

# Particle-associated microbial respiration from RESPIRE sediment trap deployments during R/V Atlantis cruise AT50-10 in the Eastern Tropical Pacific in May 2023 and R/V Sally Ride cruise SR1919 in the Santa Barbara Basin in Dec 2019

**Website:** <https://www.bco-dmo.org/dataset/1008909>

**Data Type:** Cruise Results

**Version:** 1

**Version Date:** 2026-10-02

## Project

» [Collaborative Research: Underexplored Connections between Nitrogen and Trace Metal Cycling in Oxygen Minimum Zones Mediated by Metalloenzyme Inventories](#) (CliOMZ)

| Contributors                       | Affiliation                                         | Role                   |
|------------------------------------|-----------------------------------------------------|------------------------|
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## Abstract

These data include measurements of particulate organic carbon (POC) flux and POC-attached microbial respiration rates measured from RESPIRE trap deployments across two cruises (SR1919 and AT50-10), as well as specific parameter values underlying these measurements, including oxygen drawdown, carbon utilization, dissolved and particulate organic carbon concentrations, carbon-specific respiration rates, and cell concentrations, derived from RESPIRE trap deployments at depths of 80–225 m. The SR1919 cruise was aboard the R/V Sally Ride in December 2019 around the Santa Barbara Basin. The AT50-10 cruise was aboard the R/V Atlantis from Golfito, Costa Rica to San Diego, USA in May-June 2023. We aimed to quantify microbial respiration rates on sinking particles in low oxygen waters using in situ incubation systems (RESPIRE traps).

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## Coverage

**Location:** Eastern Tropical Pacific Oxygen Minimum Zone waters 9.18N-10S 90-100W depth 125 m to 225 m; Santa Barbara Basin 34.308N 119.966W depth 80 m to 124 m

**Spatial Extent:** N:34.30868333 E:-89.99734 S:-10.003051 W:-119.96605

**Temporal Extent:** 2019-12-15 - 2023-05-30

## Methods & Sampling

### Sediment trap deployments and sample collection

REspiration on Sinking Particles In the subsurface ocean (RESPIRE) particle collection and incubation systems (Boyd et al., 2015; Bressac et al., 2024) were deployed on a drifting, surface-tethered trap (STT) array at each station for 2-3 days at depths between 80-225 m. RESPIRE traps were filled with 0.2  $\mu\text{m}$ -filtered seawater collected from a CTD cast 2-3 hours prior to deployment. Upon recovery, overlying seawater in RESPIRE traps was siphoned off immediately after recovery, remaining RESPIRE water was collected for bacterial production, dissolved organic carbon (DOC), and cell count measurements, and remaining sample water was passed through a rotary wet splitter and divided into equal fractions. All trap samples were passed through screens to remove zooplankton “swimmers”. Split fractions of the sample water were then vacuum filtered onto pre-combusted 25mm GF/F (Whatman, Maidstone, Kent, United Kingdom) or quartz (Whatman) filters for CHN analyses. Samples collected for DNA were vacuum-filtered onto 25 mm or 47 mm 0.2  $\mu\text{m}$  pore size polyethersulfone filters (Pall Supor, Port Washington, New York, USA), flash-frozen, then stored at  $-80^{\circ}\text{C}$  until further processing in the lab. Filters for cell counts and CHN analyses were stored at  $-20^{\circ}\text{C}$  and  $-80^{\circ}\text{C}$  respectively until further processing in a shore-based lab.

### Dissolved and total organic carbon measurements

Prior to each deployment, the 0.2  $\mu\text{m}$ -filtered seawater used to fill RESPIRE traps prior to deployment was sampled for DOC and used as the  $\text{DOC}_{\text{initial}}$  timepoint. After recovery, particle-containing water was collected from RESPIRE traps for DOC or total organic carbon (TOC) determination ( $\text{DOC}_{\text{final}}$  or  $\text{TOC}_{\text{final}}$ ). Combusted 40 mL glass vials with Teflon-lined caps were used for sample collection. For DOC samples, water was filtered into the vial using a 0.2  $\mu\text{m}$  filter to a volume of  $\sim 30$  mL and was acidified with 50  $\mu\text{L}$  of DOC-free 4 N hydrochloric acid (Stephens et al., 2020). TOC samples were collected following the same protocol but without 0.2  $\mu\text{m}$  filtration. All samples were stored at  $4^{\circ}\text{C}$  until measurements could be made in a shore-based lab. DOC and TOC concentrations were measured via the high temperature combustion method using modified Shimadzu TOC-V or TOC-L analyzers following Halewood et al. (2022).

