Results from nutrient limitation assessments quantifying the level of Si, N, and Fe stress being experienced by phytoplankton in samples collected on EXPORTS cruise DY131 in the North Atlantic during May 2021

Website: https://www.bco-dmo.org/dataset/893324
Data Type: Cruise Results
Version: 1
Version Date: 2023-04-06

Project
» Collaborative Research: Diatoms, Food Webs and Carbon Export - Leveraging NASA EXPORTS to Test the Role of Diatom Physiology in the Biological Carbon Pump (Diatoms and carbon export)

Program
» EXport Processes in the Ocean from Remote Sensing (EXPORTS)

Contributors	Affiliation	Role
Brzezinski, Mark A.	University of California-Santa Barbara (UCSB-MSI)	Principal Investigator
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Abstract
This dataset includes data from the nutrient amendment experiments. In these experiments, tracer additions (14C, 32Si) were used to quantify the level of Si, N, and Fe stress being experienced by the phytoplankton and to contextualize taxa-specific metatranscriptome responses for resolving gene expression profiles in the in situ communities. Seawater samples were collected on EXPORTS cruise DY131 during May 2021. This research focuses on the vertical export of the carbon associated with a major group of phytoplankton, the diatoms in the North Atlantic near the Porcupine Abyssal Plain. The major objective is to understand how diatom community composition and the prevailing nutrient conditions create taxonomic differences in metabolic state that combine to direct diatom taxa to different carbon export pathways. The focus is on diatoms, given their large contribution to global marine primary productivity and carbon export which translates into a significant contribution to the biogeochemical cycling of carbon (C), nitrogen (N), phosphorus (P), iron (Fe) and silicon (Si). It is hypothesized that the type and degree of diatom physiological stress are vital aspects of ecosystem state that drive export. To test this hypothesis, combined investigator expertise in phytoplankton physiology, genomics, and trace element chemistry is used to assess the rates of nutrient use and the genetic composition and response of diatom communities, with measurements of silicon and iron stress to evaluate stress as a predictor of the path of diatom carbon export. The EXPORTS field campaign in the North Atlantic sampled a retentive eddy over nearly a month. At the beginning of the cruise, nitrate was abundant while silicic acid was nearly undetectable. Such low dissolved Si concentrations significantly limit diatom silicification resulting in diatoms with reduced mineral ballast and low Si:C and Si:N ratios that would reduce sinking rates and competition for Si can alter diatom taxonomic composition. Both factors can the path cells follow through the food web ultimately altering diatom carbon export. Within each ecosystem state examined in the EXPORTS program, nutrient biogeochemistry, diatom and phytoplankton community structure, and global diatom gene expression patterns (metatranscriptomics) are characterized in the ocean. Nutrient amendment experiments with tracer addition (14C, 32Si) are used to quantify the level of Si, N, and Fe stress being experienced by the phytoplankton and to contextualize taxa-specific metatranscriptome responses for resolving gene expression profiles in the in situ communities.

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Coverage

Spatial Extent: **N**:49.2341 **E**:-14.5095 **S**:48.7816 **W**:-14.9764
Temporal Extent: 2021-05-06 - 2021-05-27

Dataset Description

Depth profiles in the euphotic zone of nutrient (nitrate, silicate, phosphate) concentrations, profiles of silicic acid uptake rates, and assessment of limitation by Si, N, and Fe on both silicic acid uptake and carbon fixation.

See the related dataset (https://www.bco-dmo.org/dataset/893293) for the profile data.

Methods & Sampling

Seawater samples were collected using an epoxy coated CTD-rosette mounted with Go-Flo samplers and a Sea-Bird Electronics CTD (SBE9plus). Go-Flo bottles were transferred to a trace metal clean van for subsampling into polypropylene tubes (nutrients), polypropylene bottle (biogenic silica and particulate carbon and nitrogen) or TM acid-cleaned polycarbonate incubation bottles (Si-32 & C-14 incubation experiments).

Nutrient samples were filtered through 0.2 micrometer (µm) polycarbonate filters and frozen at -20° Celsius (C). Samples for biogenic silica concentrations were size fractionated by serial filtration through 5 µm and 0.6 µm polycarbonate filters Filters were stored frozen at -20°C. Particulate organic carbon and nitrogen were measured on samples from experiments examining the effect of added Fe and Si on carbon fixation. These samples were filtered through precombusted GFF filters placed in glass scintillation vials and frozen at -20°C.

Samples for silicic acid uptake profiles were spiked with the radioisotope Si-32. Nutrient limitation assays were performed on pairs of samples where the rate of silicic acid uptake (Si-32) or carbon fixation (C-14 in paired light/dark bottles) were determined in unaltered controlled samples and in samples augmented with either silicic acid (20 µM), nitrate (20 µM) or iron chloride (1 nanomolar (nM)). All samples were incubated on deck in simulated in situ incubators cooled with flowing surface seawater for 24 hours. Profiles sampled six depths from near surface to the 1% light level. Nutrient limitation assays were performed at the 40% and 10% light levels.

