

# N2-fixation rate measurements from R/V Kilo Moana KM0812, KM0814 in the North Pacific Subtropical Gyre north of Hawaii from July to August 2008 (C-MORE project, Silica Cycling project, Phosphorus Bioavailability project)

**Website:** <https://www.bco-dmo.org/dataset/3396>

**Version:** December 6, 2010

**Version Date:** 2010-12-06

## Project

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- » [Silica Cycling and the Role of Diatoms in the North Pacific Subtropical Gyre](#) (Silica Cycling)
- » [Phosphorus Bioavailability and its Effect on the Role of Trichodesmium in Elemental Cycling](#) (Phosphorus Bioavailability)

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## Dataset Description

N2-fixation rate measurements employed the 15-N2 isotopic tracer method described by Montoya et al.

## Methods & Sampling

See Platform Deployments for cruise specific documentation

## Data Processing Description

See Platform Deployments for cruise specific documentation

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## Parameters

Parameter	Description	Units
date	date	YYYYMMDD
sta	station number	dimensionless
cast	cast number	dimensionless
bots	rosette bottle numbers composite sample drawn from two or more bottles	dimensionless
depth	depth	meters
lat	latitude negative denotes south	decimal degrees
lon	longitude negative denotes west	decimal degrees
N2_1_no_prefilter	N2 fixation rate (filtered onto GFF 1 with no prefilter)	nmol N L-1 d-1
N2_2_no_prefilter	N2 fixation rate (filtered onto GFF 2 with no prefilter)	nmol N L-1 d-1
N2_average_no_prefilter	average N2 fixation rate (with no prefilter)	nmol N L-1 d-1
N2_stderr_no_prefilter	standard error for the N2 fixation rate (with no prefilter)	nmol N L-1 d-1
N2_3_10um_prefilter	N2 fixation rate (filtered onto GFF 3 with 10 um prefilter)	nmol N L-1 d-1
N2_4_10um_prefilter	N2 fixation rate (filtered onto GFF 4 with 10 um prefilter)	nmol N L-1 d-1
N2_average_10um_prefilter	average N2 fixation rate (with 10 um prefilter)	nmol N L-1 d-1
N2_stderr_10um_prefilter	standard error for the N2 fixation rate (with 10 um prefilter)	nmol N L-1 d-1
N2_gt_10um_fraction	N2 fixation rate greater than 10 um fraction	nmol N L-1 d-1
activity_and_comments	comments	text

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## Deployments

**KM0812**

<b>Website</b>	<a href="https://www.bco-dmo.org/deployment/58162">https://www.bco-dmo.org/deployment/58162</a>
<b>Platform</b>	R/V Kilo Moana
<b>Start Date</b>	2008-07-01
<b>End Date</b>	2008-07-22
<b>Description</b>	<p>This cruise was funded by NSF award OCE-0648130. Original cruise data are available from the NSF R2R data catalog. Note that the cruise dates were determined from the information reported in the UNOLS STRS system and the R2R catalog.</p> <p><b>Methods &amp; Sampling</b>  GeoLocation: Frontal boundary separating the North Pacific subtropical and subarctic gyres (28-32° N, 145-150° W). # Discrete samples of 15N<sub>2</sub> fixation rates # CMORE affiliated / POOB # Ocean Microbial Ecology Laboratory # Ricardo Letelier # # original file: White_15N13C.xls # originally ingested into BCO-DMO: December 6, 2010 # updated : Feb 11 2011 (ancillary columns added - data not changed) # Using a gas tight syringe, 2.0 ml of 15N<sub>2</sub> gas (99 atom %, Cambridge Scientific) was injected into a 4L polycarbonate bottle and the bottles were inverted several times. Samples were incubated at appropriate light levels and temperature for 24 hours. Duplicate samples were taken when adequate water was available. Incubations were terminated by filtering the entire incubation volume onto a 25 mm pre-combusted glass fiber filter (GF/F, Whatman); following filtration, the filters were stored at -20°C until later analysis. Once ashore, samples were acid-fumed, dried overnight at 60°C and then encapsulated in tin and silver capsules. Particulate C, N and the isotopic composition of particulate material (<math>\delta^{15}\text{NPN}</math> and <math>\delta^{13}\text{CPC}</math>) were determined using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer in the University of California Davis stable isotope facility.</p> <p><b>Processing Description</b>  Related files and references for calculation parameters:  <a href="http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/15N_Calcs.xlsx">http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/15N_Calcs.xlsx</a>"&gt;di... 15N Calcs  <a href="http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/Montoya_et_al_1996">http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/Montoya_et_al_1996</a>.... et al, 1996</p>