### DAPI staining and cell enumeration on particles

Particle-containing fluid ( $\sim 15\text{mL}$ ) from RESPIRE traps were collected and fixed with 0.405 mL of formalin for the purposes of DAPI staining and cell enumeration. Samples were vacuum filtered onto 25 mm, 0.2  $\mu\text{m}$  poresize polycarbonate filters (Pall Supor). Five mL were pipetted into the filtration tower and filtered using vacuum filtration until  $\sim 0.5$  mL remained above the filter. 0.5 mL DAPI solution (5  $\mu\text{g/mL}$ ) was added to the sample, and the filtration tower was covered with foil and left to stain for 3 min. After 3 min, the remaining sample was filtered. The filtered sample was removed from the filtration tower and mounted on a labeled glass microscope slide using a drop of immersion oil between the slide and filter and another drop between the filter and cover slip. Filters were stored at  $-20^{\circ}\text{C}$  until imaging and counting on-shore. Epifluorescence microscopy (63X objective, Zeiss Axio Observer 7 Inverted microscope, Carl Zeiss Microscopy, LLC, White Plains, NY, USA) was used to take 12 digital images across different parts of each sample filter.

## Data Processing Description

### RESPIRE trap mechanism and respiration rate calculations

The RESPIRE particle collection and incubation apparatus is designed to non-intrusively intercept sinking particles, deposit them into an incubation chamber containing 0.2  $\mu\text{m}$ -filtered seawater from depth and incubate the particles *in situ* (Boyd et al., 2015; Bressac et al., 2024). Particle collection phases for the RESPIRE trap deployments in this study ranged from 0.5 to 1 d with the following incubation phases lasting 0.5 to 1.5 d. An oxygen optode (Aanderaa 4831 series) within the RESPIRE incubation chamber measured oxygen concentration every five minutes. Dissolved oxygen concentrations were corrected for pressure, salinity, and temperature (if temperature varied notably over the course of the incubation; AT5010 deployment 3) according to the Aanderaa Operating Manual and Thierry et al. (2018). The change in oxygen over the incubation phase time was determined from these measurements for the volume of the RESPIRE incubation chamber. A respiratory quotient (RQ), the incubation length ( $t_{\text{inc}}$ ), and the volume of the RESPIRE incubation chamber ( $V_{\text{RES}}$ , 1.45 L) were used to convert the oxygen-based remineralization rate ( $O_{2,\text{cons}}$ ) to units of carbon (**Equation 1**). Here, we define RQ to be the molar drawdown of dioxygen to carbon ( $\text{O}_2:\text{C}$ ). We selected an RQ of 1.1 (L. A. Anderson, 1995) for our calculations. End-point POC measurements ( $\text{POC}_{\text{final}}$ ), the change in DOC over the course of the incubation ( $\text{delta DOC}$ ), and the rate of oxygen consumption ( $O_{2,\text{cons}}$ ) were used to back-calculate the starting concentration of POC ( $\text{POC}_{\text{initial}}$ ) at the beginning of the RESPIRE incubation phase (**Equation 1**). For deployments where TOC samples were taken, DOC concentrations were calculated by subtracting the POC concentration (after RESPIRE incubation) from the  $\text{TOC}_{\text{final}}$  concentration

(SR1919, AT5010). The change in dissolved organic carbon (DOC) concentration over the course of RESPIRE incubations was measured from two timepoints—an initial (before particle collection) and final (recovered RESPIRE water minus the measured POC concentration). The calculated amount of  $POC_{initial}$  (mmol C) was divided by the length of the collection period ( $t_{col}$ ) and the area of the RESPIRE trap ( $A_{RES}$ , 0.014 m<sup>2</sup>) to estimate POC fluxes (**Equation 2**). Carbon remineralization rates were normalized to mean POC concentration ( $[POC]_{avg}$ ) of the incubation chamber to achieve carbon-specific (C-specific) remineralization rates ( $R_{norm}$ ; **Equation 3**). Uncertainties related to sample splitting, averaging sample replicates, and linear regressions were propagated through all calculations.

