Quantification of zooplankton fecal-pellet production by on-board incubation experiments during seven Bermuda Atlantic Time-series Study (BATS) cruises aboard the R/V Atlantic Explorer from Jul 2021 to Mar 2023

Website: https://www.bco-dmo.org/dataset/997926
Data Type: Cruise Results, Other Field Results
Version: 1
Version Date: 2026-05-13

Project
» Collaborative Research: Zooplankton mediation of particle formation in the Sargasso Sea (Zooplankton Mediation)

Contributors	Affiliation	Role
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Abstract
This dataset documents zooplankton fecal-pellet production, organismal traits, and zooplankton-mediated aggregation measured during seven Bermuda Atlantic Time-series Study (BATS) cruises (AE2112, AE2114, AE2124, AE2204, AE2214, AE2224, AE2306) aboard the R/V Atlantic Explorer between 2021-07-08 and 2023-03-26 in the Sargasso Sea near Bermuda. Zooplankton were collected from the upper 300 m using MOCNESS tows and incubated onboard in 12-hour experiments conducted during both day and night. Species-specific fecal-pellet production rates were quantified from these incubations across all six cruises and are reported in this dataset, along with experiment metadata (cruise identifiers, collection and incubation times, and notes) and taxonomic identification of zooplankton used in each incubation. Supplemental files provide individual fecal pellet morphometrics, classification, and summed pellet volumes (Fecal_Pellets.csv), and individual zooplankton biovolume and biomass estimates from post-incubation images (FPP_Zooplankton.csv). Together with the related datasets, these datasets provide integrated measurements linking zooplankton identity, size, fecal-pellet production, pellet elemental composition, and aggregate formation, supporting process-based analyses of zooplankton roles in particle production and vertical carbon transfer at BATS. The data were collected aboard the R/V Atlantic Explorer through the collaborative efforts of the laboratories of Dr. Susanne Neuer, Dr. Amy Maas, and Dr. Leocadio Blanco-Bercial, affiliated with Arizona State University and the Bermuda Institute of Ocean Sciences.

Table of Contents

- Coverage
- Dataset Description
  - Methods & Sampling
  - Data Processing Description
  - BCO-DMO Processing Description
  - Problem Description
- Data Files
- Supplemental Files
- Related Publications
- Related Datasets
- Parameters
- Instruments
- Deployments

- Project Information
- Funding

Coverage

Location: Bermuda Atlantic Time-series Study (BATS) site, Sargasso Sea in the Western North-Atlantic. 31 50'N 64 10'W. Depths 0-300m.
Spatial Extent: **N**:32.22523 **E**:-63.91948 **S**:31.617685 **W**:-64.494367
Temporal Extent: 2021-07 - 2023-03

Methods & Sampling

Zooplankton Collection

Zooplankton were collected during six Bermuda Atlantic Time-series Study (BATS) cruises between July 2021 and March 2023 aboard the R/V Atlantic Explorer. Sampling was conducted using a 1-m² Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) equipped with 150-µm mesh nets, Scripps Institution of Oceanography electronics, and strobe lights to enhance capture of fast-swimming taxa. Tows were performed during both day and night from the surface to 600 m, with a focus on the upper 300 m.

Fecal Pellet Production Experiments

Target zooplankton taxa were collected using MOCNESS tows and incubated individually in 1-L acid-washed plastic containers ("Copepotties") filled with 0.2-µm filtered seawater. Each container included an inner insert constructed from a 1-mm mesh-bottomed plastic cup to allow separation of fecal pellets from the zooplankton. Incubations were conducted in the dark at approximately 20°C for 8–12 hours during both day and night periods.

Following incubation, fecal pellets were collected under a dissection microscope using glass pipettes and rinsed three times with nuclease-free water. Pellets were imaged under a stereomicroscope, and morphometric measurements were obtained using INFINITY ANALYZE 7 software (Teledyne Technologies, Inc). Fecal pellet areas measured from images were converted to biovolumes (µm³) using shape-specific geometric formulas applied to different particle categories (e.g., spherical for fecal and phytodetrital aggregates, cylindrical for euphausiid pellets). Biovolumes were then converted to carbon content (mg C) using empirically derived conversion factors from published oceanographic studies (Alldredge & Gotschalk, 1990; Silver & Bruland, 1981; Durkin et al., 2021). Zooplankton individuals responsible for pellet production were imaged separately after incubation to confirm taxonomic identity and to measure body dimensions, which were used to estimate individual biovolume and biomass.