**KM0814**

<b>Website</b>	<a href="https://www.bco-dmo.org/deployment/58018">https://www.bco-dmo.org/deployment/58018</a>
<b>Platform</b>	R/V Kilo Moana
<b>Start Date</b>	2008-07-30
<b>End Date</b>	2008-08-14
<b>Description</b>	<p>OPEREX Cruise Objective The objective of the OPEREX cruise will be to explore the potential and limitations of perturbation experiments at sea. We will follow some natural perturbations including blooms and eddies, and we will perform some of the artificial perturbation experiments including bench/lab scale incubations, ship deck incubations, and ship deck pH shift experiments. Original cruise data are available from the NSF R2R data catalog Related information from the C-MORE OPEREX cruise Web site: Homepage: <a href="http://cmore.soest.hawaii.edu/cruises/operex/index.htm">http://cmore.soest.hawaii.edu/cruises/operex/index.htm</a> Science plan: <a href="http://cmore.soest.hawaii.edu/cruises/operex/science_objective.htm">http://cmore.soest.hawaii.edu/cruises/operex/science_objective.htm</a> Data: <a href="http://hahana.soest.hawaii.edu/cmoredata/operex/operex.html">http://hahana.soest.hawaii.edu/cmoredata/operex/operex.html</a> Cruise track: <a href="http://hahana.soest.hawaii.edu/cmoredata/OPEREXtrack.gif">http://hahana.soest.hawaii.edu/cmoredata/OPEREXtrack.gif</a> Cruise plan: <a href="http://cmore.soest.hawaii.edu/cruises/operex/documents/km0814_cruise_pla...">http://cmore.soest.hawaii.edu/cruises/operex/documents/km0814_cruise_pla...</a> Cruise overview: <a href="http://hahana.soest.hawaii.edu/cmoredata/OPEREX_overview.pdf">http://hahana.soest.hawaii.edu/cmoredata/OPEREX_overview.pdf</a> Cruise schedule: <a href="http://cmore.soest.hawaii.edu/cruises/operex/documents/OPEREX_schedule.xls">http://cmore.soest.hawaii.edu/cruises/operex/documents/OPEREX_schedule.xls</a></p> <p><b>Methods &amp; Sampling</b>  # Discrete samples of 15N2 fixation rates # CMORE/OPEREX # Ocean Microbial Ecology Laboratory # Ricardo Letelier # # original file: White_operex_15N13C.xls # originally ingested into BCO-DMO: December 6, 2010 # updated : Feb 11 2011 (ancillary columns added - data not changed) # Using a gas tight syringe, 2.0 ml of 15N2 gas (99 atom %, Cambridge Scientific) was injected into a 4L polycarbonate bottle and the bottles were inverted several times. Samples were incubated at appropriate light levels and temperature for 24 hours. Duplicate samples were taken when adequate water was available. Incubations were terminated by filtering the entire incubation volume onto a 25 mm pre-combusted glass fiber filter (GF/F, Whatman); following filtration, the filters were stored at -20°C until later analysis. Once ashore, samples were acid-fumed, dried overnight at 60°C and then encapsulated in tin and silver capsules. Particulate C, N and the isotopic composition of particulate material (<math>\delta^{15}\text{N}_{\text{PN}}</math> and <math>\delta^{13}\text{C}_{\text{PC}}</math>) were determined using a PDZ Europa ANCA-GSL elemental analyzer interfaced to a PDZ Europa 20-20 isotope ratio mass spectrometer in the University of California Davis stable isotope facility.</p> <p><b>Processing Description</b>  Related files and references for calculation parameters:  <a href="http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/15N_Calcs.xlsx">http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/15N_Calcs.xlsx</a>"&gt;di... 15N Calcs  <a href="http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/Montoya_et_al_1996">http://cmore.soest.hawaii.edu/cmoredata/OMEL/discrete/Montoya_et_al_1996</a>.... et al, 1996</p>