$$\text{Equation 1: } POC_{initial} = POC_{final} + \Delta DOC + (O_{2,cons} / RQ * t_{inc} * V_{RES})$$

$$\text{Equation 2: } POC \text{ flux} = POC_{initial} / (t_{col} * A_{RES})$$

$$\text{Equation 3: } R_{norm} = (O_{2,cons} / RQ) / [POC]_{avg}$$

### DAPI staining and cell enumeration on particles

Epifluorescence microscopy images were analyzed using CellProfiler (v4.2.8). Images were converted to grayscale as needed (Relative weight of each channel: Red = 0, Green = 0.8, Blue = 1.0) and images were analyzed sample by sample. If background intensity values were high, an illumination correction was applied to the image using a median filter smoothing method. Cells were identified based on intensity relative to the background intensity which was specific to each sample. The image with the most and least number of cells were removed from analysis and the cell counts for the remaining 10 images were averaged for each sample. Cell concentration in the RESPIRE incubation chamber was back-calculated from cell counts using the area imaged, the area of the filter, the volume of sample filtered, and the volume of the RESPIRE incubation chamber (1.45 L). Cell counts were converted to cell carbon using a carbon conversion factor of 20 fg C cell<sup>-1</sup> (Ducklow, 2000).

### BCO-DMO Curation Notes

This section documents curation actions performed prior to publication review with the submitter, and additional information relevant to understanding and reusing this dataset. It distinguishes changes made to the submitted (meta)data from unresolved issues and/or enhancements that improve future reuse and interoperability.

#### CURATION ACTIONS PERFORMED ON DATA

- Loaded BCO-DMO\_AT5010\_SR1919\_2026-05-19.csv, using filename as resource name, with header row 1 and row 2 skipped; set missing value markers to "", "nd", and "NA"
- Output file as 1008909\_v1\_respire\_rates\_at5010\_sr1919.csv

#### CURATION ACTIONS PERFORMED ON METADATA

- BCO-DMO's standard metadata entry and text formatting steps were performed. See: <https://www.bco-dmo.org/how-to/standard-curation-edits>

#### ISSUES POTENTIALLY IMPACTING REUSE

- N/A

### Problem Description

Initial TOC sample for AT50-10, deployment 4 at 175 m, broke in transit to the shore-based lab, therefore DOC concentration is estimated from 175 m average across other sample stations.

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## Data Files

| File                                                                                                                               |
|------------------------------------------------------------------------------------------------------------------------------------|
| <b>1008909_v1_respire_rates_at5010_sr1919.csv</b> (Comma Separated Values (.csv), 2.65 KB)<br>MD5:0724d05b0c55da0f8a9409c951ae6d24 |
| Primary data file for dataset ID 1008909, version 1                                                                                |

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## Related Publications

Boyd, P. W., McDonnell, A., Valdez, J., LeFevre, D., & Gall, M. P. (2015). RESPIRE: An in situ particle interceptor to conduct particle remineralization and microbial dynamics studies in the oceans’ Twilight Zone. *Limnology and Oceanography: Methods*, 13(9), 494–508. Portico. <https://doi.org/10.1002/lom3.10043>  
*Methods*

Bressac, M., Laurenceau-Cornec, E. C., Kennedy, F., Santoro, A. E., Paul, N. L., Briggs, N., Carvalho, F., & Boyd, P. W. (2024). Decoding drivers of carbon flux attenuation in the oceanic biological pump. *Nature*, 633(8030), 587–593. <https://doi.org/10.1038/s41586-024-07850-x>  
*Methods*

Halewood, E., Opalk, K., Custals, L., Carey, M., Hansell, D. A., & Carlson, C. A. (2022). Determination of dissolved organic carbon and total dissolved nitrogen in seawater using High Temperature Combustion Analysis. *Frontiers in Marine Science*, 9. <https://doi.org/10.3389/fmars.2022.1061646>  
*Methods*

