Copepod density gradient experiments near Scripps Canyon in La Jolla, CA from August to September 2017

Website: https://www.bco-dmo.org/dataset/773555
Data Type: experimental
Version: 1
Version Date: 2019-07-30

Project
» CAREER: Small-scale plankton-aggregate dynamics and the biological pump: Integrating mathematical biology in research and education (PlanktonAggDyn)

Contributors	Affiliation	Role
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Abstract
This dataset is from a set of three experiments conducted on August 1, September 6, and September 9 in 2017, to observe the effect of density gradients (of differing strengths) on the vertical distribution and behavior of the copepod Calanus pacificus. Each experiment consisted of three treatments: a control (without a density gradient), a tank with a weak gradient (with the density of the top layer about 0.0020 kg/m3 less than that of the bottom layer), and a tank with a strong gradient (with the density of the top layer about 0.0040 kg/m3 less than that of the bottom layer). Copepod movement was recorded with two cameras to construct 2D and 3D trajectories of the copepods.

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Coverage

Spatial Extent: **Lat**:32.8566 **Lon**:-117.2667
Temporal Extent: 2017-08-01 - 2017-09-09

Dataset Description

Data from a set of 3 experiments of copepod swimming trajectories for three different treatments with varying strength density gradients: control (no gradient), weak gradient, and strong gradient.

Included are three Matlab data files (one for each of the three experiments) providing copepod tracks in 2D and 3D for each treatment (control, weak gradient, and strong gradient).

Experiment 1
Experiment 2
Experiment 3

Below are descriptions for the vectors/matrices included in these files.

copepod_track_expX_treatment_... all copepod track files are named in this format, where “expX” will read

“exp1”, “exp2”, or “exp3” depending on the experiment number, and “treatment” will read “control”, “weak”, or “strong” depending on the treatment type. In all of the “copepod_track…” matrices, the rows correspond to distinct copepod tracks and the columns correspond to sequential image numbers (the time stamps of the image numbers are given in time vectors that are included). The value in each matrix cell provides the location of the copepod in cm for that dimension: 1) cam1_x is the horizontal dimension for camera 1 and location is given in cm to the right of the left tank wall, 2) cam1_z is the vertical dimension for camera 1 and location is given in cm below the center of the density gradient (so negative values correspond to locations above the density gradient), 3) cam2_y s the horizontal dimension for camera 2 and location is given in cm to the right of the left tank wall, 4) cam2_z is the vertical dimension for camera 2 and location is given in cm below the center of the density gradient (so negative values correspond to locations above the density gradient). Any cell with a value of “NaN” indicates that copepod track was not present in that image.

For each treatment, there are 14 “copepod_track…” matrices that include:
All 2D tracks for the 4 dimensions respectively:
copepod_track_expX_treatment_2D_all_cam1_x
copepod_track_expX_treatment_2D_all_cam1_z
copepod_track_expX_treatment_2D_all_cam2_y
copepod_track_expX_treatment_2D_all_cam2_z

2D tracks longer than 10s from camera 1, which were used in analyses for 2D behavioral properties (vertical velocity and jump frequency):
copepod_track_expX_treatment_2D_10s_cam1_x
copepod_track_expX_treatment_2D_10s_cam1_z

All 3D tracks for the 4 dimensions respectively:
copepod_track_expX_treatment_3D_all_cam1_x
copepod_track_expX_treatment_3D_all_cam1_z
copepod_track_expX_treatment_3D_all_cam2_y
copepod_track_expX_treatment_3D_all_cam2_z

3D tracks longer than 10s, which were used in analyses for 3D behavioral properties (overall velocity and net-to-gross displacement ratio). For the vertical dimension of the 3D tracks, the z-coordinate from camera 1 was used for analyses:
copepod_track_expX_treatment_3D_10s_cam1_x
copepod_track_expX_treatment_3D_10s_cam1_z
copepod_track_expX_treatment_3D_10s_cam2_y
copepod_track_expX_treatment_3D_10s_cam2_z

time_expX_treatment For each treatment, a time vector is included that provides the time in seconds after imaging began. The length of this vector is the same as the number of columns in the “copepod_track…” matrices for that treatment (i.e. each entry in the vector provides the time for that corresponding image).

track_length_expX_treatment_2D_cam1 For each treatment, this vector provides the duration of each 2D track from camera 1 in seconds. The length of this vector is the same as the number of rows in the “copepod_track…” matrix for all 2D tracks from camera 1 for that treatment (i.e. each entry in the “track_length..” vector provides the duration in seconds for that corresponding track).

track_length_expX_treatment_3D Same meaning as vector described above, but provides duration of each 3D track in seconds for that treatment.