Particles from incubated samples were size fractionated by serial filtration through 5 µm and 0.6 µm 25-millimeter (mm) polycarbonate filters. For C-14 incubations, total radioactivity in each sample was determined by sampling 100 µl of sample seawater prior to filtration. Filters from Si-32 incubations were placed on plastic planchettes and dried before covering with mylar film and stored for analysis ashore using low-level beta counters (Riso Inc). Filters from C-14 incubations were acidified in glass scintillation vials, scintillation cocktail (Ultima Gold XR) was added followed by liquid scintillation counting. Total radioactivity samples received 100 µL of b-phenethylamine and 5 mL of scintillation cocktail prior to analysis at sea using a Tri-Carb 3110TR scintillation counter.

Biogenic silica concentrations were determined by NaOH digestion followed by colorimetric analysis of the resulting dissolved Si. Particulate organic carbon and nitrogen samples were analyzed by Dumas combustion. Nutrient concentrations were determined by flow injection using a Lachat Instruments QuikChem 8500 Series 2 anayzer.

For more information, see the Protocol documents attached as Supplemental Files and https://msi.ucsb.edu/facilities-services/analytical-lab/services.

Data Processing Description

Silicon uptake was calculated as the product of the fraction of total Si-32 radioactivity taken up and the ambient silicic acid concertation. Rates of primary production were calculated as the product of the fraction of total C-14 radioactivity taken up and a DIC value of 2132 micromoles per kilogram (µmol kg-1) correcting for isotope discrimination (x 1.05).

Nutrient concentrations were adjusted using certified JAMSTEC CRMs.

BCO-DMO Processing:
- removed "~" and "ND" as a missing data values (replaced by blanks/empty values);
- renamed fields to comply with BCO-DMO naming conventions;
- created ISO 8601 date-time field and removed original date and column columns;
- rounded last 6 columns to 9 decimal places.

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Data Files

File	
exports_dy131_experiments.csv	(Comma Separated Values (.csv), 6.19 KB) MD5:b45b12892926f9f8cb3a14be44ffefe0
Primary data file for dataset ID 893324	

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Supplemental Files

File	
Brzezinski Lab 14C Primary Production Protocols filename: 14C_Primary_Production.pdf	(Portable Document Format (.pdf), 287.04 KB) MD5:98b17db0d497db8baef492b6f642dd05
Brzezinski Lab 14C Primary Production Protocols	
Brzezinski Lab 32Si Sample Processing Protocols filename: 32Si_Sample_Processing.pdf	(Portable Document Format (.pdf), 218.87 KB) MD5:a4958e873573df157b6a20b4a2028c35
Brzezinski Lab 32Si Sample Processing Protocols	
Brzezinski Lab bSi Protocols filename: bSi_Protocol.pdf	(Portable Document Format (.pdf), 214.54 KB) MD5:32afa2b8fe4d9ce0cde6b78bc9687248
Brzezinski Lab bSi Protocols	
Brzezinski Lab Chl Filtration Protocols filename: Brzezinski_Lab_Chl_filtration_protocols.pdf	(Portable Document Format (.pdf), 260.99 KB) MD5:03fbf36e45c7f1969b00f4dc6e095b3a
Brzezinski Lab Discrete Chlorophyll Filtration Procedure	
Brzezinski Lab Chl Reading Protocols filename: Brzezinski_Lab_Chl_reading_protocols.pdf	(Portable Document Format (.pdf), 204.98 KB) MD5:e7444ee1719794046e34ac15e92663ea
Brzezinski Lab Chlorophyll Sample Processing Protocols	

