Particle fluxes calculated from gel trap images taken on R/V Endeavor and R/V Falkor cruises off the New England shelf break and in the North Pacific during 2016-2017

Website: https://www.bco-dmo.org/dataset/847036
Data Type: Cruise Results
Version: 1
Version Date: 2021-04-08

Project
» Collaborative Research: EAGER: Particle-specific DNA sequencing to directly observe ecological mechanisms of the biological pump (EAGER DNA BioPump)

Contributors	Affiliation	Role
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Abstract
This dataset includes particle fluxes calculated from gel trap images. Images were collected at the New England shelf break aboard the R/V Endeavor on 3-7 November 2017 (EN572) and 13-18 June 2016 (EN581) and on a transit between Honolulu, Hawaii and Portland, Oregon aboard the R/V Falkor between 24 January-20 February, 2017 (FK170124).

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Coverage

Spatial Extent: **N**:39.94 **E**:-70.8119 **S**:21.52 **W**:-151.779
Temporal Extent: 2016-06-13 - 2017-11-07

Dataset Description

Samples were collected at the New England shelf break aboard the R/V Endeavor on 3-7 November 2017 (EN572) and 13-18 June 2016 (EN581) and on a transit between Honolulu, Hawaii and Portland, Oregon aboard the R/V Falkor between 24 January-20 February, 2017 (FK170124).

Methods & Sampling

Image Acquisition:
For more information on sediment trap deployment and image acquisition, see the related dataset "Geltrap micrographs" (https://www.bco-dmo.org/dataset/749412). In brief, sediment trap collector tubes were deployed on various platform designs, including a neutrally-buoyant sediment trap (NBST), a surface tethered sediment trap (STST), and a Wire Walker (WW) trap. Trap tubes were filled with filtered water overlying a jar containing a polyacrylamide gel layer (Durkin et al. 2015). Upon recovery, collection tubes were allowed to settle for at least 1 hour before the overlying water was siphoned off. Jars containing polyacrylamide gel were removed from trap tubes and the remaining overlying water was carefully pipetted off the gel. Gels were stored at 4 degrees C and imaged within the following 2 days before being stored at -80 degrees C.

Polyacrylamide gel layers were imaged on a dissecting microscope (Olympus SZX16) with either a Luminera Infinity 2 (FK170124) or an Allied Vision Technologies StingRay (EN572 and EN581) camera attachment. Particles collected in gel layers during EN572 and EN581 were imaged under brightfield illumination. Particles collected in gel layers during FK170124 were imaged under both brightfield and oblique illumination, producing two separate sets of images for each sample. EN572 gel layers were imaged with a transparent grid to assist in tracking gel location during imaging. The grid was not used when imaging samples collected during subsequent cruises because the pronounced grid lines complicated image analysis. All gel layers were imaged at 4 increasing magnifications, though the combination of magnifications varied by cruise. To determine whether measured particle properties changed if gel layers are frozen, samples collected during FK170124 were thawed after being stored for approximately 1 year at -80 degrees C and imaged again under both brightfield and oblique illumination

Determination of Particle Flux:
Particles in gel images were quantified with an image processing protocol created using functions available in python's Sci-Kit Image. Particles present in each micrograph were detected through a series of image transformation steps that maximize the detection of entire particle areas while minimizing the detection of imaging noise. The background was removed, a brightness threshold was applied, and an edge-detection kernel transformation was used to identify the in-focus particles. Duplicate particles detected in multiple focal planes were removed and the remaining particles were counted and measured.

