFF | N Uptake GFF: absolute nitrate uptake rates for the greater than 0.7 micrometers size fraction. | micromoles per liter per day (umol/L/day) |
| N_Uptake_Total | N Uptake Total: absolute nitrate uptake rates for both cell size-fractions. | micromoles per liter per day (umol/L/day) |
| Biomass_normalized_N_Uptake_gt_5um | Biomass-normalized N Uptake >5um: biomass-normalized nitrate uptake rates for the greater than 5 micrometers size fraction. | per day |
| Biomass_normalized_N_Uptake_GFF | Biomass-normalized N Uptake GFF: biomass-normalized nitrate uptake rates for the greater than 0..7 micrometers size fraction. | per day |
| Biomass_normalized_N_Uptake_Total | Biomass-normalized N Uptake Total: biomass-normalized nitrate uptake rates for both cell size-fractions. | per day |
| C_Uptake_5um | C Uptake >5um: absolute dissolved inorganic carbon (DIC) uptake rates for the greater than 5 micrometers size fraction. | micromoles per liter per day (umol/L/day) |
| C_Uptake_GFF | C Uptake GFF: absolute dissolved inorganic carbon (DIC) uptake rates for the greater than 0..7 micrometers size fraction. | micromoles per liter per day (umol/L/day) |
| C_Uptake_Total | C Uptake Total: absolute dissolved inorganic carbon (DIC) uptake rates for both cell size-fractions. | micromoles per liter per day (umol/L/day) |
| Biomass_normalized_C_Uptake_gt_5um | Biomass-normalized C Uptake >5um: biomass-normalized dissolved inorganic carbon (DIC) uptake rates for the greater than 5 micrometers size fraction. | per day |

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|---|---|---|
| Biomass_normalized_C_Uptake_GFF | Biomass-normalized C Uptake GFF: biomass-normalized dissolved inorganic carbon (DIC) uptake rates for the greater than 0..7 micrometers size fraction. | per day |
| Biomass_normalized_C_Uptake_Total | Biomass-normalized C Uptake Total: biomass-normalized dissolved inorganic carbon (DIC) uptake rates for both cell size-fractions. | per day |
| Particulate_DA | Particulate DA: domoic acid concentrations in the particulate fraction. | micrograms per liter (ug/L) |
| Dissolved_DA | Dissolved DA: domoic acid concentrations in the dissolved fraction. | micrograms per liter (ug/L) |
| Dissolved_Y | Dissolved yttrium concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_Cd | Dissolved cadmium concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_La | Dissolved lanthanum concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_Pb | Dissolved lead concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_Ce | Dissolved cerium concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_Sc | Dissolved scandium concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_Mn | Dissolved manganese concentration. | nanomoles per kilogram (nmol/kg) |
| Dissolved_Co | Dissolved cobalt concentration. | picomoles per kilogram (pmol/kg) |
| Dissolved_Ni | Dissolved nickel concentration. | nanomoles per kilogram (nmol/kg) |
| Dissolved_Cu | Dissolved copper concentration. | nanomoles per kilogram (nmol/kg) |
| Dissolved_Zn | Dissolved zinc concentration. | nanomoles per kilogram (nmol/kg) |
| Dissolved_Fe | Dissolved iron concentration. | nanomoles per kilogram (nmol/kg) |

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|---|---|---|
| Particulate_Fe_pFe_leached_gt_5um | Particulate iron concentration | nanomoles per kilogram (nmol/kg) |
| Fe_N_ratio | Fe/N ratio | unitless |
| Fe_uptake_lt_5um | Fe uptake (<5um) | picomoles Fe per liter per hour (pmol Fe/L/h) |
| Fe_uptake_gt_5um | Fe uptake (>5um) | picomoles Fe per liter per hour (pmol Fe/L/h) |
| Fe_uptake_lt_5um_pmol_Fe_ug_Chla_h | Fe uptake (<5um) | picomoles Fe per microgram chla per hour (pmol Fe/ug Chla/h) |
| Fe_uptake_gt_5um_pmol_Fe_ug_Chla_h | Fe uptake (>5um) | picomoles Fe per microgram chla per hour (pmol Fe/ug Chla/h) |
| Fe_uptake_lt_5um_pmol_Fe_umol_POC_h | Fe uptake (<5um) | picomoles Fe per micromole POC per hour (pmol Fe/umol POC/h) |
| Fe_uptake_gt_5um_pmol_Fe_umol_POC_h | Fe uptake (>5um) | picomoles Fe per micromole POC per hour (pmol Fe/umol POC/h) |

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## Instruments

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|---|---|
| **Dataset-specific Instrument Name** | High Resolution Inductively Coupled Plasma Mass Spectrometer |
| **Generic Instrument Name** | Inductively Coupled Plasma Mass Spectrometer |
| **Dataset-specific Description** | Used in analysis of samples for dissolved iron (dFe). |
| **Generic Instrument Description** | An ICP Mass Spec is an instrument that passes nebulized samples into an inductively-coupled gas plasma (8-10000 K) where they are atomized and ionized. Ions of specific mass-to-charge ratios are quantified in a quadrupole mass spectrometer. |

