Observations of Copepod Reactions to Sinking Aggregates Experiments 2019

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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
These data are from a set of two experiments of tethered copepods reacting to sinking marine snow aggregates. Experiments were conducted in July 2019 in the Prairie research lab at the University of San Diego, California, USA.

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Coverage

Spatial Extent: **Lat**:32.862 **Lon**:-117.280267
Temporal Extent: 2019-07-01 - 2019-07-11

Methods & Sampling

During the summer of 2019, two sets of experiments were conducted on July 1 and July 11 to observe reactions of the copepod *Calanus pacificus* to sinking aggregates.

C. pacificus was collected using a small boat near Scripps Canyon in La Jolla, CA (32° 51.720' N, 117° 16.816' W) at least 4 days before each experiment with a 333 µm mesh plankton net (0.5 m diameter mouth). Samples were sorted in the lab to isolate individuals of the species *C. pacificus*. Copepods were maintained with regular water changes in an incubator in the dark at 18°C until the experiment and fed *Thalassiosira weissflogii*. Copepods were starved for 24 hours prior to each experiment by transferring them into beakers with filtered seawater which were wrapped in aluminum foil to maintain darkness and kept at room temperature. Starved female *C. pacificus* were tethered the morning of each experiment and placed in a beaker with filtered seawater at room temperature without food until they were used for the experiment.

Prior to each experiment, phytoplankton cultures of the species *T. weissflogii* were started in 2L flasks and were grown in f/2 media at room temperature under 12:12 hour LED light:dark cycle for 3-5 days corresponding to the exponential growth phase. Three days before each experiment, the cultures were diluted to 30,000 cell/mL, using filtered seater that had a density between 0.001-0.002 g/cm3 less than the density of the filtered seawater used in the experimental tank (densities were measured with a handheld density meter). This was done to slow down the sinking velocity of the aggregates. The diluted cultures were then added to

cylindrical acrylic tanks (each with a volume of 2.2 L). These cylindrical tanks were allowed to rotate in the dark on roller table for 3 days at a rate of 3.3 rpm to form aggregates.

Individual copepods, tethered to a strand of hair to ensure they stayed in the field of view of the camera, were placed in a 30.5 cm x 16 cm x 8 cm tank filled with filtered seawater. Individual aggregates were then pipetted into a funnel in the top of the tank, and allowed to sink towards the tethered copepod. A Point Grey Grasshopper camera (Model GS3-U3-41C6NIR-C) was used to image the interactions between the copepods and aggregates, recording at rate of 30 fps. The experiments were filmed completely in the dark with the exception of a near-infrared LED light from below, which was used to ensure there was no effect of light on copepod behavior. In Experiment 1, 4 different copepods were each exposed to 6 different aggregates. In Experiment 2, 10 individual copepods were each exposed to 4 different marine snow aggregates (with the exception of the first copepod which was just exposed to one aggregate). In Experiment 1, some copepod/aggregate interactions were not successfully recorded or the aggregate never entered the field of view of the camera and so these were not included in the data sheet.

Data Processing Description

Data Processing:
Image analysis was performed in order to determine characteristics of the aggregates when a reaction occurred. Copepods were usually not moving at all when there was no marine snow present in the tank. Once a marine snow aggregate was inserted into the tank, a "reaction" was then defined as any substantial movement by the copepod that could be detected by the naked eye. MATLAB was used to quantify several different characteristics of the aggregates including: the x and y coordinates of the aggregate's centroid when the copepod reacted, the distance between the nearest part of the aggregate to the copepod's head when the copepod reacted, the projected area of the aggregate in the 2D image when the copepod reacted, and the major and minor axis length of the projection of the aggregate in the 2D image when the copepod reacted. The x and y coordinates of the aggregate are given in centimeters relative to the copepod's head (i.e. with the copepod's head defined as the origin), where positive x values indicate locations in front of the copepod and negative x values indicate locations behind the copepod, and positive y values indicate locations above the copepod and negative y values indicate locations below the copepod. All length scales were converted to centimeters using images of a ruler taken in the tank for each experiment.

BCO-DMO Processing:
- concatenated data from two separate Excel sheets into a single dataset;
- replaced "NaN" with "nd" (no data).

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Parameters

Parameter	Description	Units
Experiment_Number	experiment number. Experiment 1 was conducted on July 1, 2019 and Experiment 2was conducted on July 11, 2019.	unitless
Copepod	copepod number	unitless
Aggregate	aggregate number (each copepod was observed reacting to multiple aggregates, see Acquisition Description for more details)	unitless
Reaction	0 indicates a reaction was not observed. 1 or 2 indicates a reaction was observed (a value of 2 indicates the second distinct reaction by the copepod to the same aggregate, which is presented in a separate row).	unitless
AggregateXPosition_cm	the X location in centimeters of the centroid of the aggregate when the copepod reacted. "nd" (no data) means the copepod did not react.	centimeters (cm)
AggregateYPosition_cm	the Y location in centimeters of the centroid of the aggregate when the copepod reacted. "nd" (no data) means the copepod did not react.	centimeters (cm)
NearestDistance_cm	the distance (in cm) from the nearest part of the aggregate to the copepod’s head when the reaction occurred. "nd" (no data) means the copepod did not react.	centimeters (cm)
Aggregate_Area_cm2	the projected area of the aggregate (in cm squared) measured from the image when the copepod reacted. If the copepod did not react, the aggregate area was measured from an arbitrary image where the aggregate was completely visible.	square centimeters (cm^2)
Agg_Maj_Length_cm	the major axis length (in cm) of the projection of the aggregate from the image when the copepod reacted. If the copepod did not react, the major axis length was measured from an arbitrary image where the aggregate was completely visible.	centimeters (cm)
Agg_Min_Length_cm	the minor axis length (in cm) of the projection of the aggregate from the image when the copepod reacted. If the copepod did not react, the major axis length was measured from an arbitrary image where the aggregate was completely visible.	centimeters (cm)

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Instruments

Dataset-specific Instrument Name	Point Grey Grasshopper camera (Model GS3-U3-41C6NIR-C)
Generic Instrument Name	Camera
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	hand-held density meter: DMA 35, Anton Paar
Generic Instrument Name	density meter
Generic Instrument Description	Portable or bench-top instruments to measure density of liquids. [lab]

Dataset-specific Instrument Name	near-infrared light-emitting diode: M730L4 730 nm, 515 mW Mounted LED, Thorlabs
Generic Instrument Name	LED light
Generic Instrument Description	A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. Electrons in the semiconductor recombine with electron holes, releasing energy in the form of photons.

Dataset-specific Instrument Name	333 µm mesh plankton net (0.5 m diameter mouth)
Generic Instrument Name	Plankton Net
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.

Dataset-specific Instrument Name	cylindrical acrylic tanks (each with a volume of 2.2 L)
Generic Instrument Name	Roller Tank
Generic Instrument Description	Rolling tanks, which keep particles in suspension, thus simulating aggregate formation in situ. Marine snow experiments are conducted in roller tanks, which turn continuously, keeping marine snow in suspension. It is important for marine snow not to touch surfaces. The rolling tanks, which keep particles in suspension, thus simulate aggregate formation in situ. Marine snow formation due to different types of oil was tested. Some treatments are easily identifiable as containing oil by their color (middle). UCSB, CA 2012.

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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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