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Related Datasets

IsRelatedTo

Brzezinski, M. A., Buck, K., Jenkins, B. D. (2023) **Depth profiles in the euphotic zone of nitrate, silicate, and phosphate concentrations and profiles of silicic acid uptake rates from EXPORTS cruise DY131 in the North Atlantic during May 2021.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2023-04-12 doi:10.26008/1912/bco-dmo.893293.1 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
Cruise	cruise during which sample was collected	unitless
ISO_DateTime_UTC	date and time (UTC) of sample collection in ISO 8601 format	unitless
Event	event number from R2R event log	unitless
Activity	which instrument was used for sample collection	unitless
Station	station identifier	unitless
Cast	CTD or TM cast number	unitless
Latitude	latitude (positive values = North; negative values = South)	decimal degrees
Longitude	longitude (positive values = East; negative values = West)	decimal degrees
Target_Depth	target depth for sample collection	meters (m)
Actual_Depth	actual depth for sample collection	meters (m)
Light_Level	percent light level (PAR sensor)	unitless (percent)
Treatment	experimental treatment: CTRL = no nutrient additions; +Si = addition of volume of 0.1M sodium metasilicate (Na2SiO3) solution to increase ambient dissolved silicon by 20uM; +Fe = addition of volume of 0.01mM ferric chloride (FeCl3) for a total concentration of 1nM; +Si+Fe = addition of both Si + Fe; +N = addition of volume of 0.1M sodium nitrate (NaNO3) solution to 20uM; +Si+N = addition of both Si + N.	unitless
rate_14C_uptake_24hr_0_6umfilt_to_5umprefilt	size fractionated primary production 14C uptake for the 0.6 to 5 micrometer (um) size fraction	micromoles Carbon per liter per day (umol C L^1 d^1)
rate_14C_uptake_24hr_gt_5umfilt	size fractionated primary production 14C uptake for the size fraction of 5 micrometers (um) and greater	micromoles Carbon per liter per day (umol C L^1 d^1)

rate_32Si_uptake_24hr_0_6umfilt_to_5umprefilt	size fractionated silicic acid 32Si uptake for the 0.6 to 5 micrometer (um) size fraction	micromoles Carbon per liter per day (umol C L^1 d^1)
rate_32Si_uptake_specific_24hr_0_6umfilt_5umprefilt	size fractionated specific silicic acid 32Si uptake for the 0.6 to 5 micrometer (um) size fraction	per day (d^1)
rate_32Si_uptake_24hr_gt_5umfilt	size fractionated silicic acid 32Si uptake for the size fraction of 5 micrometers (um) and greater	nanomoles Si per liter per day (nmol Si L^1 d^1)
rate_32Si_uptake_specific_24hr_gt_5umfilt	size fractionated specific silicic acid 32Si uptake for the size fraction of 5 micrometers (um) and greater	per day (d^1)

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Instruments

Dataset-specific Instrument Name	Sea-Bird Electronics CTD (SBE9plus)
Generic Instrument Name	CTD Sea-Bird
Generic Instrument Description	Conductivity, Temperature, Depth (CTD) sensor package from SeaBird Electronics, no specific unit identified. This instrument designation is used when specific make and model are not known. See also other SeaBird instruments listed under CTD. More information from Sea-Bird Electronics.

Dataset-specific Instrument Name	Go-Flo samplers
Generic Instrument Name	GO-FLO Bottle
Generic Instrument Description	GO-FLO bottle cast used to collect water samples for pigment, nutrient, plankton, etc. The GO-FLO sampling bottle is specially designed to avoid sample contamination at the surface, internal spring contamination, loss of sample on deck (internal seals), and exchange of water from different depths.

Dataset-specific Instrument Name	Lachat Instruments QuikChem 8500 Series 2 analyzer
Generic Instrument Name	Lachat QuikChem 8500 flow injection analysis system
Generic Instrument Description	The Lachat QuikChem 8500 Series 2 Flow Injection Analysis System features high sample throughput and simple, but rapid, method changeover. The QuikChem 8500 Series 2 system maximises productivity in determining ionic species in a variety of sample types, from sub-ppb to percent concentrations. Analysis takes 20 to 60 seconds, with a sample throughput of 60 to 120 samples per hour.

Dataset-specific Instrument Name	Tri-Carb 3110TR
Generic Instrument Name	PerkinElmer Tri-Carb 3110TR low activity liquid scintillation analyzer
Generic Instrument Description	The PerkinElmer Tri-Carb 3110TR is a benchtop liquid scintillation analyzer for detecting small amounts of alpha, beta, and gamma radioactivity. It features a Multichannel Analyzer with an effective resolution of 1/10 keV and an extended dynamic quench range. Sample capacity is either 408 standard 20 mL vials, or 720 small 4 or 7 mL vials. The instrument includes a barium-133 low-energy external standard source centered under the sample vial which eliminates the effects of volume variations. It has an energy range of 0-2000 keV and an operating ambient temperature range of 15-35 degrees Celsius.