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|---|---|
| **Dataset-specific Instrument Name** | isotope ratio mass spectrometer (EA-IRMS) |
| **Generic Instrument Name** | Isotope-ratio Mass Spectrometer |
| **Dataset-specific Description** | Atom percentages of 13C and 15N were quantified using an isotope ratio mass spectrometer (EA-IRMS) at the UC Davis Stable Isotope Facility. |
| **Generic Instrument Description** | The Isotope-ratio Mass Spectrometer is a particular type of mass spectrometer used to measure the relative abundance of isotopes in a given sample (e.g. VG Prism II Isotope Ratio Mass-Spectrometer). |

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|---|---|
| **Dataset-specific Instrument Name** | OI Analytical Flow Solutions IV auto analyzer |
| **Generic Instrument Name** | Nutrient Autoanalyzer |
| **Dataset-specific Description** | Dissolved inorganic nutrients were measured using the OI Analytical Flow Solutions IV auto analyzer by Wetland Biogeochemistry Analytical Services at Louisiana State University. |
| **Generic Instrument Description** | Nutrient Autoanalyzer is a generic term used when specific type, make and model were not specified. In general, a Nutrient Autoanalyzer is an automated flow-thru system for doing nutrient analysis (nitrate, ammonium, orthophosphate, and silicate) on seawater samples. |

| | |
|---|---|
| **Dataset-specific Instrument Name** | |
| **Generic Instrument Name** | Satlantic Submersible Ultraviolet Nitrate Analyser |
| **Dataset-specific Description** | Nitrate concentrations of the deep-water and surface water in both incubation sites were measured using the Submersible Ultraviolet Nitrate Analyzer (SUNA). |
| **Generic Instrument Description** | The Submersible Ultraviolet Nitrate Analyser (SUNA) uses ultraviolet absorption spectroscopy to measure in-situ dissolved nitrate. It is a chemical-free method that allows real-time and continuous nitrate concentration measurements in a variety of environments. It has a 1 cm path length, 190 - 370 nm wavelength range and a depth rating of 100 m. |

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|---|---|
| **Dataset-specific Instrument Name** | 10-AU fluorometers (Turner Designs) |
| **Generic Instrument Name** | Turner Designs Fluorometer-10 |
| **Dataset-specific Description** | Chlorophyll was measured using a 10-AU fluorometers (Turner Designs, San Jose, CA). |
| **Generic Instrument Description** | The Turner Designs Model 10 fluorometer (manufactured by Turner Designs, turnerdesigns.com, Sunnyvale, CA, USA) is used to measure Chlorophyll fluorescence. No information could be found for this specific model. |

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## Deployments

**OC1905B**

| | |
|---|---|
| **Website** | https://www.bco-dmo.org/deployment/940128 |
| **Platform** | R/V Oceanus |
| **Start Date** | 2019-05-24 |
| **End Date** | 2019-06-06 |

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## Project Information

**CAREER: An integrated molecular and physiological approach to examining the dynamics of upwelled phytoplankton in current and changing oceans (Upwelled Phytoplankton Dynamics)**

**Coverage**: California Upwelling Zone

*NSF Award Abstract:*
Upwelling zones are hotspots of photosynthesis that are very dynamic in space and time. Microsocopic algae, known as phytoplankton, bloom when deep, nutrient-rich waters are upwelled into sunlit surface layers of the ocean, providing nourishment that supports productive food webs and draws down carbon dioxide (CO2) from the atmosphere to the deep ocean. Photosynthetic microbes in these regions must constantly adapt to changes in their chemical and physical environments. For example, subsurface populations respond to changes in light as they approach the surface. When upwelled waters move offshore, cells sink out of the illuminated zone, establishing seed populations that remain inactive until the next upwelling event. This process is called the upwelling conveyor belt cycle (UCBC). How phytoplankton respond to these changes in environmental conditions and how they may influence their nutrient requirements remains unknown. With future ocean changes predicted to alter seawater chemistry, including ocean acidification and decreased iron availability, some phytoplankton groups may be more vulnerable than others. Accompanying educational activities provide learning experiences to enhance understanding and awareness of marine microbes. The development of a research hub at UNC aims to provide infrastructure and support for scientists and students conducting research on environmental genomics. A laboratory component for an upper-level undergraduate course focused on marine phytoplankton is being developed. Educational outreach activities to broader communities include creation of a lesson plan on phytoplankton in upwelling zones and a virtual research cruise experience for middle-school students, as well as a hands-on lab activity for a local museum focused on marine phytoplankton and the important roles they play in shaping our planet.

The project examines how phytoplankton respond at the molecular and physiological level to the different UCBC stages, which seed populations (i.e., surface versus subsurface) contribute most to phytoplankton blooms during upwelling events of varying intensity, how phytoplankton elemental compositions are altered throughout UCBC stages, and how future predicted ocean conditions will affect the phytoplankton responses to UCBC conditions. This project contains both laboratory and fieldwork. In the laboratory, phytoplankton isolates recently obtained from upwelling regions are exposed to simulated UCBC conditions to examine changes in gene expression, growth and photosynthetic characteristics and elemental composition. Cultures are subjected to both current and future ocean conditions, including reduced iron availability and higher CO2. In the field, research cruises within upwelling regions study the dynamics of natural phytoplankton communities (both surface and subsurface) experiencing upwelling and relaxation and within simulated upwelling incubation experiments. Knowledge of how phytoplankton are affected by UCBC conditions at an integrated molecular, physiological and elemental level under both current and future scenarios is imperative for the proper conservation and management of these critically important ecosystems.

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## Funding


| Funding Source | Award |
| --- | --- |
| NSF Division of Ocean Sciences (NSF OCE) | OCE-1751805 |


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