Data Processing Description

Raw zooplankton sample metadata (cruise ID, station, date, time, depth interval, and diel period) were recorded at sea during each cruise. Zooplankton taxa used in fecal pellet production experiments were identified to the lowest practical taxonomic level using stereomicroscope images and standard taxonomic references.

Fecal pellet morphometric measurements (length, width, and projected area) were obtained from stereomicroscope images using INFINITY ANALYZE 7 software (Teledyne Technologies, Inc). Pellet volumes were calculated from measured dimensions assuming cylindrical geometry. Individual fecal pellet production rates were calculated by dividing the total number of pellets produced per individual by the incubation duration (hours).

Zooplankton individual biovolume was estimated from measured body dimensions obtained from post-incubation images.

All data were compiled, quality-checked for transcription errors, and formatted into standardized tables for submission. No statistical analyses, model-based flux calculations, or graphical processing are included in the submitted datasets.

BCO-DMO Processing Description

- Loaded FPP.csv, using filename as table name (fpp), treating empty strings and "nd" as missing values
- Renamed multiple columns: removed units and special characters from column names (e.g., Min_Depth_(m) to Min_Depth, Max_Depth_(m) to Max_Depth), replaced # prefix with num_, renamed duplicate header columns (blank columns " (1)" and " (2)") to Animal/FecalPellet_Notes_2 and Animal/FecalPellet_Notes_3, and renamed Animal/FecalPellet_Notes to Animal/FecalPellet_Notes_1
- Converted Date column from M/D/YYYY format to ISO 8601 date format (YYYY-MM-DD)
- Combined Date and Start_Time fields into new Datetime_Start column, converting from Atlantic/Bermuda timezone to UTC, output as ISO 8601 datetime format
- Renamed Animal/FecalPellet_Notes_1 Animal, FecalPellet_Notes_2, and Animal/FecalPellet_Notes_3 columns (removing slash) to Animal_FecalPellet_Notes_1, Animal_FecalPellet_Notes_2, Animal_FecalPellet_Notes_3, and Sum_FP_µm3 to Sum_FP_um3
- Applied find-replace to Animal_FecalPellet_Notes_1 to replace non-standard Unicode whitespace characters with standard ASCII spaces
- Renamed Datetime_Start to Datetime_Start_UTC
- Renamed table from fpp to 997926_v1_fecal_pellet_production
- Merged the three Animal_FecalPellet_Notes_1, Animal_FecalPellet_Notes_2, Animal_FecalPellet_Notes_3 columns into a single Animal_FecalPellet_Notes column, joining non-null values with semicolons
- Deleted the three individual Animal_FecalPellet_Notes_1, Animal_FecalPellet_Notes_2, and Animal_FecalPellet_Notes_3 columns
- Split num_of_Zooplankton_At_Beginning on the first space or underscore using pattern ^([^_]+)[_]?(.*)$, placing the numeric portion back into num_of_Zooplankton_At_Beginning and any trailing text into a temporary _zoo_extra column
- Prepended any extracted _zoo_extra text to Animal_FecalPellet_Notes with a semicolon separator
- Replaced all underscores with spaces in the Animal_FecalPellet_Notes column
- Deleted temporary _zoo_extra column
- Output final table as 997926_v1_fecal_pellet_production.csv

Problem Description

Fewer zooplankton were collected for fecal pellet experiments during daytime tows due to lower net-caught abundances, as many of the targeted taxa are diel vertical migrators.

