Grazing Processes and the Structure and Persistence of Thin Biological Layers

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LONG-TERM GOALS

My long-term goal is to understand the functional roles of microzooplankton (20-200 um) 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

My principal scientific objectives during are two-fold:

(1) Collection of high-resolution (cm-scale) profiles of nanoplankton (<20 um) and microplankton (20-200 um) in the water column, with emphasis on distributions within and around layers.

(2) Measurement of the impact of the biological dynamics (i.e., rates of phytoplankton growth and loss due to microzooplankton grazing) within and around layers using the seawater dilution technique.

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. Samples are analyzed for size-fractionated extracted chlorophyll, nanoplankton (<20 um), and microplankton (20-200 um). 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

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a computer readout which tells us the depth of collection precisely and 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 adjust the depth of collection by following the density readout or 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. 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. 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, I 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.

WORK COMPLETED

During June 1998, I participated in a three-week field exercise in East Sound, WA. My component of this multi-investigator effort was located on the R.V. *Henderson*, which was anchored in East Sound adjacent to the mooring array deployed by D.V. Holliday and associates.

High Resolution Profiles. Two high resolution (50 cm sampling intervals) profiles of the entire water column and 3 "mini-high resolution profiles" (50 cm sampling intervals) through layered features of interest were collected by D. Gifford and J. Merrell in June 1998. P. Donaghay also collected 7 lower resolution profiles of microplankton samples for us in August 1998 during the Hycode overflights. Samples collected from the high resolution profiles in June 1998 are listed in Table 1.

Table 1. Samples and data collected from high-resolution profiles in East Sound, June 1998.

Samples Collected	**Principal Investigator**
CTD and transmission	D. Gifford
Extracted chlorophyll *a*	D. Gifford
Nanoplankton (epifluorescence microscopy)	D. Gifford
Microplankton (inverted microscopy)	D. Gifford
Diatoms and large phytoplankton	J. Rines
Bacterial numbers	D. Smith
Bacterial production	D. Smith
Major nutrients	M. Perry
Primary production	M. Perry
Particulate absorption	M. Perry
Phytoplankton pigments (HPLC)	L. Eisner

Grazing Experiments. We performed a series of experiments to measure microzooplankton grazing within and around a layer dominated by the colonial diatom *Chaetoceros socialis*. Analysis of the extracted chlorophyll data indicates that phytoplankton growth rates and microzooplankton grazing rates were in balance within the layer and in the water column above the layer. Neither growth nor grazing rates were statistically significant in the water column below the layer. These results indicate that grazing by microzooplankton functioned to maintain the upper boundary of the layer. The lower boundary was likely detremined by a combination of phytoplankton growth within the layer and the location of the pycnocline.

Marine Snow Studies. We performed collaborative experiments with A.L. Alldredge, which successfully measured the impact of microzooplankton grazing on marine snow for the first time. Preliminary analysis of extracted chlorophyll data indicates that microzooplankton grazing on the chlorophyll-containing component of the marine snow was highly significant. In addition, we prepared epifluorescence preparations of one diver-collected marine snow profile and prepared numerous epifluorescence samples of other material collected by A.L. Alldredge and associates.

CTD data. Data collected include CTD and transmissometry records associated with the two high-resolution profiles, the 3 "mini-profiles" and depth-keeping records for all water collections, a cumulative total of approximately 150 data records. All data collected using the SBE Sealogger CTD profiling system have been processed, depth-corrected, and archived. We are currently in the process of integrating the CTD and taxonomic data from the high resolution profiles. The depth corrected CTD and transmissometry data have been distributed to other program PIs for assimilation of nutrient, bacteria, and primary productivity data.

Nanoplankton Samples. Of the approximately 450 nanoplankton samples collected from the combined high resolution profiles, grazing experiments and marine snow studies, approximately half have been processed to date.

Of particular note, the colonial diatom *Chaetoceros socialis*, a major layer organism in East Sound in both 1997 and 1998, can only be enumerated quantitatively from our epifluorescent preparations (i.e., the nanoplankton samples) even though it is relatively large organism. The rapid preservation technique and subsequent capture onto a black Nuclepore filter for epifluorescence microscopy preserves the colony's gelatinous matrix. We are able to enumerate both number of colonies and number of cells per colony by this method using a semi-automated procedure and my laboratory's image analysis system. These organisms were originally supposed to be enumerated in J. Rines' aldehyde-preserved samples from the same high resolution profiles. However, the diatom's gelatinous matrix is not preserved in aldehyde, preventing adequate processing of this important species in those samples. Obtaining accurate counts of *C. socialis* has been important for understanding layer dynamics in East Sound during both 1997 and 1998.

Microplankton Samples. Of the 340 microplankton samples collected for the high resolution profiles, grazing experiments and marine snow studies, approximately half have been processed to date.

Chlorophyll *a* samples. Approximately 1500 samples for extracted chlorophyll *a* were collected from the high resolution profiles and the grazing experiments. All samples were processed and analyzed in the field. The data have been analyzed and assimilated with the CTD and transmissometry data.

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. The taxonomic composition of microorganisms 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 scintillans* 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. Alldredge on a layer of marine snow indicated that microzooplankton grazed a significant amount of the chlorophyll associated with the marine snow particles within the snow layer.

IMPACT/IMPLICATIONS

Our research in East Sound (in conjunction with measurements of primary production and bacterial production made by M.J. Perry and D.C. Smith, respectively) represents the first measurements of biological dynamics (i.e., rates of growth and loss) in and around thin layers and the first cm-scale profiles of nano- and micro-plankton collected in a layered coastal water column. When complete, our information from June 1998 will constitute an impressively detailed set of data. Analyses to date indicates that layers are taxonomically diverse and that each layer has its own particular biological dynamics. We have observed layers composed of a variety of species of dinoflagellates, diatoms, protozoans, and marine snow. In the three instances where the biological dynamics within and around layers have been examined to date, we have observed that the layers can be (or not) a locus of biological activity in the water column. The dynamics of a particular layer are likely to depend on the taxonomic composition of the organisms comprising the layer and their physiological state.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.

RELATED PROJECTS

1 - Horizontal distributions of layers in East Sound 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. Alldredge 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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