Stephens, B. M., Opalk, K., Petras, D., Liu, S., Comstock, J., Aluwihare, L. I., Hansell, D. A., & Carlson, C. A. (2020). Organic Matter Composition at Ocean Station Papa Affects Its Bioavailability, Bacterioplankton Growth Efficiency and the Responding Taxa. *Frontiers in Marine Science*, 7. <https://doi.org/10.3389/fmars.2020.590273>  
*Methods*

Thierry, V., Bittig, H., Gilbert, D., Kobayashi, T., Kanako, S. and Schmid, C. (2018) Processing Argo oxygen data at the DAC level. Version 2.3.1. Villefranche-sur-Mer, France, IFREMER for Argo Data Management, 138pp. DOI:/10.13155/39795  
*Methods*

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## Parameters

| Parameter | Description                                                                             | Units           |
|-----------|-----------------------------------------------------------------------------------------|-----------------|
| Cruise    | Cruise name from which sampling took place.                                             | unitless        |
| Station   | Station number of specified cruise.                                                     | unitless        |
| Latitude  | Sampling latitude in decimal degrees; a positive value indicates a northern coordinate. | decimal degrees |
|           |                                                                                         |                 |

|                            |                                                                                                |                                                                                       |
|----------------------------|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Longitude                  | Sampling longitude in decimal degrees; a negative value indicates a western coordinate.        | decimal degrees                                                                       |
| Deployment                 | Deployment number for the surface-tethered sediment trap array during the specified cruise.    | unitless                                                                              |
| Deploy_date.UTC            | Date of sediment trap array deployment.                                                        | unitless                                                                              |
| Recovery_date.UTC          | Date of sediment trap array recovery.                                                          | unitless                                                                              |
| Depth                      | Deployment depth of RESPIRE sediment trap.                                                     | meters (m)                                                                            |
| Deployment_length          | Length sediment trap array was deployed for                                                    | days (d)                                                                              |
| Particle_collection_period | Length of time RESPIRE traps collected particles for prior to incubation.                      | days (d)                                                                              |
| RESPIRE_O2_drawdown        | Rate of oxygen drawdown measured in RESPIRE trap incubations.                                  | millimoles of oxygen per meter cubed per day (mmol O <sub>2</sub> /m <sup>3</sup> /d) |
| RESPIRE_O2_drawdown_sd     | Standard deviation of rate of oxygen drawdown measured in RESPIRE trap incubations.            | millimoles of oxygen per meter cubed per day (mmol O <sub>2</sub> /m <sup>3</sup> /d) |
| Respiratory_quotient       | Respiratory quotient used to convert rates from oxygen to carbon units                         | unitless                                                                              |
| RESPIRE_C_utilization      | Rate of carbon utilization calculated for RESPIRE trap incubations.                            | millimoles of carbon per meter cubed per day (mmol C/m <sup>3</sup> /d)               |
| RESPIRE_C_utilization_sd   | Standard deviation of the rate of carbon utilization calculated for RESPIRE trap incubations   | millimoles of carbon per meter cubed per day (mmol C/m <sup>3</sup> /d)               |
| Avg_POC_final              | Amount of POC at the end of RESPIRE trap incubations averaged from triplicate CHN measurements | millimoles of carbon (mmol C)                                                         |
| Avg_POC_final_sd           | Standard deviation of the average amount of POC at the end of RESPIRE trap incubations.        | millimoles of carbon (mmol C)                                                         |
|                            |                                                                                                |                                                                                       |

