

Grazing Processes and the Structure and Persistence of Thin Biological Layers

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Award #: N00014-96-1-0291
http://www.onr.navy.mil/sci_tech/ocean/onrpgahj.htm

LONG-TERM GOALS

My long-term goal is to understand the functional roles of microzooplankton (20-200 microns) in the sea, with emphasis on their contribution to grazing. It has been argued that on a timescale of days the instantaneous grazing rate of zooplankton in toto is greater than the instantaneous rates of vertical and horizontal mixing by at least an order of magnitude, and is the same order of magnitude as the instantaneous rate of phytoplankton cell division. Hence, grazing is a critically important term in the dynamics of phytoplankton loss (Banse 1992). Because microzooplankton are the major grazers in pelagic food webs under most circumstances, their grazing activities exert an important impact on phytoplankton losses in the sea. My specific interests lie in (1) studying their processes of feeding and reproduction at the level of the individual organisms and the community and (2) understanding their function as prey for higher order consumers.

OBJECTIVES

The objectives of the current research are two-fold: (1) to measure the impact of grazing by microzooplankton on thin biological layers of phytoplankton and (2) to collect fine-scale (10-25 cm resolution) vertical profiles of nanoplankton (2-20 microns) and microplankton (20-200 microns) in the water column. Data on the vertical distribution and abundance of organisms is used to fully interpret the grazing experiments.

APPROACH

Fine-scale profiles. The vertical structure of the water column is first characterized using an updated version of the high-resolution profiling system developed by Donaghay, et al. (1992). Profiles of salinity, temperature, chlorophyll, oxygen, transmission, and various optical parameters are produced. Bulk water is collected from specific density surfaces of bio-optical layers using a siphon system

mounted on the profiling package. A number of sample types are collected and processed by different investigators. Specific to this award, samples are analyzed for size-fractionated extracted chlorophyll, nanoplankton (<20 μm), and microplankton (20-200 μm). Extracted chlorophyll is analyzed by fluorometry. Samples for nanoplankton are analyzed by image-enhanced epifluorescence microscopy. Microplankton samples are analyzed using an inverted microscope. The data are plotted as a function of depth and in conjunction with physical and optical parameters. Water samples are collected at 10-50 cm intervals during one tidal cycle. The interval chosen depends on sea state and timing. The profiling package has a computer readout which tells us the depth of collection precisely; a continuous data record for the duration of water collection at each depth is logged and stored on disk. In the event that collection is disrupted by internal waves or boat wakes, we are able to (1) adjust the depth of collection by following the density readout or (2) suspend sampling until the interruption has passed.

Grazing methodology. In situ grazing rates of microzooplankton are measured using the seawater dilution technique (Landry and Hassett, 1982; Gifford, 1988), which simultaneously measures instantaneous rates of phytoplankton growth and mortality due to grazing. Using this method, phytoplankton growth is partitioned according to size (from measurements of size-fractionated chlorophyll and/or microscopy) or taxon (from microscopic counts). Because of the fragility of the microzooplankton organisms (which cannot be hand picked into incubation bottles like crustacean zooplankton), this is the only feasible method to use. The method, while well established for use with bulk seawater and average conditions, must be adapted for use in an environment partitioned spatially into layers. Water for the experiments is collected from the target layer using the siphon system mounted on the fine-scale profiler. The protistan microzooplankton consists of an assemblage of fragile organisms. Seawater for experiments must be collected and handled as gently as possible to avoid destroying the target organisms. We have found that our siphon system collects both phytoplankton and microzooplankton in excellent condition, so that water used in experiments is in as pristine condition as is humanly possible. Because the biological layers of interest are thin, experimental treatments are incubated in situ or in on-deck incubators in vessels whose vertical dimension is less than that of the target layer. To date, we have found that 0.5 to 2 L cylindrical polycarbonate incubation bottles are ideal for this purpose, eliminating the need to construct special incubation chambers. Calculation of grazing on chlorophyll represents the first cut through data collected using the seawater dilution method.

WORK COMPLETED

We participated in a 30-day multi-investigator field exercise in East Sound, WA during June 1998. During the field program, we accomplished the following: (1) Collected 3 fine scale profiles. Two of these profiles sampled the water column completely. One profile sampled within, above and below a layer. We collaborated closely with Mary Jane Perry, David Smith, Van Holliday and Alice Alldredge in these endeavors.

At the time of writing, we have analyzed preliminary grazing results on the basis of chlorophyll. The real power of the method lies in its ability to examine species- or taxon-specific rates of phytoplankton growth and loss. Rates can be calculated for any category of particles which are sufficiently abundant (generally 200-400/subsample counted). During the second year of the award, we will process (by various kinds of microscopy) samples from both the fine scale profiles and the grazing experiments and we will produce taxon-specific phytoplankton growth and loss rates from the microscopy for the grazing experiments. We will also analyze samples collected from partial profiles collected at

somewhat less fine scale intervals by P. Donaghay in a separate field experiment in East Sound, WA in August 1998.

RESULTS

Microzooplankton grazing within and around a layer of phytoplankton associated with the pycnocline was measured in June 1998 in East Sound, WA using the seawater dilution method. Preliminary analysis indicates that the taxonomic composition of organisms within the layer was similar to that of the surrounding water. Phytoplankton taxa consisted of chains of various diatom species, degraded colonies of *Chaetoceros socialis*, and nanoplankton cells < 20 um. The microzooplankton was dominated by the heterotrophic dinoflagellate *Noctiluca miliaris* and rotifers. The standing stock of chlorophyll was 1.5 to 3 times higher within the layer than above or below it. Experiments were done to measure the impact of microzooplankton grazing within, above, and below the layer. Chlorophyll above and within the layer grew at similar rates of approximately 1 doubling/day, while chlorophyll below the layer grew at 0.83 doublings/day. The impact of microzooplankton grazing above and within the layer was statistically significant ($p < 0.0001$), with approximately 100% of the daily chlorophyll production consumed at both depths. In contrast, below the layer, 39% of the daily chlorophyll production was consumed, but this was not statistically significant. The results suggest that the similar grazing rates within and above the layer served to maintain the layer's upper boundary, while the lower boundary appeared to be delimited by the base of the pycnocline. Similar experiments performed in conjunction with A.L. Allredge on a layer of marine snow indicated that microzooplankton grazed a significant amount of the chlorophyll within the snow layer.

IMPACT/IMPLICATION

The research represents an exciting opportunity to study a cutting-edge problem concerning the structure and function of pelagic ecosystems. The study provides new insight into how grazers, particularly protozoans, exploit thin layers and control them. Grazing by microzooplankton contributes to the maintenance of thin layer structure. While we have documented the existence of thin layers for several years, this is the first time their biological dynamics have been examined in detail in a representative coastal water column.

RELATED PROJECTS

- 1 - Temporal and spatial coherence of layers in East Sound and their relationship to physical structure and currents are being studied by P.L. Donaghay and M.M. Dekshenieks (University of Rhode Island).
- 2 - Primary production within and around thin layers in East Sound is being studied by M.J. Perry (University of Washington).
- 3 - Bacterial distribution and production within and around layers in East Sound is being studied by D.C. Smith (University of Rhode Island).
- 4 - Distribution of marine snow within and around layers in East Sound is being studied by A.L. Allredge and S. MacIntyre (University of California, Santa Barbara).

5 - Distribution and abundance of crustacean zooplankton within and around layers in East Sound, WA is being studied by D.V. Holliday (Tracor) and R.E. Pieper (University of Southern California).

6 - Distribution of large diatoms is being studied by J. Rines (University of Rhode Island).

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