[table of contents | back to top]

Data Files

File	
997926_v1_fecal_pellet_production.csv	(Comma Separated Values (.csv), 28.07 KB) MD5:c3e21894edb80bf434f97f9fabe5e778
Primary data file for dataset ID 997926, version 1	

[table of contents | back to top]

Supplemental Files

File

Fecal_Pellets.csv

(Comma Separated Values (.csv), 105.17 KB)
MD5:029186922cdd0dbf449dd367e73eee8f

Fecal pellet measurement data

Date,Calendar date of experiment start or sample collection., Units: MM-DD-YYYY
Latitude,Latitude of sampling or experiment location., Units: decimal degrees (°N)
Longitude,Longitude of sampling or experiment location., Units: decimal degrees (°W)
Cruise,R/V Atlantic Explorer (AE) cruise ID number
D_N,Day or night classification of sampling period., Units: categorical (Day/Night)
Start_Time,Time when experiment or deployment started., Units: HH:MM (Atlantic Standard Time GMT-4)
End_Time,Time when experiment or deployment ended., Units: HH:MM (Atlantic Standard Time GMT-4)
Total_Time,Duration of experiment, incubation, or deployment., Units: hours (h) or minutes (min)
Hour,The Hours column represents the total deployment duration expressed as whole hours. It is calculated by rounding the Total_Time (hh:mm) up to the nearest hour.
Min_Depth_(m),Minimum depth of sampling or incubation., Units: meters (m)
Max_Depth_(m),Maximum depth of sampling or incubation., Units: meters (m)
Experiment,Experimental treatment or experiment identifier.
Zooplankton_Groups,Broad taxonomic or functional group of zooplankton.
Zooplankton_Taxa,Lowest identified taxonomic classification of zooplankton.
#_Zooplankton_Alive, Number of zooplankton alive or present at end of experiment or analysis., Units: individuals (ind).
File_name_of_Image,Filename of microscopy image used for measurements.
Fecal_Pellet#,Number of fecal pellets produced or analyzed., Units: count
Area_(µm²),Two-dimensional projected area of fecal pellet or organism., Units: square micrometers (µm²)
Area_(mm^2),Two-dimensional projected area of fecal pellet or organism., Units: square micrometers (mm²)
ESD_(mm^2),Equivalent spherical diameter calculated from projected area.
Width_(mm^2),Measured width and length of fecal pellet., Units: millimeters (mm^2)
Length_(mm^2),Measured width and length of fecal pellet., Units: millimeters (mm^2)
Volume_(mm^3),Calculated volume of fecal pellet or organism., Units: cubic millimeters (mm³)
Classification,Morphological classification of fecal pellet type., Units: categorical
Color_of_Fecal_Pellet,Observed color of fecal pellet under microscopy., Units: text
Sum_FP_(mm^3),total summed fecal pellet volume per experiment or sample., Units: cubic millimeters (mm³)
Sum_FP_(µm^3),Total summed fecal pellet volume converted to micrometer scale., Units: cubic micrometers (µm³)
Notes, Qualitative observations on animal condition, pellet structure, or anomalies., Units: text

FPP_Zooplankton.csv

(Comma Separated Values (.csv), 73.92 KB)
MD5:5fd2799d38bc6b2b663f26550b58d154

Data of zooplankton used for the fecal pellet production experiment.

Date,Calendar date of experiment start or sample collection., Units: MM-DD-YYYY
Latitude,Latitude of sampling or experiment location., Units: decimal degrees (°N)
Longitude,Longitude of sampling or experiment location., Units: decimal degrees (°W)
Cruise,R/V Atlantic Explorer (AE) cruise ID number
D_N,Day or night classification of sampling period., Units: categorical (Day/Night)
Start_Time,Time when experiment or deployment started., Units: HH:MM (Atlantic Standard Time GMT-4)
End_Time,Time when experiment or deployment ended., Units: HH:MM (Atlantic Standard Time GMT-4)
Total_Time,Duration of experiment, incubation, or deployment., Units: hours (h) or minutes (min)
Hour,The Hours column represents the total deployment duration expressed as whole hours. It is calculated by rounding the Total_Time (hh:mm) up to the nearest hour.
Min_Depth_(m),Minimum depth of sampling or incubation., Units: meters (m)
Max_Depth_(m),Maximum depth of sampling or incubation., Units: meters (m)
Experiment,Experimental treatment or experiment identifier.
Zooplankton_Groups,Broad taxonomic or functional group of zooplankton.
Zooplankton_Taxa,Lowest identified taxonomic classification of zooplankton.
#_Zooplankton_Alive,Number of zooplankton alive or present at end of experiment or analysis., Units: individuals (ind)
Fecal_Pellet_#,Number of fecal pellets produced or analyzed., Units: count
Image_Name,Filename of microscopy image used for measurements.
Area_(µm^2),Two-dimensional projected area of fecal pellet or organism., Units: µm^2
Area_(mm^2),Two-dimensional projected area of fecal pellet or organism., Units: mm^2
ESD,Equivalent spherical diameter calculated from projected area., Units: millimeters (mm)
Biovolume_(mm^3),Estimated organism biovolume from image analysis., Units: mm^3
Biomass_(mg),Estimated biomass derived from biovolume or allometric relationships., Units: milligrams (mg)
Notes,Qualitative observations on animal condition, pellet structure, or anomalies., Units: text