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Deployments

DY131

Website	https://www.bco-dmo.org/deployment/893299
Platform	RRS Discovery
Start Date	2021-05-01
End Date	2021-06-01
Description	See additional information from the British Oceanographic Data Centre (BODC): https://www.bodc.ac.uk/resources/inventories/cruise_inventory/report/17779/

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Project Information

Collaborative Research: Diatoms, Food Webs and Carbon Export - Leveraging NASA EXPORTS to Test the Role of Diatom Physiology in the Biological Carbon Pump (Diatoms and carbon export)

Coverage: Sub-Arctic Pacific, Ocean Station Papa

NSF Award Abstract:
This project focuses on a group of microscopic single-celled photosynthetic organisms in the ocean called

diatoms. Diatoms float in the surface ocean as part of a group of organisms collectively called phytoplankton. There are thousands of different species of diatoms distributed across the global ocean. A famous oceanographer Henry Bigelow once said "All fish is diatoms" reflecting the importance of diatoms as the base of the food chain that supports the world's largest fisheries. Despite their small size, diatom photosynthesis produces 20% of the oxygen on earth each year. That's more than all of the tropical rain forests on land. The major objective of the research is to understand how the metabolic differences among diatom species affects the amount of diatom organic carbon that is carried, or exported, from the surface ocean to the deep ocean. As diatoms are photo-synthesizers like green plants, their biological carbon comes from converting carbon dioxide dissolved in seawater from the atmosphere into organic forms. Diatoms also require a series of other nurtrients supplied by the ocean such as nitrogen and phosphorous and, uniquely for diatoms, the silicon used to construct their glass shells. This research will investigate how genetic and physiological differences among diatoms influence how each species react to changes in nutrient levels in the ocean and how those shifts affect the export of diatom carbon to the deep sea. The link between diatoms' physiological response and their carbon export comes about because shifts in physiology affect diatom attributes like how fast they sink and how tasty they are to predators. So if we can relate the physiological condition of different diatoms to the food-web pathways followed by different species, we can ultimately use knowledge of diatom physiological status and food web structure to predict how much diatom carbon gets to the deep sea. The research involves investigators with expertise in the physiology and genomics of diatoms and in the ocean's chemistry. The work will initially take place in the subarctic North Pacific in conjunction with the NASA Export Processes in the Ocean from RemoTe Sensing (EXPORTS) field program. The EXPORTS program is using a wide variety of methods to quantify the export and fate of photo-synthetically fixed carbon in the upper ocean. The research supports the training of undergraduate students, graduate students and a postdoctoral scholar. The research will also serve as the basis for activities aimed at K-12 and junior high school students.

The research will broadly impact our understanding of the biology of the biological pump (the transport of photo-synthetically fixed organic carbon to the deep sea) by forming a mechanistic basis for predicting the export of diatom carbon. It is hypothesized that the type and degree of diatom physiological stress are vital aspects of ecosystem state that drive export. To test this hypothesis, the genetic composition, rates of nutrient use and growth response of diatom communities will be evaluated and supported with measurements of silicon and iron stress to evaluate stress as a predictor of the path of diatom carbon export. The subarctic N. Pacific ecosystem is characterized as high nutrient low chlorophyll (HNLC) due to low iron (Fe) levels that are primary controllers constraining phytoplankton utilization of other nutrients. It has been a paradigm in low Fe, HNLC systems that diatoms grow at elevated Si:C and Si:N ratios and should be efficiently exported as particles significantly enriched in Si relative to C. However, Fe limitation also alters diatoms species composition and the high Si demand imposed by low Fe can drive HNLC regions to Si limitation or Si/Fe co-limitation. Thus, the degree of Si and/or Fe stress in HNLC waters can all alter diatom taxonomic composition, the elemental composition of diatom cells, and the path cells follow through the food web ultimately altering diatom carbon export.

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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Program Information

EXport Processes in the Ocean from Remote Sensing (EXPORTS)

Website: http://oceanexports.org/

EXport Processes in the Ocean from Remote Sensing (EXPORTS) is a large-scale NASA-led field campaign that will provide critical information for quantifying the export and fate of upper ocean net primary production (NPP) using satellite observations and state of the art ocean technologies.

Ocean ecosystems play a critical role in the Earth’s carbon cycle and the quantification of their impacts for both present conditions and for predictions into the future remains one of the greatest challenges in oceanography. The goal of the EXport Processes in the Ocean from Remote Sensing (EXPORTS) Science Plan is to develop a predictive understanding of the export and fate of global ocean net primary production (NPP) and its implications for present and future climates. The achievement of this goal requires a quantification of

the mechanisms that control the export of carbon from the euphotic zone as well as its fate in the underlying "twilight zone" where some fraction of exported carbon will be sequestered in the ocean's interior on time scales of months to millennia. In particular, EXPORTS will advance satellite diagnostic and numerical prognostic models by comparing relationships among the ecological, biogeochemical and physical oceanographic processes that control carbon cycling across a range of ecosystem and carbon cycling states. EXPORTS will achieve this through a combination of ship and robotic field sampling, satellite remote sensing and numerical modeling. Through a coordinated, process-oriented approach, EXPORTS will foster new insights on ocean carbon cycling that maximizes its societal relevance through the achievement of U.S. and International research agency goals and will be a key step towards our understanding of the Earth as an integrated system.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1756442

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