Particles were categorized into 9 different sinking particle classes. Identities were assigned by manually identifying particle images. Aggregates were defined as loosely packed detritus with irregular edges. Dense detritus was defined as densely packed amorphous material, often brown or golden in color. Large, loose pellets were similar to dense detritus but were also elongated like a fecal pellet. Long fecal pellets were defined as long, thin, cylindrical fecal pellets with a smooth edge, such as the chitin-encased pellets produced by euphausiids. Short fecal pellets were also smooth-edged pellets but with an oval or ellipsoid shape, such as those produced by larvaceans. Mini pellets were defined as small (usually <100 micrometer ESD), spheres such as those produced by rhizarians and microzooplankton (Gowing & Silver, 1985). A small number of individual organisms considered to be passively sinking were also detected, including Rhizarians, primarily Phaeodaria, and various phytoplankton, usually diatoms. Pteropods, copepods, amphipods, foraminifera, and other zooplankton that probably swam into the gel and human-produced fibers were also detected but not considered passive flux and not included in the categories of sinking particles. Unidentifiable objects were also detected and were likely caused by out-of-focus particles, shadows, smudges, or noise detected by the image processing steps that are sensitive to the particular thresholds used.

Only identifiable, sinking particle classes from the dataset were considered in calculations of sinking flux. For each imaging magnification, particles were grouped by their equivalent spherical diameter (ESD) into logarithmically-scaled size bins. To calculate number fluxes at each magnification, the number of particles counted in each size bin was divided by the total imaged surface area of the gel and the trap collection time. Uncertainty of the number flux was estimated by applying these same calculations to the counting uncertainty (square root of the number of particles counted, ie. Poisson distribution).

The carbon flux by each particle type was determined by modeling particle volumes, calculating the carbon per unit volume, and multiplying the carbon per particle by the measured particle number fluxes in each size category.

Data Processing Description

BCO-DMO Processing:
- Adjusted field/parameter names to comply with BCO-DMO naming conventions;
- Concatenated data from separate files into one dataset;
- Rounded "_flux" and "_uncertainty" columns to 3 decimal places,
- Added a conventional header with dataset name, PI names, version date.

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Data Files

File
particle_flux.csv (Comma Separated Values (.csv), 271.45 KB) MD5:a67bb4ed132019c3ecf790e97677da6d Primary data file for dataset ID 847036

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Related Publications

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. doi:10.1101/2021.02.16.431317
General

Durkin, C. A., Estapa, M. L., & Buesseler, K. O. (2015). Observations of carbon export by small sinking particles in the upper mesopelagic. Marine Chemistry, 175, 72–81. doi:10.1016/j.marchem.2015.02.011
Results

Gowing, M. M., & Silver, M. W. (1985). Minipellets: A new and abundant size class of marine fecal pellets. Journal of Marine Research, 43(2), 395–418. doi:10.1357/002224085788438676
Methods

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Related Datasets

IsRelatedTo

Durkin, C., Estapa, M., Omand, M. (2020) **Images of particles collected in sediment traps for quantitative analysis from multiple platforms from 2016-2017.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2018-11-07 doi:10.26008/1912/bco-dmo.749412.1 [view at BCO-DMO]

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Parameters

Parameter	Description	Units
orig_file_name	original file name	unitless
trap	trap identification	unitless
cruise_id	Name of the cruise that the sample was collected	name
depth_meters	Depth of sample collection	meters
trap_platform	Type of sediment trap platform and numerical identifier	name