[table of contents | back to top]

Related Publications

Alldredge, A. L., & Gotschalk, C. C. (1990). The relative contribution of marine snow of different origins to biological processes in coastal waters. Continental Shelf Research, 10(1), 41–58. https://doi.org/10.1016/0278-4343(90)90034-j
Methods

Durkin, C. A., Buesseler, K. O., Cetinić, I., Estapa, M. L., Kelly, R. P., & Omand, M. (2021). A Visual Tour of Carbon Export by Sinking Particles. Global Biogeochemical Cycles, 35(10). Portico. https://doi.org/10.1029/2021gb006985
Methods

Niimi et. al. "Understanding the Seasonal Contributions of Key Zooplankton Fecal Pellet Production in the Sargasso Sea" (in preparation).
Results

Silver, M. W., & Bruland, K. W. (1981). Differential feeding and fecal pellet composition of salps and pteropods, and the possible origin of the deep-water flora and olive-green "Cells" Marine Biology, 62(4), 263–273. https://doi.org/10.1007/bf00397693
Methods

[table of contents | back to top]

Related Datasets

IsRelatedTo

Brenner, A., Maas, A., Blanco-Bercial, L., Noyes, K., Neuer, S. (2025) **Measurements of sinking particle types from deployed Particle Interceptor Trap System (PITS) at the Bermuda Atlantic Time-series Study (BATS) site from Jul 2021 to Mar 2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2025-10-08 doi:10.26008/1912/bco-dmo.982170.1 [view at BCO-DMO]
Relationship Description: Roller tank and fecal pellet production experiments used zooplankton collected during the same cruises and from the same depth strata associated with the PITs aggregate collections.

Maas, A., Blanco-Bercial, L. (2024) **ZooSCAN images of zooplankton collected with MOCNESS tows during six R/V Atlantic Explorer cruises in the northwest Atlantic (Sargasso Sea) from 2021 to 2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2024-07-11 doi:10.26008/1912/bco-dmo.932236.1 [view at BCO-DMO]
Relationship Description: ZooSCAN images were generated from zooplankton community samples collected during these cruises to characterize zooplankton abundance, size structure, and taxonomy associated with aggregate formation and particle flux processes.

Neuer, S., Blanco-Bercial, L., Maas, A. E., Baird, K., Niimi, Y. J. (2026) **Fecal pellet elemental composition (CHN), production rates, and morphometrics from zooplankton incubation experiments collected during R/V Atlantic Explorer cruise AE2306 at the Bermuda Atlantic Time-series Study (BATS) site in Mar 2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2026-05-13 doi:10.26008/1912/bco-dmo.998152.1 [view at BCO-DMO]
Relationship Description: This dataset reports elemental composition of individual fecal pellets measured.

Neuer, S., Blanco-Bercial, L., Maas, A. E., Baird, K., Niimi, Y. J. (2026) **Zooplankton-mediated aggregate formation was measured during seven Bermuda Atlantic Time-series Study (BATS) cruises aboard the R/V Atlantic Explorer Jul 2021 to Mar 2023.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 2) Version Date 2026-05-14 doi:10.26008/1912/bco-dmo.998220.2 [view at BCO-DMO]
Relationship Description: Roller tank and fecal pellet production experiments used zooplankton collected during the same cruises and from the same depth strata associated with the PITs aggregate collections.

