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

Website: https://www.bco-dmo.org/dataset/982170
Data Type: Cruise Results
Version: 1
Version Date: 2025-10-08

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

Contributors	Affiliation	Role
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Abstract
These data represent measurements of individual sinking particle types—specifically fecal aggregates, phytodetrital aggregates, euphausiid and other crustacean fecal pellets, and debris—collected from the Bermuda Atlantic Time-series Study (BATS) site. Sampling occurred during six time points: July 2021, November 2021, March 2022, July 2022, November 2022, and March 2023. Particle interceptor traps (PITs) were deployed at depths of 150 m, 200 m, and 300 m, each equipped with three gel-filled collection cups to preserve particle morphology. The collected particles were analyzed to quantify area and biovolume for each particle type, contributing to a better understanding of the composition and flux of sinking material in the mesopelagic zone. 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. These measurements support research into particle-mediated carbon flux and the biological carbon pump, and are intended for use by scientists studying marine biogeochemistry, particle dynamics, and oceanic carbon cycling.

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Coverage

Location: Bermuda Atlantic Time-series Site (BATS)

Spatial Extent: **N**:31.683 **E**:-64.152 **S**:31.653 **W**:-64.185
Temporal Extent: 2021-07-13 - 2023-03-19

Methods & Sampling

Samples for the Bermuda Atlantic Time-series Study (BATS) were collected during monthly cruises in July 2021 (AE2112), November 2021 (AE2124), March 2022 (AE2204), July 2022 (AE2214), November 2022 (AE2224), and March 2023 (AE2306) for seasonal comparison. Particle Interceptor Traps (PITs) were deployed at depths of 150 m, 200 m, and 300 m.

Sinking particles were collected using triplicate polycarbonate gel cups per depth, each containing 100 mL of 12% Tissue Tek polyacrylamide gel to preserve particle structure (Durkin et al., 2015; Ebersbach & Trull, 2008). Gel cups were housed in 70 mm diameter PIT tubes overlaid with dense seawater collected below the halocline (~1000 m), which was filtered (0.2 µm capsule filter, Pall Corp.) and fixed with 2% formalin (final concentration).

Triplicate PIT tubes fitted with acid-cleaned polycarbonate membrane filters (0.8 µm pore size) and filled with poisoned seawater brine (50 g NaCl L^{-1}, 0.7% formalin) were deployed alongside gel cups to measure bulk particulate organic carbon (POC) flux. Membrane filters were processed using standard BATS protocols for C/N analysis (Knap et al., 1997). See the related dataset for more information on the BATS Sediment Trap Particle Flux dataset.

After recovery, seawater above the dense brine layer was siphoned off, and the remaining seawater was drained. Excess seawater on gel cup surfaces was removed before storage at -80°C. Gel cups were transported on dry ice from Bermuda Institute of Ocean Sciences (BIOS) to Arizona State University for image analysis.

Gel cup surfaces were imaged with a Zeiss Discovery.V12 Stereo Microscope equipped with a 3.2 MP color camera. A Python-based image analysis pipeline was used to segment particles and quantify sinking particle types and size distributions. For most gel cups, 20 non-overlapping images were collected per cup, divided evenly between two focal planes: one at a higher Z-plane to capture smaller particles near the gel surface and one at a lower Z-plane to capture larger particles near the bottom of the gel. Two scale images were captured for each change in Z. The only exception was the July 2021 sampling, where each of the nine gel cups was imaged with 10 pictures and one scale image per cup.

Particles were categorized as fecal aggregates (dense, dark), phytodetrital aggregates (fluffy, amorphous), crustacean fecal pellets (ovular, dense), euphausiid fecal pellets (cylindrical, dense), or debris (fragments <60 µm, amorphous). Sinking particles like animal tissue, molts, and swimmers were excluded.

Particle areas (μm^2) were measured using the Particle Image Analysis tool, then converted to biovolumes (μm^3) using shape-specific formulas: spherical for fecal and phytodetrital aggregates, combined spherical/cylindrical for crustacean fecal pellets, and cylindrical for euphausiid pellets. Debris particles were treated as spherical. Biovolumes were converted to carbon content (mg C per particle) using published conversion factors from multiple ocean regions (Alldredge & Gotschalk, 1990; Silver & Bruland, 1981; Durkin et al., 2021).