deployment_duration	Elapsed time over which particles were collected	days
bin_mids	middle of size bin	micrometers
bin_width	width of the size bin	micrometers
flux	number flux of all passively sinking particles particles	number per square meter per day (# m^-2 d^-1)
flux_uncertainty	counting uncertainty of the number flux of all passively sinking particles	number per square meter per day (# m^-2 d^-1)
number_counted	Number of raw counts of passively sinking particles	scalar
aggregate_flux	number flux of aggregates	number per square meter per day (# m^-2 d^-1)
aggregate_flux_uncertainty	counting uncertainty of the number flux of aggregates	number per square meter per day (# m^-2 d^-1)
aggregate_number_counted	Number of raw counts of aggregates	scalar
long_fp_flux	number flux of long fecal pellets	number per square meter per day (# m^-2 d^-1)
long_fp_flux_uncertainty	counting uncertainty of the number flux of long fecal pellets	number per square meter per day (# m^-2 d^-1)
long_fp_number_counted	Number of raw counts of long fecal pellets	scalar
dense_detritus_flux	number flux of dense detritus	number per square meter per day (# m^-2 d^-1)
dense_detritus_flux_uncertainty	counting uncertainty of the number flux of dense detritus	number per square meter per day (# m^-2 d^-1)
dense_detritus_number_counted	Number of raw counts of dense detritus	scalar
large_loose_flux	number flux of large-loose fecal pellets	number per square meter per day (# m^-2 d^-1)
large_loose_flux_uncertainty	counting uncertainty of the number flux of large-loose fecal pellets	number per square meter per day (# m^-2 d^-1)
large_loose_number_counted	Number of raw counts of large-loose fecal pellets	scalar
short_fp_flux	number flux of short fecal pellets	number per square meter per day (# m^-2 d^-1)
short_fp_flux_uncertainty	counting uncertainty of the number flux of short fecal pellets	number per square meter per day (# m^-2 d^-1)
short_fp_number_counted	Number of raw counts of short fecal pellets	scalar
mini_pellet_flux	number flux of mini pellets	number per square meter per day (# m^-2 d^-1)
mini_pellet_flux_uncertainty	counting uncertainty of the number flux of mini pellets	number per square meter per day (# m^-2 d^-1)
mini_pellet_number_counted	Number of raw counts of mini pellets	scalar
salp_pellet_flux	number flux of salp fecal pellets	number per square meter per day (# m^-2 d^-1)
salp_pellet_flux_uncertainty	counting uncertainty of the number flux of salp fecal pellets	number per square meter per day (# m^-2 d^-1)

salp_pellet_number_counted	Number of raw counts of salp fecal pellets	scalar
phyto_flux	number flux of phytoplankton cells	number per square meter per day (# m^-2 d^-1)
phyto_flux_uncertainty	counting uncertainty of the number flux of phytoplankton cells	number per square meter per day (# m^-2 d^-1)
phyto_number_counted	Number of raw counts of phytoplankton cells	scalar
foraminifera_flux	number flux of foraminifera	number per square meter per day (# m^-2 d^-1)
foraminifera_flux_uncertainty	counting uncertainty of the number flux of foraminifera	number per square meter per day (# m^-2 d^-1)
foraminifera_number_counted	Number of raw counts of foraminifera	scalar
rhizaria_flux	number flux of rhizaria	number per square meter per day (# m^-2 d^-1)
rhizaria_flux_uncertainty	counting uncertainty of the number flux of rhizaria	number per square meter per day (# m^-2 d^-1)
rhizaria_number_counted	Number of raw counts of rhizaria	scalar
fiber_flux	number flux of fibers	number per square meter per day (# m^-2 d^-1)
fiber_flux_uncertainty	counting uncertainty of the number flux of fibers	number per square meter per day (# m^-2 d^-1)
fiber_number_counted	Number of raw counts of fibers	scalar
copepod_flux	number flux of copepods	number per square meter per day (# m^-2 d^-1)
copepod_flux_uncertainty	counting uncertainty of the number flux of copepods	number per square meter per day (# m^-2 d^-1)
copepod_number_counted	Number of raw counts of copepods	scalar
pteropod_flux	number flux of pteropods	number per square meter per day (# m^-2 d^-1)
pteropod_flux_uncertainty	counting uncertainty of the number flux of pteropods	number per square meter per day (# m^-2 d^-1)
pteropod_number_counted	Number of raw counts of pteropods	scalar
amphipod_flux	number flux of amphipods	number per square meter per day (# m^-2 d^-1)
amphipod_flux_uncertainty	counting uncertainty of the number flux of amphipods	number per square meter per day (# m^-2 d^-1)
amphipod_number_counted	Number of raw counts of amphipods	scalar
other_zooplankton_flux	number flux of other zooplankton	number per square meter per day (# m^-2 d^-1)
other_zooplankton_flux_uncertainty	counting uncertainty of the number flux of other zooplankton	number per square meter per day (# m^-2 d^-1)
other_zooplankton_number_counted	Number of raw counts of other zooplankton	scalar
zooplankton_part_flux	number flux of zooplankton body parts	number per square meter per day (# m^-2 d^-1)
zooplankton_part_flux_uncertainty	counting uncertainty of the number flux of zooplankton body parts	number per square meter per day (# m^-2 d^-1)