|                                    |                                                                                                                                                                                                                                                |                                                                           |
|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| DOC_initial                        | Concentration of dissolved organic carbon prior to RESPIRE trap deployment. Measured from the filtered seawater that fills the RESPIRE trap prior to deployment.                                                                               | micromoles per liter (μmol/L)                                             |
| DOC_initial_sd                     | Standard deviation of the concentration of duplicate or triplicate dissolved organic carbon samples taken prior to RESPIRE trap deployment.                                                                                                    | micromoles per liter (μmol/L)                                             |
| DOC_final                          | Concentration of dissolved organic carbon after RESPIRE trap recovery. Estimated by subtracting the concentration of particulate organic carbon from the concentration of total organic carbon, where total organic carbon samples were taken. | micromoles per liter (μmol/L)                                             |
| DOC_final_sd                       | Standard deviation of the concentration of dissolved organic carbon from duplicate or triplicate samples taken after RESPIRE trap recovery.                                                                                                    | micromoles per liter (μmol/L)                                             |
| C_specific_respiration             | Carbon-specific respiration rate from RESPIRE trap incubation                                                                                                                                                                                  | per day (d <sup>-1</sup> )                                                |
| C_specific_respiration_uncertainty | Propagated uncertainty for carbon-specific respiration rate from RESPIRE trap incubation                                                                                                                                                       | per day (d <sup>-1</sup> )                                                |
| POC_flux                           | Particulate organic carbon fluxes back-calculated from RESPIRE trap measurements                                                                                                                                                               | millimoles of carbon per meter squared per day (mmol C/m <sup>2</sup> /d) |
| POC_flux_uncertainty               | Uncertainty associated with calculation of particulate organic carbon fluxes                                                                                                                                                                   | millimoles of carbon per meter squared per day (mmol C/m <sup>2</sup> /d) |
| RESPIRE_cell_conc                  | Concentration of cells in RESPIRE trap incubation chamber                                                                                                                                                                                      | cells per liter (cells/L)                                                 |
| RESPIRE_cell_conc_uncertainty      | Uncertainty associated with the calculation of the concentration of cells in the RESPIRE trap incubation chamber                                                                                                                               | cells per liter (cells/L)                                                 |

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## Instruments

|                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dataset-specific Instrument Name</b> | Aanderaa oxygen optode (Aanderaa 4831 series)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Generic Instrument Name</b>          | Aanderaa 4831 oxygen optode                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Dataset-specific Description</b>     | RESPIRE particle collection and incubation systems (custom build) with Aanderaa oxygen optode (Aanderaa 4831 series): Sinking particles were collected and incubated using RESPIRE trap particle collection and incubation systems and oxygen drawdown rates were determined from oxygen measurements using the Aanderaa oxygen optode located within the RESPIRE trap incubation chamber.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Generic Instrument Description</b>   | A dissolved oxygen sensor which provides analogue (0-5V) and digital output (RS-232) to third party data loggers, gliders and floats. Measurement based on the ability of selected substances to act as dynamic fluorescence quenchers. The fluorescent indicator is a special platinum porphyrin complex embedded in a gas permeable foil that is exposed to the surrounding water. In this standard model, a black optical isolation coating protects the complex from sunlight and fluorescent particles in the water. This sensing foil is attached to a window providing optical access for the measuring system from inside a watertight housing. The foil is excited by modulated blue light, and the phase of a returned red light is measured. For improved stability the 4831 optode also performs a reference phase reading by use of a red LED that does not produce fluorescence in the foil. This model is fitted with a standard sensing foil. By linearizing and temperature compensating, with an incorporated temperature sensor, the absolute O <sub>2</sub> concentration can be determined. Accuracy +/- 1.5% or 2uM; precision +/- 0.2 uM. |

|                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|-----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dataset-specific Instrument Name</b> | CTD                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Generic Instrument Name</b>          | CTD - profiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Dataset-specific Description</b>     | RESPIRE traps were filled with 0.2 µm-filtered seawater collected from a CTD cast 2-3 hours prior to deployment.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Generic Instrument Description</b>   | The Conductivity, Temperature, Depth (CTD) unit is an integrated instrument package designed to measure the conductivity, temperature, and pressure (depth) of the water column. The instrument is lowered via cable through the water column. It permits scientists to observe the physical properties in real-time via a conducting cable, which is typically connected to a CTD to a deck unit and computer on a ship. The CTD is often configured with additional optional sensors including fluorometers, transmissometers and/or radiometers. It is often combined with a Rosette of water sampling bottles (e.g. Niskin, GO-FLO) for collecting discrete water samples during the cast. This term applies to profiling CTDs. For fixed CTDs, see <a href="https://www.bco-dmo.org/instrument/869934">https://www.bco-dmo.org/instrument/869934</a> . |

