Growth, carbon fixation, and nitrogen fixation rates of Trichodesmium erythraeum GBRTRLIN201 and Synechococcus WH8012 from laboratory culture experiments under temperature and nutrient limitation treatments

Website: https://www.bco-dmo.org/dataset/1010465
Data Type: experimental
Version: 1
Version Date: 2026-10-21

Project
» NSFGEO-NERC: Understanding the consequences of changing phytoplankton elemental use efficiencies for global ocean biogeochemistry (EUEs and global ocean biogeochemistry)

Contributors	Affiliation	Role
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Abstract
This dataset contains growth rates, carbon (CO2) fixation rates, and nitrogen (N2) fixation (for diazotrophs only) rates for two marine cyanobacteria, Trichodesmium erythraeum (strain GBRTRLIN201) and Synechococcus WH8012, measured across a range of temperatures and nutrient conditions in laboratory culture experiments conducted at the University of Southern California. The goal of these experiments was to characterize how nutrient availability modulates the thermal performance of ecologically important marine cyanobacteria in the context of ocean warming and nutrient limitation. Thermal performance curves were established by acclimating cultures to temperatures spanning 15 to 34 °C (Synechococcus) and 20 to 34 °C (Trichodesmium), under nutrient-replete conditions and iron (Fe)-, phosphorus (P)-, and nitrogen (N)-limiting conditions (Synechococcus only) or Fe- and P-limiting conditions (Trichodesmium). Growth rates were determined from in vivo chlorophyll a fluorescence measurements. CO2 fixation rates were measured using the radiocarbon-labeled bicarbonate method. N2 fixation rates of Trichodesmium were measured using the acetylene reduction assay. Fixation rates were normalized to particulate organic carbon or particulate organic nitrogen content measured using a Costech elemental analyzer.

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Coverage

Location: Laboratory culture experiments conducted at the University of Southern California
Temporal Extent: 2024-03 - 2025-04

Methods & Sampling

Culturing Methods

Synechococcus WH8012 and *Trichodesmium erythraeum* GBRTRLIN201 were isolated from the Sargasso Sea and the North Great Barrier Reef Lagoon, respectively (Waterbury et al. 1986; Bell et al. 2005). Thermal performance curves were established by stepwise acclimation of stock cultures from 28 °C to target temperatures, with approximately 3–4 days of acclimation between sequential transfers to minimize transient stress responses. *Synechococcus* was grown from 15 to 34 °C and *Trichodesmium* from 20 to 34 °C, both at 2–3 °C intervals. Triplicate cultures were grown in 0.2 µm-filtered, microwave-sterilized artificial seawater under nutrient-replete (100µM nitrate; 10µM phosphate; 125nM Fe- 25µM EDTA) and N- (7µM nitrate), P- (0.4µM phosphate), or Fe-limited (5nM Fe-25µM EDTA) conditions (*Synechococcus*), or replete(10µM phosphate; 250nM Fe- 25µM EDTA), P- (0.4µM phosphate), and Fe-limited (10nM Fe-25µM EDTA) conditions (*Trichodesmium*). Light was provided at ~40 µmol photons m^{-2} s^{-1} (*Synechococcus*) and ~150 µmol photons m^{-2} s^{-1} (*Trichodesmium*) on a 12:12 h light: dark cycle. Cultures were maintained in semi-continuous exponential growth for at least one month, and measurements were conducted after steady-state growth was achieved (Jiang et al., 2018; Qu et al., 2019).

Physiological Analyses

Specific growth rates. Daily growth rates were determined from in vivo chlorophyll *a* fluorescence measured with a Turner Designs 10-AU fluorometer. Specific growth rates were calculated as µ = ln[N(T1)/N(T0)] / (T1–T0).

Carbon and nitrogen fixation rates. Carbon fixation rates were measured using the 14C-labeled bicarbonate method. Triplicate 30 mL subsamples were incubated for 24 h with added H14CO3- alongside dark controls, then filtered onto GF/F filters, and analyzed by liquid scintillation counting (Beckman LS 6000; Qu et al. 2019). Nitrogen fixation rates were measured by acetylene reduction: 30 mL subsamples were incubated in 75 mL sealed bottles with 2 mL acetylene for 4 h, and ethylene production was quantified by gas chromatography (Shimadzu GC-8A). Procedural blanks were subtracted from all values. Carbon and Nitrogen fixation rates were normalized to particulate organic carbon (POC) and nitrogen (PON), respectively, collected on pre-combusted GF/F filters and analyzed with a Costech elemental analyzer using acetanilide calibration standards (Yang et al., 2021).

This experiment was conducted from March 2024 to April 2025. This period does not include the date when the culture was originally isolated from the field.