[table of contents | back to top]

Parameters

Parameter	Description	Units
Date	Date of experiment start or sample collection (Atlantic/Bermuda timezone (GMT-4))	unitless
Latitude	Latitude of sampling or experiment location, positive is North	decimal degrees
Longitude	Longitude of sampling or experiment location, negative is West	decimal degrees
Cruise	R/V Atlantic Explorer (AE) cruise ID number	unitless
D_N	Day or night classification of sampling period	unitless
Start_Time	Time when experiment or deployment started (Atlantic/Bermuda timezone (GMT-4))	unitless
End_Time	Time when experiment or deployment ended (Atlantic/Bermuda timezone (GMT-4))	unitless
Total_Time	Duration of experiment, incubation, or deployment	hours
Hours	The Hours column represents the total deployment duration expressed as whole hours. It is calculated by rounding the Total_Time (hh:mm) up to the nearest hour.	hours
Min_Depth	Minimum depth of sampling or incubation.	meters (m)
Max_Depth	Maximum depth of sampling or incubation.	meters (m)
Experiment	Experimental treatment or experiment identifier.	unitless
Zooplankton_Groups	Broad taxonomic or functional group of zooplankton.	unitless
Zooplankton_Taxa	Lowest identified taxonomic classification of zooplankton.	unitless
num_of_Zooplankton_At_Beginning	Number of live zooplankton individuals at experiment start	unitless
num_Zooplankton_Alive	Number of zooplankton alive or present at end of experiment or analysis.	unitless

num_Fecal_Pellet	Number of fecal pellets produced or analyzed.	unitless
Sum_FP_mm3	Total summed fecal pellet volume per experiment or sample.	cubic millimeters (mm^3)
Sum_FP_um3	Total summed fecal pellet volume converted to micrometer scale.	cubic micrometers (μm^3)
mgC_um3	Carbon density conversion factor used to estimate carbon content from volume.	mg C μm^{-3}
FPP	Fecal pellet production per individual.	mg C $individual^{-1}$
Animal_FecalPellet_Notes	Qualitative observations on Qualitative observations on animal condition, pellet structure, or anomalies animal condition	unitless
Datetime_Start_UTC	Datetime of experiment start (UTC)	unitless

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	dissection microscope
Generic Instrument Name	Microscope - Optical
Dataset-specific Description	Following incubation, fecal pellets were collected under a dissection microscope using glass pipettes and rinsed three times with nuclease-free water.
Generic Instrument Description	Instruments that generate enlarged images of samples using the phenomena of reflection and absorption of visible light. Includes conventional and inverted instruments. Also called a "light microscope".

Dataset-specific Instrument Name	stereomicroscope
Generic Instrument Name	Microscope - Optical
Dataset-specific Description	Pellets were imaged under a stereomicroscope, and morphometric measurements were obtained using INFINITY ANALYZE 7 software.
Generic Instrument Description	Instruments that generate enlarged images of samples using the phenomena of reflection and absorption of visible light. Includes conventional and inverted instruments. Also called a "light microscope".

Dataset-specific Instrument Name	Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS)
Generic Instrument Name	MOCNESS
Dataset-specific Description	Sampling was conducted using a 1-m² Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) equipped with 150-µm mesh nets, Scripps Institution of Oceanography electronics, and strobe lights to enhance capture of fast-swimming taxa.
Generic Instrument Description	The Multiple Opening/Closing Net and Environmental Sensing System or MOCNESS is a family of net systems based on the Tucker Trawl principle. There are currently 8 different sizes of MOCNESS in existence which are designed for capture of different size ranges of zooplankton and micro-nekton Each system is designated according to the size of the net mouth opening and in two cases, the number of nets it carries. The original MOCNESS (Wiebe et al, 1976) was a redesigned and improved version of a system described by Frost and McCrone (1974). (from MOCNESS manual)

Dataset-specific Instrument Name	strobe lights
Generic Instrument Name	no_bcodmo_term
Dataset-specific Description	Sampling was conducted using a 1-m² Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS) equipped with 150-µm mesh nets, Scripps Institution of Oceanography electronics, and strobe lights to enhance capture of fast-swimming taxa.
Generic Instrument Description	No relevant match in BCO-DMO instrument vocabulary.