|                                         |                                                                                                                                                                                                                           |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dataset-specific Instrument Name</b> | Exeter Analytical Elemental Analyzer                                                                                                                                                                                      |
| <b>Generic Instrument Name</b>          | Elemental Analyzer                                                                                                                                                                                                        |
| <b>Dataset-specific Description</b>     | Exeter Analytical Elemental Analyzer (Model: CEC 440HA): GF/F filters were analyzed for CHN on an Exeter Analytical Elemental Analyzer at the Marine Science Institute at UC Santa Barbara.                               |
| <b>Generic Instrument Description</b>   | Instruments that quantify carbon, nitrogen and sometimes other elements by combusting the sample at very high temperature and assaying the resulting gaseous oxides. Usually used for samples including organic material. |

|                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dataset-specific Instrument Name</b> | Zeiss Axio Observer 7 Inverted microscope                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Generic Instrument Name</b>          | Inverted Microscope                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Dataset-specific Description</b>     | Zeiss Axio Observer 7 Inverted microscope: DAPI-stained filters were imaged using a Zeiss Axio Observer 7 Inverted microscope at 63X objective.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Generic Instrument Description</b>   | An inverted microscope is a microscope with its light source and condenser on the top, above the stage pointing down, while the objectives and turret are below the stage pointing up. It was invented in 1850 by J. Lawrence Smith, a faculty member of Tulane University (then named the Medical College of Louisiana). Inverted microscopes are useful for observing living cells or organisms at the bottom of a large container (e.g. a tissue culture flask) under more natural conditions than on a glass slide, as is the case with a conventional microscope. Inverted microscopes are also used in micromanipulation applications where space above the specimen is required for manipulator mechanisms and the microtools they hold, and in metallurgical applications where polished samples can be placed on top of the stage and viewed from underneath using reflecting objectives. The stage on an inverted microscope is usually fixed, and focus is adjusted by moving the objective lens along a vertical axis to bring it closer to or further from the specimen. The focus mechanism typically has a dual concentric knob for coarse and fine adjustment. Depending on the size of the microscope, four to six objective lenses of different magnifications may be fitted to a rotating turret known as a nosepiece. These microscopes may also be fitted with accessories for fitting still and video cameras, fluorescence illumination, confocal scanning and many other applications. |

|                                         |                                                                                                                                                                                                                                                                                                                                               |
|-----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Dataset-specific Instrument Name</b> | Shimadzu TOC Analyzer                                                                                                                                                                                                                                                                                                                         |
| <b>Generic Instrument Name</b>          | Total Organic Carbon Analyzer                                                                                                                                                                                                                                                                                                                 |
| <b>Dataset-specific Description</b>     | Shimadzu TOC Analyzer: DOC and TOC samples were analyzed via the high temperature combustion method using modified Shimadzu TOC-V or TOC-L analyzers following Halewood et al. (2022).                                                                                                                                                        |
| <b>Generic Instrument Description</b>   | A unit that accurately determines the carbon concentrations of organic compounds typically by detecting and measuring its combustion product (CO <sub>2</sub> ). See description document at: <a href="http://bcodata.whoi.edu/LaurentianGreatLakes_Chemistry/bs116.pdf">http://bcodata.whoi.edu/LaurentianGreatLakes_Chemistry/bs116.pdf</a> |

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## Deployments

### AT50-10

|                   |                                                                                                       |
|-------------------|-------------------------------------------------------------------------------------------------------|
| <b>Website</b>    | <a href="https://www.bco-dmo.org/deployment/916122">https://www.bco-dmo.org/deployment/916122</a>     |
| <b>Platform</b>   | R/V Atlantis                                                                                          |
| <b>Report</b>     | <a href="https://www.rvdata.us/search/cruise/AT50-10">https://www.rvdata.us/search/cruise/AT50-10</a> |
| <b>Start Date</b> | 2023-05-02                                                                                            |
| <b>End Date</b>   | 2023-06-09                                                                                            |

## SR1919

|                   |                                                                                                     |
|-------------------|-----------------------------------------------------------------------------------------------------|
| <b>Website</b>    | <a href="https://www.bco-dmo.org/deployment/1009064">https://www.bco-dmo.org/deployment/1009064</a> |
| <b>Platform</b>   | R/V Sally Ride                                                                                      |
| <b>Start Date</b> | 2019-12-13                                                                                          |
| <b>End Date</b>   | 2019-12-19                                                                                          |