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## Project Information

**Center for Microbial Oceanography: Research and Education (C-MORE)**

**Website:** <http://cmore.soest.hawaii.edu/>

**Coverage:** North Pacific Subtropical Gyre (large region around 22 45 N, 158 W)

## Project summary

The **Center for Microbial Oceanography: Research and Education (C-MORE)** is a recently established (August 2006; NSF award: EF-0424599) NSF-sponsored Science and Technology Center designed to facilitate a more comprehensive understanding of the diverse assemblages of microorganisms in the sea, ranging from the genetic basis of marine microbial biogeochemistry including the metabolic regulation and environmental controls of gene expression, to the processes that underpin the fluxes of carbon, related bioelements and

energy in the marine environment. Stated holistically, C-MORE's primary mission is: *Linking Genomes to Biomes*.

We believe that the time is right to address several major, long-standing questions in microbial oceanography. Recent advances in the application of molecular techniques have provided an unprecedented view of the structure, diversity and possible function of sea microbes. By combining these and other novel approaches with more well-established techniques in microbiology, oceanography and ecology, it may be possible to develop a meaningful predictive understanding of the ocean with respect to energy transduction, carbon sequestration, bioelement cycling and the probable response of marine ecosystems to global environmental variability and climate change. The strength of C-MORE resides in the synergy created by bringing together experts who traditionally have not worked together and this, in turn, will facilitate the creation and dissemination of new knowledge on the role of marine microbes in global habitability.

The new Center will design and conduct novel research, broker partnerships, increase diversity of human resources, implement education and outreach programs, and utilize comprehensive information about microbial life in the sea. The Center will bring together teams of scientists, educators and community members who otherwise do not have an opportunity to communicate, collaborate or design creative solutions to long-term ecosystem scale problems. The Center's research will be organized around four interconnected themes:

- (Theme I) microbial biodiversity,
- (Theme II) metabolism and C-N-P-energy flow,
- (Theme III) remote and continuous sensing and links to climate variability, and
- (Theme IV) ecosystem modeling, simulation and prediction.

Each theme will have a leader to help coordinate the research programs and to facilitate interactions among the other related themes. The education programs will focus on pre-college curriculum enhancements, in service teacher training and formal undergraduate/graduate and post-doctoral programs to prepare the next generation of microbial oceanographers. The Center will establish and maintain creative outreach programs to help diffuse the new knowledge gained into society at large including policymakers. The Center's activities will be dispersed among five partner institutions:

- Massachusetts Institute of Technology,
- Woods Hole Oceanographic Institution,
- Monterey Bay Aquarium Research Institute,
- University of California at Santa Cruz and
- Oregon State University

and will be coordinated at the University of Hawaii at Manoa.

#### **Related Files:**

[Strategic plan \(PDF file\)](#)

### **Silica Cycling and the Role of Diatoms in the North Pacific Subtropical Gyre (Silica Cycling)**

**Coverage:** North Pacific Subtropical Gyre north of Hawaii, near (30 N, 140 W)

This study examines the unique silicon cycle of the North Pacific Subtropical Gyre (NPSG).

Most marine silicon cycle studies have focused on the more productive coastal waters or the Southern Ocean where diatoms typically dominate the phytoplankton. Although diatom biomass is much lower in subtropical gyres, silica production is significant in global terms. Silicon cycle studies of the Sargasso Sea in the 1990's implied that subtropical gyres account for 13% of global marine silica production. More recent data from the NPSG show much higher rates of silica production that would increase the contribution of subtropical gyres to as much as 40%. The new estimate is uncertain and based on few data, but suggests that the contribution of subtropical gyres has been underestimated. Differences in the silicon cycle between the NPSG and the Sargasso Sea go beyond differences in average production rates. The two systems are several months out of phase with each other in terms of their seasonal silica production cycles. Unlike the Sargasso Sea, where diatoms bloom regularly in spring in response to winter convective overturn, permanent stratification prevents spring diatom blooms events in the NPSG, where annual diatom blooms occur in summer, when stratification is strongest and nutrient concentrations are at a seasonal minimum. These enigmatic summer blooms contribute

significantly to carbon and nitrogen export in the NPSG and likely dominate the annual silicon cycle.