zooplankton_part_number_counted	Number of raw counts of zooplankton body parts	scalar
unidentifiable_flux	number flux of unidentifiable particles or imagine noise	number per square meter per day (# m^-2 d^-1)
unidentifiable_flux_uncertainty	counting uncertainty of the number flux of unidentifiable particles or imagine noise	number per square meter per day (# m^-2 d^-1)
unidentifiable_number_counted	Number of raw counts of unidentifiable particles or imagine noise	scalar
long_fp_Cflux	modeled carbon flux by long fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
short_fp_Cflux	modeled carbon flux by short fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
salp_fp_Cflux	modeled carbon flux by salp fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
mini_fp_Cflux	modeled carbon flux by mini pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
phytoplankton_Cflux	modeled carbon flux by phytoplankton cells	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
rhizaria_Cflux	modeled carbon flux by rhizaria cells	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
agg_Cflux	modeled carbon flux by aggregates	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
dense_Cflux	modeled carbon flux by dense detritus	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
large_fp_Cflux	modeled carbon flux by large-loose fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
long_fp_Cflux_uncertainty	uncertainty of modeled carbon flux by long fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
short_fp_Cflux_uncertainty	uncertainty of modeled carbon flux by short fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
salp_fp_Cflux_uncertainty	uncertainty of modeled carbon flux by salp fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
mini_fp_Cflux_uncertainty	uncertainty of modeled carbon flux by mini pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
phytoplankton_Cflux_uncertainty	uncertainty of modeled carbon flux by phytoplankton cells	millimole of carbon per square meter per day (mmol C m^-2 d^-1)

rhizaria_Cflux_uncertainty	uncertainty of modeled carbon flux by rhizaria cells	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
agg_Cflux_uncertainty	uncertainty of modeled carbon flux by aggregates	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
dense_Cflux_uncertainty	uncertainty of modeled carbon flux by dense detritus	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
large_fp_Cflux_uncertainty	uncertainty of modeled carbon flux by large-loose fecal pellets	millimole of carbon per square meter per day (mmol C m^-2 d^-1)
long_fp_Vflux	modeled volume flux by long fecal pellets	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
short_fp_Vflux	modeled volume flux by short fecal pellets	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
salp_fp_Vflux	modeled volume flux by salp fecal pellets	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
mini_fp_Vflux	modeled volume flux by mini pellets	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
phytoplankton_Vflux	modeled volume flux by phytoplankton cells	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
rhizaria_Vflux	modeled volume flux by rhizaria cells	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
agg_Vflux	modeled volume flux by aggregates	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
dense_Vflux	modeled volume flux by dense detritus	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)
large_fp_Vflux	modeled volume flux by large-loose fecal pellets	cubic millimeters per square meter per day (mm^3 m^-2 d^-1)

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Instruments

Dataset-specific Instrument Name	Luminera Infinity 2 microscope camera
Generic Instrument Name	Camera
Dataset-specific Description	Polyacrylamide gel layers were imaged on a dissecting microscope (Olympus SZX16) with either a Luminera Infinity 2 (FK170124) or an Allied Vision Technologies StingRay (EN572 and EN581) camera attachment.
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	Olympus SZX16 Stereomicroscope
Generic Instrument Name	Microscope - Optical
Dataset-specific Description	Polyacrylamide gel layers were imaged on a dissecting microscope (Olympus SZX16)
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	
Generic Instrument Name	Sediment Trap
Dataset-specific Description	Sediment trap collector tubes were deployed on various platform designs, including a neutrally-buoyant sediment trap (NBST), a surface tethered sediment trap (STST), and a Wire Walker (WW) trap.
Generic Instrument Description	Sediment traps are specially designed containers deployed in the water column for periods of time to collect particles from the water column falling toward the sea floor. In general a sediment trap has a jar at the bottom to collect the sample and a broad funnel-shaped opening at the top with baffles to keep out very large objects and help prevent the funnel from clogging. This designation is used when the specific type of sediment trap was not specified by the contributing investigator.