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## Project Information

### **Collaborative Research: Underexplored Connections between Nitrogen and Trace Metal Cycling in Oxygen Minimum Zones Mediated by Metalloenzyme Inventories (CliOMZ)**

**Coverage:** Eastern Tropical Pacific

#### *NSF abstract:*

Though scarce and largely insoluble, trace metals are key components of sophisticated enzymes (protein molecules that speed up biochemical reactions) involved in biogeochemical cycles in the dark ocean (below 1000m). For example, metalloenzymes are involved in nearly every reaction in the nitrogen cycle. Yet, despite direct connections between trace metal and nitrogen cycles, the relationship between trace metal distributions and biological nitrogen cycling processes in the dark ocean have rarely been explored, likely due to the technical challenges associated with their study. Availability of the autonomous underwater vehicle (AUV) Clio, a sampling platform capable of collecting high-resolution vertical profile samples for biochemical and microbial measurements by large volume filtration of microbial particulate material, has overcome this challenge. Thus, this research project plans an interdisciplinary chemistry, biology, and engineering effort to test the hypothesis that certain chemical reactions, such as nitrite oxidation, could become limited by metal availability within the upper mesopelagic and that trace metal demands for nitrite-oxidizing bacteria may be increased under low oxygen conditions. Broader impacts of this study include the continued development and application of the Clio Biogeochemical AUV as a community resource by developing and testing its high-resolution and adaptive sampling capabilities. In addition, metaproteomic data will be deposited into the recently launched Ocean Protein Portal to allow oceanographers and the metals in biology community to examine the distribution of proteins and metalloenzymes in the ocean. Undergraduate students will be supported by this project at all three institutions, with an effort to recruit minority students. The proposed research will also be synergistic with the goals of early community-building efforts for a potential global scale microbial biogeochemistry program modeled after the success of the GEOTRACES program, provisionally called "Biogeoscapes: Ocean metabolism and nutrient cycles on a changing planet".

The proposed research project will test the following three hypotheses: (1) the microbial metalloenzyme distribution of the mesopelagic is spatially dynamic in response to environmental gradients in oxygen and trace metals, (2) nitrite oxidation in the Eastern Tropical Pacific Ocean can be limited by iron availability in the upper mesopelagic through an inability to complete biosynthesis of the microbial protein nitrite oxidoreductase, and (3) nitrite-oxidizing bacteria increase their metalloenzyme requirements at low oxygen, impacting the distribution of both dissolved and particulate metals within oxygen minimum zones. One of the challenges to characterizing the biogeochemistry of the mesopelagic ocean is an inability to effectively sample it. As a sampling platform, we will use the novel biogeochemical AUV Clio that enables high-resolution vertical profile samples for biochemical and microbial measurements by large volume filtration of microbial particulate material on a research expedition in the Eastern Tropical Pacific Ocean. Specific research activities will be orchestrated to test the hypotheses. Hypothesis 1 will be explored by comparison of hydrographic, microbial distributions, dissolved and particulate metal data, and metaproteomic results with profile samples collected by Clio. Hypothesis 2 will be tested by incubation experiments using  $15\text{NO}_2^-$  oxidation rates on Clio-collected incubation samples. Hypothesis 3 will be tested by dividing targeted nitrite oxidoreductase protein copies by qPCR (quantitative polymerase chain reaction)-based nitrite oxidizing bacteria abundance (NOB) to determine if cellular copy number varies with oxygen distributions, and by metalloproteomic analyses of NOB cultures. The demonstration of trace metal limitation of remineralization processes, not just primary production, would transform our understanding of the role of metals in biogeochemical cycling and provide new ways with which to interpret sectional data of dissolved and particulate trace metal distributions in the ocean. The idea that oxygen may play a previously underappreciated role in controlling trace metals due not just to metals' physical

chemistry, but also from changing biological demand, will improve our ability to predict trace metal distributions in the face of decreasing ocean oxygen content.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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## Funding

| Funding Source                                           | Award                       |
|----------------------------------------------------------|-----------------------------|
| <a href="#">NSF Division of Ocean Sciences (NSF OCE)</a> | <a href="#">OCE-1924512</a> |

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