Data Processing Description

Growth rates

Growth rates were calculated from in vivo chlorophyll a fluorescence readings measured with a Turner Designs 10-AU fluorometer using the equation: mu = ln[N(T1)/N(T0)] / (T1 - T0), where N(T0) and N(T1) are fluorescence values at two consecutive time points.

Carbon fixation rates

Carbon fixation rates were calculated from disintegrations per minute (DPM) measured by liquid scintillation counting (Beckman LS 6000), using the specific activity of the added H14CO3- tracer and total dissolved inorganic carbon concentration, and normalized to particulate organic carbon (POC) content.

Nitrogen fixation rates

Nitrogen fixation rates were calculated from ethylene production measured by gas chromatography (Shimadzu GC-8A) using a standard conversion factor (acetylene: N2 = 3:1), and normalized to particulate organic nitrogen (PON) content.

POC and PON

POC and PON were calculated from elemental analyzer (Costech) output using calibration curves generated from acetanilide standards, with blank filter values subtracted.

Data calculations were performed in R version 4.6.0.

BCO-DMO Curation Notes

Curation Actions Performed on Data File:

Loaded Tricho_Syn_data.csv as table 1010465_v1_phytoplankton_physiology_data (CSV format, header in row 1; "" and "N/A" treated as missing values).
Renamed specific growth rates (d-1) to specific_growth_rates, carbon fixation rate (hr-1) to carbon_fixation_rate, Nitrogen fixation rates (hr-1) to Nitrogen_fixation_rates, and Date (yyyy-mm-dd) to Date.
Set Date as a date formatted %Y-%m-%d; temperature as an integer; specific_growth_rates, carbon_fixation_rate, and Nitrogen_fixation_rates as numbers; and Species, sampleID, and treatment as strings.
Updated column metadata, including BCO-DMO descriptions, supplied units, and standard parameter name IDs, for Date, Nitrogen_fixation_rates, Species, carbon_fixation_rate, sampleID, specific_growth_rates, temperature, and treatment.
Saved the processed file as 1010465_v1_phytoplankton_physiology_data.csv.

Problem Description

No problems or issues related to this dataset have ben reported by the dataset authors.

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Related Publications

Bell, P. R. F., Uwins, P. J. R., Elmetri, I., Phillips, J. A., Fu, F. X., & Yago, A. J. E. (2005). Laboratory culture studies of Trichodesmium isolated from the Great Barrier Reef Lagoon, Australia. Hydrobiologia, 532(1-3), 9–21. https://doi.org/10.1007/s10750-004-8768-1
Methods

Capone, D. G. (2018). Determination of Nitrogenase Activity in Aquatic Samples Using the Acetylene Reduction Procedure. Handbook of Methods in Aquatic Microbial Ecology, 621–631. https://doi.org/10.1201/9780203752746-74
Methods

Jiang, H.-B., Fu, F.-X., Rivero-Calle, S., Levine, N. M., Sañudo-Wilhelmy, S. A., Qu, P.-P., … Hutchins, D. A. (2018). Ocean warming alleviates iron limitation of marine nitrogen fixation. Nature Climate Change, 8(8), 709–712. doi:10.1038/s41558-018-0216-8
Methods

Qu, P., Fu, F.-X., Kling, J. D., Huh, M., Wang, X., & Hutchins, D. A. (2019). Distinct Responses of the Nitrogen-Fixing Marine Cyanobacterium Trichodesmium to a Thermally Variable Environment as a Function of Phosphorus Availability. Frontiers in Microbiology, 10. https://doi.org/10.3389/fmicb.2019.01282
Methods

Waterbury, J. B., Watson, S. W., Valois, F. W., & Franks, D. G. (1986). Biological and ecological characterization of the marine unicellular cyanobacterium Synechococcus. In T. Platt & W. K. W. Li (Eds.), Photosynthetic picoplankton (Canadian Bulletin of Fisheries and Aquatic Sciences, No. 214, pp. 71–120). Department of Fisheries and Oceans. https://publications.gc.ca/pub?id=9.952113&sl=0 cir.nii.ac.jp https://cir.nii.ac.jp/crid/1573105974970382336
Methods

Yang, N., Merkel, C. A., Lin, Y.-A., Levine, N. M., Hawco, N. J., Jiang, H.-B., … Hutchins, D. A. (2021). Warming Iron-Limited Oceans Enhance Nitrogen Fixation and Drive Biogeographic Specialization of the Globally Important Cyanobacterium Crocosphaera. Frontiers in Marine Science, 8. doi:10.3389/fmars.2021.628363
Methods