Data Processing Description

Raw images of sinking particles collected in polyacrylamide gel cups were processed using a Python-based image analysis pipeline. The pipeline utilizes the Particle Image Analysis tool (version 1.0; Rao & Blanco-Bercial, 2023) to perform image segmentation and masking, allowing for precise delineation of individual particle boundaries and measurement of particle area (μm^2).

Particle areas were converted to biovolumes (μm^3) using shape-specific 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 multiple oceanographic studies (Alldredge & Gotschalk, 1990; Silver & Bruland, 1981; Durkin et al., 2021).

All image processing and data extraction steps were automated within the Python pipeline to ensure reproducibility and consistency across samples. Additional information can be found on the Zooplankton Vertical Migration website referenced below (Zooplankton Vertical Migration).

BCO-DMO Processing Description

- Imported "BCO_DMO_Particle_Sizes.csv" into the BCO-DMO system
- Added deployment and recovery times from BATS dataset, working with submitter
- Converted deployment and retrieval dates to ISO 8601 UTC datetime format, YYYY-MM-DDTHH:MM:SSZ
- Converted longitudes to the preferred BCO-DMO format, adding negative to values that are West
- Renamed fields to comply with BCO-DMO naming conventions, removing units, special characters, and spaces
- Replaced 2205 with 2204 in the "Cruise_num" parameter, based on deployment information
- Added "Particle_ID" values provided by the submitter
- Exported file as "982170_v1_pits_particle_sizes.csv"

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Data Files

File
982170_v1_pits_particle_sizes.csv (Comma Separated Values (.csv), 868.60 KB) MD5:58843d26aff9c30f407ff424028a662a Primary data file for dataset ID 982170, version 1

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Supplemental Files

File
Gel cup images for six cruises and their respective metadata filename: GelCupImages_BCODMO.zip (ZIP Archive (ZIP), 23.46 GB) MD5:d1ae26ba72216db7f72df40efe885593 Compressed images that were used in the Python masking code. The .tiff, .xml, and .czi for each of the pictures are included within the cruise folders, sorted by higher and lower z.
GelCupImages_Inventory.tsv (Tab Separated Values (.tsv), 353.11 KB) MD5:7bfed2e20c8e8e625a27146fa6d7917b Inventory of images in the zip file containing all the images used in analysis with checksum information

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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

Brenner et al. "Particle transformations and POC export at BATS" (in preparation)
Results

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

Ebersbach, F., & Trull, T. W. (2008). Sinking particle properties from polyacrylamide gels during the KErguelen Ocean and Plateau compared Study (KEOPS): Zooplankton control of carbon export in an area of persistent natural iron inputs in the Southern Ocean. Limnology and Oceanography, 53(1), 212–224. doi:10.4319/lo.2008.53.1.0212

Methods

Knap, A.H., Michaels, A.F., Steinberg, D.K., Bahr, F., Bates, N.R., Bell, S., Countway, P., Close, A.R., Doyle, A.P., Dow, R.L., Howse, F.A., Gundersen, K., Johnson, R.J., Kelly, R., Little, R., Orcutt, K., Parsons, R., Rathburn, C., Sanderson, M. and Stone, S. (1997) BATS Methods Manual, Version 4 Woods Hole, MA, US. U.S. JGOFS Planning Office 136pp. http://eprints.soton.ac.uk/id/eprint/361194
Methods

Rahul Rao & Leocadio Blanco-Bercial. (2025). blancobercial/Gel_Cups_Particle_Analysis: First draft release (v0.1). Zenodo. https://doi.org/10.5281/ZENODO.17279785 https://doi.org/10.5281/zenodo.17279785
Software

Rao, Rahul. (2023). particle_image_analysis_wcph_lab. Github.
https://github.com/rahulrao011/particle_image_analysis_wcph_lab
Software

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

Zooplankton Vertical Migration. Bermuda Institute of Ocean Sciences.
https://bios.asu.edu/databytes/zooplankton-vertical-migration
Methods