Methods & Sampling

During the summer of 2017, three sets of experiments were conducted on August 1, September 6, and September 9, to observe the effect of density gradients (of differing strengths) on the vertical distribution and behavior of the copepod Calanus pacificus. Each experiment consisted of three treatments: a control (without a density gradient), a tank with a weak gradient (with the density of the top layer about 0.0020 kg/m3 less than that of the bottom layer), and a tank with a strong gradient (with the density of the top layer about 0.0040 kg/m3 less than that of the bottom layer).

C. pacificus was collected using a small boat near Scripps Canyon in La Jolla, CA (32° 51’ 23.8” N, 117° 16’ 00.1” W) 6-7 days before each experiment. With a 300 µm mesh plankton net (0.5 m diameter mouth), 5-6

oblique tows were taken per sampling trip to a depth of at least 40 m and for a duration of 3 to 5 minutes. Samples were sorted in the lab to isolate late-stage copepodites (C4 and C5 stages) and adults of C. pacificus. Copepods were maintained with regular water changes in an incubator in the dark at 18 degC until the experiment and fed a mixed diet of Thalassiosira weissflogii and haptophytes (Tisochrysis sp. and Pavlova sp.).

Prior to each experiment, the top layer fluid was mixed by diluting filtered seawater with distilled (DI) water. The density of the top layer fluid was measured immediately before each experiment, using a handheld density meter (DMA 35, Anton Paar), and was kept roughly consistent between experiments. Copepods were starved for 24 hours prior to each experiment by transferring 20-25 C. pacificus individuals (late-stage copepodites and adults) into a 1 L beaker, and acclimated to the top layer fluid for each treatment. Each beaker was wrapped in aluminum foil to maintain darkness, and was kept at room temperature. Copepods were inspected to ensure a normal swimming behavior before being transferred to the experimental tank.

The experimental tank had a square base (10 cm × 10 cm) and a height of 50 cm. The non-stratified control treatment was set up by pouring ~5 L of filtered seawater (hereafter referred to as bottom layer fluid) into the tank. For the stratified treatments, density gradients were established by filling the tank with ~2.5 L of bottom layer fluid, followed by 2.5 L of less dense top layer fluid. Top layer fluid was slowly pumped on top of the bottom layer fluid through a diffuser to minimizing mixing.

Once the tanks were set up, 15 - 17 copepods were chosen for each treatment, and were transferred into a 50 mL beaker by pipette.

Once image recording had initiated, copepods were slowly poured into the top of the tank, with care so as to not disturb the density gradient. For each treatment, copepods were observed in the tank using two high-resolution cameras (Grasshopper3 4.1 MP Mono USB3 Vision, Pt. Grey) set up perpendicularly to one another to allow for 3D imaging. To image without visible light, a 730 nanometer near-infrared light-emitting diode (M730L4 730 nm, 515 mW Mounted LED, Thorlabs), collimated using a Fresnel Lens, illuminated the tank from below through an acrylic panel installed in the table supporting the experimental tank. Preliminary experiments demonstrated that this light source caused no noticeable heat effects within the tank. Each treatment was recorded for ~30-35 minutes at 12 frames per second. The field of view of each camera was ~30 cm x ~10 cm (with the horizontal section cropped to the width of the tank), allowing observation of copepods ~15 cm above and below the center of the tank.

Vertical profiles of conductivity and temperature were taken after each treatment using a conductivity probe (MSCTI, Precision Measurement Engineering, Encinitas, CA).

Data Processing Description

For all analyses, depth was defined relative to the middle of the density gradient (that is, a depth of 0 cm indicates the depth of the density gradient); this was determined as the depth of the average density (between the top and bottom layer) as measured by the conductivity probe. Thus, negative depth values indicate positions above the density gradient, and positive depth values indicate positions below the density gradient. For control treatments (without a density gradient), the middle depth was chosen as the averaged middle depth from the stratified treatments from each corresponding experiment.

To quantify zooplankton swimming behavior, copepod tracks were reconstructed in both 2D and 3D using MATLAB. Copepods were first identified in images in both cameras as objects above a specified brightness threshold and size, and positions of copepods were recorded. Potential copepod tracks were then identified using a program that minimized a combination of the distance and change in velocity between individual copepods in neighboring frames. Any errant tracks were removed by eye to compile the final copepod tracks for each treatment. Position was linearly converted from pixels to cms using the measured dimensions of the field of view of the camera (from images of a ruler taken immediately after each treatment concluded). Corresponding tracks from each camera that aligned in the z-axis (vertical direction) were then combined to reconstruct 3D copepod tracks. In some cases, 2D tracks were not able to be combined because the copepod was not visible in both cameras concurrently (particularly when copepods were near a wall or not in the center of the tank and thus out of focus in one camera).

Behavioral analysis was conducted only on copepod tracks longer than 10 s in duration. The behavioral properties that were calculated from copepod tracks include vertical velocity and jump frequency (calculated from the 2D tracks) and overall velocity and net-to-gross displacement ratio (calculated from the 3D tracks). For 3D tracks, the vertical dimension was used from camera 1.