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Related Datasets

IsRelatedTo

Hutchins, D. A., Fu, F. (2026) **Growth rates of Trichodesmium erythraeum GBRTRLIN201 and Synechococcus WH8012 from phosphate-manipulation laboratory culture experiments.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-10-21 http://lod.bco-dmo.org/id/dataset/1010479 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
sampleID	A unique identifier for each sample, formatted as species code-temperature-phosphate concentration-replicate number. SYN and TRI indicate the species codes; R, N, P, Fe indicate the experimental nutrient treatment; 15/20..35 indicate the experimental temperature; and 1, 2, and 3 indicate replicate numbers.	unitless
Species	Species name	unitless
temperature	Experimental temperature	degree C
treatment	Experimental nutrient treatments	unitless
specific_growth_rates	The specific growth rate under certain experimental condition	day -1
carbon_fixation_rate	The carbon fixation rate under certain experimental condition	hour -1
Nitrogen_fixation_rates	The nitrogen fixation rate under certain experimental condition	hour -1
Date	Experimental date	unitless

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Instruments

Dataset-specific Instrument Name	Elemental Analyzer (Costech)
Generic Instrument Name	Elemental Analyzer
Dataset-specific Description	POC and PON were calculated from elemental analyzer (Costech) output using calibration curves generated from acetanilide standards, with blank filter values subtracted.
Generic Instrument Description	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.

Dataset-specific Instrument Name	Turner Designs 10-AU fluorometer (Turner Designs, San Jose, CA, USA)
Generic Instrument Name	Fluorometer
Dataset-specific Description	Growth rates were calculated from in vivo chlorophyll a fluorescence readings measured with a Turner Designs 10-AU fluorometer using the equation: mu = ln[N(T1)/N(T0)] / (T1 - T0), where N(T0) and N(T1) are fluorescence values at two consecutive time points.
Generic Instrument Description	A fluorometer or fluorimeter is a device used to measure parameters of fluorescence: its intensity and wavelength distribution of emission spectrum after excitation by a certain spectrum of light. The instrument is designed to measure the amount of stimulated electromagnetic radiation produced by pulses of electromagnetic radiation emitted into a water sample or in situ.

Dataset-specific Instrument Name	Shimadzu GC-8A
Generic Instrument Name	Gas Chromatograph
Dataset-specific Description	Nitrogen fixation rates were calculated from ethylene production measured by gas chromatography (Shimadzu GC-8A) using a standard conversion factor (acetylene: N2 = 3:1), and normalized to particulate organic nitrogen (PON) content.
Generic Instrument Description	Instrument separating gases, volatile substances, or substances dissolved in a volatile solvent by transporting an inert gas through a column packed with a sorbent to a detector for assay. (from SeaDataNet, BODC)

Dataset-specific Instrument Name	Beckman LS 6000 liquid scintillation counter (Beckman Coulter Inc.)
Generic Instrument Name	Liquid Scintillation Counter
Dataset-specific Description	Carbon fixation rates were calculated from disintegrations per minute (DPM) measured by liquid scintillation counting (Beckman LS 6000), using the specific activity of the added H14CO3- tracer and total dissolved inorganic carbon concentration, and normalized to particulate organic carbon (POC) content.
Generic Instrument Description	Liquid scintillation counting is an analytical technique which is defined by the incorporation of the radiolabeled analyte into uniform distribution with a liquid chemical medium capable of converting the kinetic energy of nuclear emissions into light energy. Although the liquid scintillation counter is a sophisticated laboratory counting system used to quantify the activity of particulate emitting (ß and a) radioactive samples, it can also detect the auger electrons emitted from 51Cr and 125I samples. Liquid scintillation counters are instruments assaying alpha and beta radiation by quantitative detection of visible light produced by the passage of rays or particles through a suitable scintillant incorporated into the sample.

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Project Information

NSFGEO-NERC: Understanding the consequences of changing phytoplankton elemental use efficiencies for global ocean biogeochemistry (EUEs and global ocean biogeochemistry)

Coverage: Global

NSF Award Abstract:
This project is jointly funded by the National Science Foundation's Directorate of Geosciences (NSF/GEO) and the National Environment Research Council (UKRI/NERC) of the United Kingdom (UK) via the NSF/GEO-NERC Lead Agency Agreement. This Agreement allows a single joint US/UK proposal to be submitted and peer-reviewed by the Agency whose investigator has the largest proportion of the budget. Upon successful joint determination of an award, each Agency funds the proportion of the budget and the investigators associated with its own investigators and component of the work.