Time series of rate measurements will be made in collaboration with the HOT program to define the annual silicon cycle at station ALOHA. The project will also collaborate with the new "Center for Microbial Oceanography: Research and Education" (CMORE) Science and Technology Center at the University of Hawaii to study summer blooms. Funding for this portion of the project is from NSF OCE-0648130.

Separately funded laboratory studies (NSF OCE-0726726; Title: Biological characterization of the nitrogen-fixing *Rhizosolenia-Richelia* symbiosis), looked at the role of diatom-diazotroph associations (DDAs) in elemental cycling in the NPSG.

Nitrogen-fixation provides a key input of new nitrogen into oligotrophic, oceanic regions. Work over the past two decades has highlighted the role of *Trichodesmium*. More recently, the role of coccoid cyanobacteria as well as symbiotic associations of the filamentous cyanobacteria *Richelia intracellularis* with species of diatoms (*Rhizosolenia* and *Hemiaulus*) has received attention. Little is known of the growth rates, nutrient needs, chemical composition, or environmental tolerances of these DDAs. However, it is clear that DDAs are numerically important in some oceans and can play a major role in mediating new nitrogen inputs. Recent models have identified the need for species-specific parameters, but these are lacking for DDAs. In particular, temperature dependent properties require quantification for application to global warming scenarios.

Laboratory studies of both the *Rhizosolenia-Richelia* and *Hemiaulus-Richelia* DDA are now possible due to the reproducible cultivation of this association. This four-year research program will quantify temperature and salinity effects on growth rates and N<sub>2</sub>-fixation rates. It will explore the role of silicate and phosphate (inorganic and organic) in controlling growth rates, chemical composition and N<sub>2</sub>-fixation through host-symbiont interactions. Field studies will address the distribution of both these DDAs and their contribution to Si cycling in large diatom blooms reported from the central N. Pacific gyre.

The mass accumulation of the DDAs in sediment traps as well as in the sedimentary record suggest DDAs are important vectors to depth. The potentially high sinking rates relative to *Trichodesmium* permit rapid export of new N and sequestration of C. This work will quantify settling rates under conditions of phosphate and silicate-limited growth and provide the first estimates of potential losses due to sinking. This program will provide the first broad characterization of a DDA and provide valuable input data for models.

DDA blooms are potential means to remove C and N quickly from the euphotic zone via mass sedimentation of the diatom host. Diatom remains in sediments suggest this is an important vector for sedimentary deposition. The autecological work in this study will produce information important for interpreting how such events can occur. In addition, temperature tolerance studies will yield data useful for understanding how this DDA could respond to warming oceans.

The proposed research on Si cycling combined with ongoing studies of C, N and P cycling at station ALOHA will allow, for the first time, an opportunity for a coordinated analysis the cycling of all four of these elements simultaneously in an oligotrophic gyre. The pairing of field work with laboratory studies to determine the role of DDAs will expand understanding of the mechanisms controlling the contribution of diatoms to elemental cycling in open ocean ecosystems.

## **RELATED PUBLICATIONS**

Brzezinski MA, Krause JW, Church MJ, Karl DM, Li B, Jones JL, Updyke B. "The annual silica cycle of the North Pacific subtropical gyre," *Deep Sea Research I*, v.58, 2011, p. 998.

Duhamel S., Bjorkman K. M., Van Wambeke F., Moutin T., Karl DM. "Characterization of alkaline phosphatase activity in the North and South Pacific Subtropical Gyres: Implications for phosphorus cycling," *Limnology and Oceanography*, v.56, 2011, p. 1244.

Krause J.W., Brzezinski M.A., Jones J.L. "Application of low-level beta counting of <sup>32</sup>Si for the measurement of silica production rates in aquatic environments," *Marine Chemistry*, v.127, 2011, p. 40.