BCO-DMO Processing Notes:
- served data via direct download links
- zipped the 3 experiments Matlab (.mat) files into one package for additional download option.

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Data Files

File	
Experiment1_Copepod_Tracks_Data filename: Experiment1_Copepod_Tracks_Data.mat Matlab data file for experiment 1 of Copepod Tracks.	(MATLAB Data (.mat), 7.68 MB) MD5:09c52d8f000550a445ce029b2aa292b6
Experiment2_Copepod_Tracks_Data filename: Experiment2_Copepod_Tracks_Data.mat Matlab data file for experiment 2 of Copepod Tracks.	(MATLAB Data (.mat), 8.41 MB) MD5:4c1eef79388631563d5efcf9f84be097
Experiment3_Copepod_Tracks_Data filename: Experiment3_Copepod_Tracks_Data.mat Matlab data file for experiment 3 of Copepod Tracks.	(MATLAB Data (.mat), 5.26 MB) MD5:83ea295b799dd154b94e775de2d208d3

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Related Publications

Cayson, C. (n.d.). The Effects of Density Gradients on the Distribution and Behavior of Copepods. doi:10.22371/02.2018.017
Results

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Parameters

Parameters for this dataset have not yet been identified

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Instruments

Dataset-specific Instrument Name	high-resolution cameras
Generic Instrument Name	Camera
Dataset-specific Description	For each treatment, copepods were observed in the tank using two high-resolution cameras (Grasshopper3 4.1 MP Mono USB3 Vision, Pt. Grey) set up perpendicularly to one another to allow for 3D imaging.
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	conductivity probe
Generic Instrument Name	Conductivity Meter
Dataset-specific Description	Vertical profiles of conductivity and temperature were taken after each treatment using a conductivity probe (MSCTI, Precision Measurement Engineering, Encinitas, CA).
Generic Instrument Description	Conductivity Meter - An electrical conductivity meter (EC meter) measures the electrical conductivity in a solution. Commonly used in hydroponics, aquaculture and freshwater systems to monitor the amount of nutrients, salts or impurities in the water.

Dataset-specific Instrument Name	mesh plankton net
Generic Instrument Name	Plankton Net
Dataset-specific Description	With a 300 µm mesh plankton net (0.5 m diameter mouth), 5-6 oblique tows were taken per sampling trip to a depth of at least 40 m and for a duration of 3 to 5 minutes.
Generic Instrument Description	A Plankton Net is a generic term for a sampling net that is used to collect plankton. It is used only when detailed instrument documentation is not available.

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Project Information

CAREER: Small-scale plankton-aggregate dynamics and the biological pump: Integrating mathematical biology in research and education (PlanktonAggDyn)

NSF Award Abstract:
The global carbon cycle is in part modified by marine biological processes, which can impact the amount of carbon that is transported from surface waters to the deep ocean. This project will investigate interactions between planktonic grazers and marine aggregates - sinking particles that form in the surface ocean and have been shown to play an important role in marine food webs. The small scale of these biological processes makes them particularly challenging to study, but modern advances in mathematics and computer science have made direct observations of these interactions feasible. Experiments using high-resolution imaging will provide direct visual observations of zooplankton ingestion and the alteration of marine aggregates. These laboratory studies will guide the development of mathematical models to examine how these interactions affect particulate carbon

sinking out of the surface ocean. This project will support an educational initiative focused on training undergraduate biology students in mathematical and computational techniques. This initiative includes the development of new interdisciplinary courses and undergraduate-focused independent research projects to help prepare the next generation of scientists in quantitative techniques that are essential to tackling the most challenging and complex biological problems.

Marine snow aggregates are particles that form in the surface ocean from organic and inorganic matter. These aggregates play a fundamental role in the biological pump, as sinking particles are a dominant contributor to the downward transfer of carbon in the ocean. However, much of the small-scale processes governing these particles and their role in the marine carbon cycle are still unknown. The goal of this project is to use mathematical and computational techniques to investigate interactions between aggregates and planktonic grazers, an understudied link in the planktonic food web that has important implications for carbon export. Three-dimensional trajectories of copepods within marine snow thin layers will be obtained to experimentally investigate copepod foraging behavior in response to patchy distributions of marine snow. In addition, high-speed imaging will allow for the direct observation of how copepods manipulate and ingest marine snow aggregates, thus affecting their size and settling velocity. Lastly, a mathematical model will be developed to study the impact of these small-scale interactions on large-scale carbon cycling and export. This project will also support the implementation of a comprehensive education plan focused on teaching undergraduate students how mathematical modeling and computational techniques can be used to address biological questions. This educational objective will be accomplished through the development of new courses in mathematical and computational biology and through the inclusion of undergraduate students in independent research projects.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1654276

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