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Related Datasets

IsRelatedTo

Johnson, R. J., Bates, N., Lomas, M. W., Steinberg, D. K., Derbyshire, L., Hayden, M. G., Lomas, D., Lethaby, P. J., Lopez, P. Z., May, R., Smith, D., Stuart, E., Enright, M. (2025) **Determination of carbon, nitrogen, and phosphorus content in sinking particles at the Bermuda Atlantic Time-series Study (BATS) site from December 1988 to December 2024 using a Particle Interceptor Trap System (PITS).** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 6) Version Date 2025-06-24 doi:10.26008/1912/bco-dmo.894099.6 [view at BCO-DMO]
Relationship Description: Data were derived from the the same sampling events.

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Parameters

Parameter	Description	Units
Particle_ID	Identifier for each separately identified particle type/observation	unitless
Station	Station where samples were collected	unitless
Deployment_Datetime	Date and time Particle Interceptor Traps (PITs) were deployed	unitless
Retreival_Datetime	Date and time Particle Interceptor Traps (PITs) were recovered	unitless

Deployment_Lat	Latitude Particle Interceptor Traps (PITs) were deployed, North is positive	decimal degrees
Deployment_Long	Longitude Particle Interceptor Traps (PITs) were deployed, West is negative	decimal degrees
Retreival_Lat	Latitude Particle Interceptor Traps (PITs) were recovered, North is positive	decimal degrees
Retreival_Long	Longitude Particle Interceptor Traps (PITs) were recovered, West is negative	decimal degrees
Cruise_num	Identifier for the cruise during which samples were collected; unitless (e.g., AE2214)	unitless
Depth	Depth of Particle Interceptor Traps (PITs) deployment	meters (m)
Particle_Type	Morphological category of sinking particle, (e.g., fecal aggregate, phytodetrital, debris)	unitless
Area	Two-dimensional projected area of individual particle	square micrometers (μm^2)
ESD	Equivalent spherical diameter of particle, calculated from area	micrometers (µm)
Width	Maximum width of particle	micrometers (µm)
Length	Maximum length of particle	micrometers (µm)
Volume	Estimated three-dimensional biovolume of particle using shape-specific formulas	cubic micrometers (μm^3)
Carbon	Estimated carbon content per particle, derived from biovolume and conversion factors	milligrams (mg)
POCFlux	Particulate organic carbon flux per unit area per day	milligrams C per square meter per day (mg C m^{-2} day^{-1})
Log_Biovolume	Base-10 logarithm of particle biovolume	unitless
Log_Carbon	Base-10 logarithm of particle carbon content	unitless

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Instruments

Dataset-specific Instrument Name	OMAX 3.2 Megapixel Color Camera (OMAX Microscope)
Generic Instrument Name	Camera
Dataset-specific Description	OMAX 3.2 Megapixel Color Camera (OMAX Microscope): Attached to the microscope for capturing high-resolution images.
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	Zeiss Discovery.V12 Stereo Motorized Microscope (Carl Zeiss Microscopy, LLC)
Generic Instrument Name	Microscope - Optical
Dataset-specific Description	Zeiss Discovery.V12 Stereo Motorized Microscope (Carl Zeiss Microscopy, LLC): Used for imaging particle samples in gel cups.
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	Particle Interceptor Traps (PITs)
Generic Instrument Name	Sediment Trap - Particle Interceptor
Dataset-specific Description	Particle Interceptor Traps (PITs): Deployed at 150 m, 200 m, and 300 m depths to collect sinking particles using polycarbonate gel cups containing 12% Tissue Tek polyacrylamide gel.
Generic Instrument Description	A Particle Interceptor Trap is a prototype sediment trap designed in the mid 1990s to segregate 'swimmers' from sinking particulate material sampled from the water column. The prototype trap used 'segregation plates' to deflect and segregate 'swimmers' while a series of funnels collected sinking particles in a chamber (see Dennis A. Hansell and Jan A. Newton. September 1994. Design and Evaluation of a "Swimmer"-Segregating Particle Interceptor Trap, Limnology and Oceanography, Vol. 39, No. 6, pp. 1487-1495).

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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

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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.

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Funding

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

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