[table of contents | back to top]

Deployments

AE2112

Website	https://www.bco-dmo.org/deployment/931891
Platform	R/V Atlantic Explorer
Start Date	2021-07-08
End Date	2021-07-16

AE2124

Website	https://www.bco-dmo.org/deployment/931893
Platform	R/V Atlantic Explorer
Start Date	2021-11-16
End Date	2021-11-19

AE2204

Website	https://www.bco-dmo.org/deployment/931895
Platform	R/V Atlantic Explorer
Start Date	2022-03-28
End Date	2022-04-04

AE2214

Website	https://www.bco-dmo.org/deployment/931897
Platform	R/V Atlantic Explorer
Start Date	2022-07-13
End Date	2022-07-18

AE2224

Website	https://www.bco-dmo.org/deployment/931899
Platform	R/V Atlantic Explorer
Start Date	2022-11-23
End Date	2022-11-30

AE2306

Website	https://www.bco-dmo.org/deployment/931901
Platform	R/V Atlantic Explorer
Start Date	2023-03-18
End Date	2023-03-26

AE2114

Website	https://www.bco-dmo.org/deployment/964699
Platform	R/V Atlantic Explorer
Start Date	2021-08-05
End Date	2021-08-08

[table of contents | back to top]

Project Information

Collaborative Research: Zooplankton mediation of particle formation in the Sargasso Sea (Zooplankton Mediation)

Coverage: Sargasso Sea/BATS area

NSF Award Abstract:
The purpose of this collaborative project is to advance understanding of the role of marine planktonic animals (or zooplankton) in the biological pump, or transport of carbon from surface to deeper ocean waters. This movement of carbon from surface to deep ocean water can ultimately affect carbon dioxide in the atmosphere, with implications for global climate. Many marine zooplankton, including species of copepods and krill, play a direct role in the biological pump both because they are abundant and because they can migrate from surface waters at night, where they feed, to depths of more than 500 m at night. At the same time, some organisms called flux feeders will remain at depth and do not migrate. Instead, they rely on particles produced by other zooplankton feeding in surface waters. In this project, the investigators are focusing on populations of flux feeders in the deeper ocean waters of the Sargasso Sea. They are leveraging an ongoing long-term research program, conducting field collections using specialized nets and particle traps, as well lab experiments, as a way to understand how these organisms modify the particles around them. This project is supporting a postdoctoral scientist and providing research experiences for undergraduates at two institutions. An education specialist is creating lesson plans for an award-winning Ask-A-Biologist website, designed for public and K-12 audiences. Images of zooplankton will be disseminated to the public and scientific community via EcoTaxa (a web platform devoted to plankton biodiversity, with images and taxonomic annotation) and physical samples will be archived as part of a teaching library.

The oceanic biological carbon pump refers to the export of dissolved and particulate organic carbon to the deep ocean, and it is a significant driver of atmospheric carbon uptake by the oceans. Evidence from long-term research carried out at the Bermuda Atlantic Time-series Study (BATS) site suggests that the spectrum of particles collected by gel-traps below the euphotic zone changes drastically below 150 m, which is attributed to resident populations of zooplankton that feed on vertically migrating zooplankton as well as sinking particles. The goals of this study are to investigate the role of different zooplankton taxa on both particle aggregate formation and in particle transformation, and to compare and characterize the particles generated by the zooplankton communities with those collected by particle traps. The investigators are combining field collections with experiments onboard ship and in environmental chambers. They are collecting samples over two years, with three cruises a year to capture distinct seasons. They are assessing high-resolution vertical distribution of zooplankton in the upper 600 m using Multiple Opening-Closing Net and Environmental Sensing System (MOCNESS) tows during day- and night-time, to distinguish diel vertical migrators from resident populations and to quantify contributions to particulate organic carbon flux via fecal pellet production. On each cruise, sinking particles are being collected using gel trap tubes attached to the particle traps deployed monthly at BATS. In addition, roller tank experiments are determining how individual zooplankton mediate aggregate formation. Particle types and fecal pellets are being characterized using image analysis and DNA-based analysis of microbial communities. Finally, ongoing data collection from the long-term BATS program is providing invaluable environmental context and will ensure results from this study contribute to ongoing community efforts to observe and predict the fate of carbon in our global system.

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.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023621
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023372

[table of contents | back to top]