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Deployments

EN572

Website	https://www.bco-dmo.org/deployment/749440
Platform	R/V Endeavor
Start Date	2015-11-03
End Date	2015-11-07

EN581

Website	https://www.bco-dmo.org/deployment/749505
Platform	R/V Endeavor
Start Date	2016-06-13
End Date	2016-06-18

FK170124

Website	https://www.bco-dmo.org/deployment/732225
Platform	R/V Falkor
Report	https://datadocs.bco-dmo.org/docs/302/EAGER_DNA_BioPump/data_docs/DurkinOmandEstapa_Cruise_report.pdf
Start Date	2017-01-24
End Date	2017-02-20
Description	Station 1: 01/28/2017 17:45 to 02/02/2017 05:43 (GMT) Station2: 02/05/2017 16:06 to 02/08/2017 17:20 (GMT) Station3_dep1: 02/12/2017 04:23 to 02/13/2017 16:42 (GMT) Station3_dep2: 02/13/2017 17:48 to 02/14/2017 18:46 (GMT)

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Project Information

Collaborative Research: EAGER: Particle-specific DNA sequencing to directly observe ecological mechanisms of the biological pump (EAGER DNA BioPump)

Coverage: Eastern Pacific

NSF Award Abstract:
Carbon is fixed into organic matter by phytoplankton growing in the surface ocean, and is naturally sequestered in the ocean interior when particles and organisms sink: a process called the "biological pump." Because of its recognized influence on the global carbon cycle, ocean scientists have studied the biological pump for decades. However, we still do not have a sufficient understanding of the underlying processes to accurately quantify and predict carbon cycling. Much of this uncertainty stems from an inability to directly link specific plankton in the surface ocean with the types of particles sinking out of the surface ocean. To address this missing link in biological pump research, this work will directly observe how plankton are transported out of the surface ocean using novel, particle-specific observational approaches embedded within an interdisciplinary field program that will finely resolve upper ocean plankton groups and the resulting amount of sinking carbon across space and in time. The genetic identity of organisms within different types of sinking particles will be determined by sequencing the genetic contents of individually collected particles. This new application of a molecular method will definitively link surface plankton with sinking particles at five locations across the Pacific Ocean. This work has the potential to transform our understanding of the biological pump by identifying previously unknown links between surface ecosystems and sinking carbon particles. Because this work is embedded within an interdisciplinary field program, including biogeochemical modelers and remote sensing scientists, these data will feed directly into new models of the biological pump, improving our ability to

quantify and predict carbon uptake by the ocean. This project will train 1 graduate student and at least 2 undergraduate researchers. Findings will be communicated to the non-scientific public through blogs, videos, and the public communication channels of participating institutions.

Accurate prediction of the global carbon cycle requires an understanding of the specific processes that link surface plankton communities and sinking particulate carbon flux (export) out of the surface ocean, but current methodological paradigms in biological pump research do not directly observe these processes. This project will comprehensively determine who is exported from the surface ocean and how using new, particle-resolving optical and molecular techniques embedded within a sampling scheme that characterizes export events at high time and space resolution. The investigation suggests that different plankton types in the surface waters are transported out of the surface ocean by distinct export pathways, and that an understanding of these connections is critical knowledge for global carbon cycle modeling. If successful, this work has the potential to transform our conceptual understanding of the biological pump by directly identifying mechanisms that link surface plankton with particle export, without relying on bulk sampling schemes and large-scale correlation analysis. Particle export environments will be studied at five open ocean locations during a cruise from Hawaii to Seattle in January-February 2017. The surface plankton communities will be characterized by a combination of satellite observations, sensors attached to a free-drifting, continuously profiling WireWalker, an in situ holographic camera, microscopy, and by sequencing 18S and 16S rRNA gene fragments. Exported particles will simultaneously be captured by various specialized sediment traps and their characteristics will be directly related to their sources in the surface community by identifying the genetic contents of individual particle types. Individual particles will be isolated from gel layers and the 16S and 18S rRNA gene fragments will be amplified and sequenced. This work would, for the first time, combine molecular approaches with particle-specific observations to enable simultaneous identification of both which organisms are exported and the processes responsible for their export.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1703664

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