Krause J.W., Brzezinski M.A., Villareal, T.A., Wilson C. "Increased kinetic efficiency for silicic acid uptake as a driver of summer diatom blooms in the North Pacific subtropical gyre," *Limnology and Oceanography*, v.57, 2012, p. 1084.

Villareal, T.A.; Adornato, L.; Wilson, C.; Shoenbachler, C.A. "Summer blooms of diatom-diazotroph assemblages (DDAs) and surface chlorophyll in the N. Pacific gyre - a disconnect" *Journal of Geophysical Research-Oceans*, v.116, 2011, p. DOI: 10.1.

Villareal T.A., Brown, C. G., Brzezinski M.A., Krause J.W., Wilson C.. "Summer Diatom Blooms in the North Pacific Subtropical Gyre: 2008-2009," PLoS ONE, v.7, 2012, p. e33109.

Watkins-Brandt K.S., Letelier R.M., Spitz Y.H., Church M.J., Bottjer D., White Angelique. "Addition of inorganic or organic phosphorus enhances nitrogen and carbon fixation in the oligotrophic North Pacific," Marine Ecology Progress Series, v.432, 2011, p. 17.

## **Phosphorus Bioavailability and its Effect on the Role of Trichodesmium in Elemental Cycling (Phosphorus Bioavailability)**

**Coverage:** North Pacific subtropical gyre

The vast oligotrophic gyres of the world's ocean encompass roughly 60% of the global marine environment. Once thought to be biological deserts, recent research has determined that these regions may account for up to half of the total oceanic organic carbon export. In a society faced with the task of characterizing and predicting the behavior of our ecosystem under the stress of a changing environment, a thorough understanding of these vast marine biomes can move us toward a quantitative representation of the marine ecosystem that can adapt to environmental change. In this respect, the continuous observation and study of the North Pacific subtropical gyre (NPSG) over the past 15 years by the Hawaii Ocean time-series (HOT) program has provided an extensive record of oceanic biogeochemical dynamics. The annual cycle of this system is dominated by tight coupling between the processes of photosynthesis and respiration such that the majority of biologically produced carbon is recycled to the system. In contrast, net export of carbon in the NPSG occurs primarily during summer periods as a result of regular blooms of large, buoyant N<sub>2</sub>-fixing photoautotrophs. A fundamental trait of these bloom events is the observation of elevated dissolved and particulate N:P and C:P ratios, indicating that the biological system is shifted to a more intensely phosphorus (P) limited state during bloom events. While the occurrence of pulsed export events is well documented in this system, the physiological mechanisms driving the companion stoichiometric diversions remain poorly understood.

In this proposal, the investigators have identified three ecologically relevant physiological adaptations, which may quantitatively explain the ability of a key bloom-forming organism, Trichodesmium, to increase in biomass and abundance, alter stoichiometric ratios of dissolved and particulate pools and thus regulate the flow of elements and the magnitude of export in an otherwise nutrient starved marine environment. These adaptations are: 1) utilization of dissolved organic pools, 2) extreme variability of internal P quotas and 3) buoyancy control. With these physiological adaptations in mind, the objectives of this research are as follows: 1) To measure uptake and regeneration rates of soluble reactive P (SRP) and dissolved organic P (DOP) in natural Trichodesmium populations. 2) To obtain robust estimates of the plasticity of the relative cellular content and compartmentalization of P under different environmental conditions and to characterize how changes in P quotas affect organic production of particulate and dissolved organic carbon and nitrogen by Trichodesmium spp. 3) To test the hypothesis that buoyancy-mediated vertical migration of Trichodesmium colonies facilitates mining of the phosphocline and injection of DIP into the euphotic zone. 4) To utilize the results derived from the above research activities to assess and model the role of Trichodesmium in the flux of elements (C, N, and P) and regulation of pelagic ecosystem structure under different climate scenarios (i.e. under increased or decreased periods of water column stratification). Fulfillment of these objectives will be achieved via the integration of field, and laboratory research components.

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## **Funding**

<b>Funding Source</b>	<b>Award</b>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-0623596</a>
<a href="#">NSF Division of Ocean Sciences (NSF OCE)</a>	<a href="#">OCE-0850827</a>

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