Earth system computer models that simulate the global cycles of carbon and other elements are one of our most valuable tools to predict environmental change in the future ocean. However, existing modeling methods cannot realistically test how increasing ocean temperatures will affect the needs of marine micro-organisms for the limiting nutrients that usually control their growth, including nitrogen, phosphorus and iron. Because these limiting nutrients govern how much photosynthesis occurs in the ocean, they strongly influence the fate of carbon dioxide produced by human fossil-fuel burning. For this reason, determining how nutrient use by plankton will respond to greenhouse warming of the surface ocean is a priority for scientists and policy makers. This project supports a collaboration between two marine microbiologists in the United States and an Earth system modeler from the United Kingdom that is aiming to better understand how oceanic limiting nutrient cycles and the biological communities they support will react to global warming. The U.S. investigators are using laboratory culture experiments, field work in the coastal ocean, and existing collections of past open ocean chemistry and biology measurements to generate quantitative estimates of rising temperature effects on nutrient elemental use efficiencies (EUEs). An EUE is defined as the rate at which a marine microbe can take up carbon dioxide via photosynthesis, per unit of limiting nutrient in the cell. Preliminary results show that EUEs are highly sensitive to changing temperature, which in turn has far-reaching consequences for how ocean ecosystems function. The U.K. investigator is using these experimentally-determined values to build a new Earth system model that is centered on how warmer conditions will affect EUEs for important groups of marine micro-organisms. This novel approach has the potential to yield much better estimates of the ways that ocean carbon uptake and nutrient cycling will be altered as the ocean continues to warm in the future. Broader Impacts include breaking new scientific ground in oceanography and climate science through improved Earth

system models, providing educational opportunities for graduate students, undergraduate researchers, K-12 students, and postdoctoral investigators, and strengthening collaborative ties between the marine science communities of the U.S. and the U.K.

Quantitative relationships between phytoplankton nutrient limitation, primary production and globally-rising sea surface temperatures are still not well understood, largely due to a lack of mechanistic experimental data. This is problematic for Earth system modelers who are trying to project future oceanic productivity levels that underpin predicted changes in ocean ecosystems, information that is urgently needed to inform environmental policy makers. This project addresses this knowledge gap in a closely coordinated, collaborative project between two U.S. marine microbiologists and a biogeochemical modeler from the U.K. The international team of interdisciplinary researchers are applying the emergent concept of Elemental Use Efficiencies (EUEs) to integrate flexible thermal and resource limitation responses into a new generation of Earth system models. EUEs are defined as the amount of carbon fixed per unit time, normalized to the amount of a limiting resource in a phytoplankton cell, as represented by the cellular nutrient quota. Preliminary work suggests that EUEs can be very sensitive to future ocean warning, with major downstream consequences for nutrient-limited marine plankton assemblages and thus also for ocean carbon and nutrient biogeochemistry. The investigators are using high-throughput thermal block methodology to measure EUEs for the limiting nutrients nitrogen, phosphorus and iron in a diverse set of four different functional groups of laboratory phytoplankton isolates across their entire thermal ranges. EUEs obtained for these three key limiting nutrient resources as a function of temperature and degree of nutrient stress are being applied in an iterative manner to inform a novel EUE-centric version of the established NEMO-PISCES ocean model. Field EUE data from coastal and open ocean regimes are being collected for comparison to and ground-truthing of both the laboratory culture results, and the modeling output. This project will advance the discipline of ocean global change biology by providing unique new insights into how biogeochemically-critical marine microbial functional groups may respond to simultaneous shifts in temperature and limiting nutrient resource availability both today, and in the future changing ocean.

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.

NERC award abstract:
A major focus of biological oceanography is to understand and quantify the effects of temperature and resource availability on phytoplankton productivity and ecosystem dynamics in the world ocean. Classic paradigms like Eppley's temperature curve and the resource response relationships of Liebig and Monod have served the field well, but they fail to capture the full dynamic and interactive nature of resource availability and temperature influences on primary production. This shortcoming is especially problematic for earth system modelers as they urgently try to estimate future oceanic productivity levels that underpin projected changes in the ocean ecosystem, properties that are needed to inform policy makers such as the assessment reports of the IPCC and IPBES. This proposal describes a closely coordinated collaborative project between two U.S. marine microbiologists and a biogeochemical modeler from the U.K. that will apply the emergent concept of Elemental Use Efficiencies (EUEs) to integrate flexible thermal and resource limitation responses into a new generation of earth system models. EUEs are defined as the amount of carbon fixed, per unit of cellular nutrient resource, per unit time. This simple, yet novel concept provides a unique opportunity to integrate the observed consequences of concurrent warming and altered nutrient availability for primary productivity in ocean models to quantify biogeochemical and biological responses in the rapidly changing ocean environment.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2149837

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