

Interactions of Small-Scale Physical Mixing Processes with the Structure, Morphology and Bloom Dynamics of Non-Spheroid Diatoms

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<http://www.gso.uri.edu/criticalscales>

<http://thalassa.gso.uri.edu/ESphyto>

<http://thalassa.gso.uri.edu/rines>

LONG-TERM GOALS

Our long term goal is to understand the ecology of phytoplankton, especially the large, colonial diatoms which frequently dominate the flora of coastal shelves, upwelling areas, fjords and banks. We are interested in ways in which species-specific properties, including cell and colony size and shape interact with small-scale physical mixing processes to regulate the spatio-temporal distribution of diatoms. We wish to understand these processes in sufficient detail to be able to predict bloom dynamics, size structure and the impact of species-specific characteristics of the phytoplankton on ocean optics.

OBJECTIVES

Our research addresses the role that interactions between biological and physical processes play in regulating the distribution of phytoplankton in the coastal ocean. Our goals are (1) to document the spatio-temporal patterns of distribution of large, or “net” phytoplankton in the coastal ocean from a species-specific, and size/shape specific perspective, and (2) to investigate the role that physical processes, operating at both the scale of populations and at the scale of individual cells and colonies play in controlling the patterns of distribution.

APPROACH

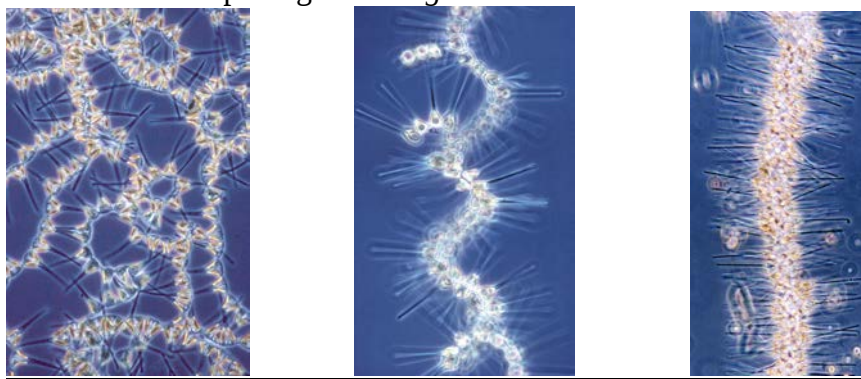
Our reflexive approach has combined field work in East Sound, Washington with laboratory experiments conducted at the University of Rhode Island. Field data is collected and analyzed, and then laboratory experiments are conducted to aid in the interpretation of field data. The resulting information is used to formulate new research questions. A comprehensive overview of field and laboratory work, to date, can be found in our current ONR proposal. In this past year, we have concentrated on the analysis of field data collected in East Sound (Phase I, below). The field

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component of this project is conducted in close collaboration with Donaghay's work on plankton dynamics (N00014-95-1-0225) and Dekshenieks, Donaghay & Osborn's (N00014-99-1-0293) study of circulation in East Sound. Analysis of our field data takes place in three phases. In Phase I, basic information on patterns of phytoplankton distribution (Rines), physical and optical profiles (Donaghay) and physical circulation (Dekshenieks, Donaghay & Osborn) are independently quantified. In Phase II, we collaboratively combine the phytoplankton and physics data sets to examine the role physical processes play in producing the spatio-temporal patterns of phytoplankton distribution. In Phase III, we use this information to examine the role of coupled, phytoplankton-physical interactions in influencing the observed zooplankton/acoustical distribution (Holliday) and in creating optical patterns (Donaghay, Weidemann, Zaneveld). We are completing Phase I, and just beginning Phase II work.

WORK COMPLETED

- (1) Quantification of field samples. In 1998, we participated in both the May-June and August experiments. From the transect vessel, we collected phytoplankton samples from along the axis of East Sound, from the east and west sides, from inside and outside of Thin layers, and in vertical profiles. Additionally, Gifford filled sample bottles for us as she collected her own samples from the moored vessel. Analysis of vertical profiles has been given first priority, as they will be used in our next manuscript. In the past year, we have quantified the diatoms and dinoflagellates in most vertical profiles, however further replicate counts are necessary in some cases for statistical reasons (an individual sample may require up to 9 separate counts in order to enumerate different kinds of organisms with good statistics). Videotaped images of phytoplankton have not yet been examined.
- (2) Comparison of Biological and Physical Data. (Phase II, above) Dekshenieks, Donaghay and Osborn have analyzed circulation patterns in East Sound during 1996 with respect to an episodic influx of buoyant, Fraser River plume water. This information has provided a context within which we can interpret the vertical location of a thin layer of the potentially toxic diatom *Pseudo-nitzschia*, observed over a 12-day period. This collaboration has resulted in a manuscript (Rines et al.) on the role of physical forcing in controlling the position of a thin layer of this diatom.
- (3) Documentation of morphological variability. We have noticed that a given species of diatom may exhibit extremely different morphology, depending on where and when in East Sound it was collected. We hypothesize that this may be related to the level of turbulence in which the colony grew, and have proposed new laboratory experiments to address this issue, and to determine whether it has an effect on optics. There are many examples, including *Chaetoceros socialis*, *Ch. debilis*, *Eucampia zodiacus*, *Asterionellopsis glacialis*, *Thalassionema nitzschioides*. The pictures below depict three distinct morphologies of *A. glacialis* observed in East Sound.



- (4) Further calibration of laboratory turbulence tanks. We have reported previously on laboratory experiments designed to examine the effects of small-scale turbulence on the size-frequency distribution, and structural integrity of chain-forming diatoms. In these experiments, turbulent energy dissipation rates (ϵ) were measured with Donaghay's Sontec Acoustic Doppler Velocimeter (ADV), with the sensor just below the surface of the water and out of the way of the stirring rods. In order to more accurately characterize the turbulent environment throughout each tank, we constructed a tank with a series of five ports along the side, through which the probe could be inserted. Time series of measurements were made at each location within the tank, for all five stirring speeds. New ϵ values for each treatment were calculated. This information will be used to help compare the results of previously conducted and future laboratory experiments to field data.
- (5) Thin Layers Web Site. Under a supplemental award to this grant, Rines has designed and constructed the Thin Layers Web Site. The goals of this project are to provide a central source of information to the scientific community at large and to the Navy, and to showcase the work of the PIs involved in the Thin Layers experiments. It is organized into two general parts, and can be entered from either one. The first provides an overview of the concept of "critical scales", and describes thin layers in general terms. The second describes the thin layers program, and outlines the thin layers experiments in East Sound. The site provides information on all PIs, links to their ONR annual reports, and links to any web sites they maintain at their respective institutions.

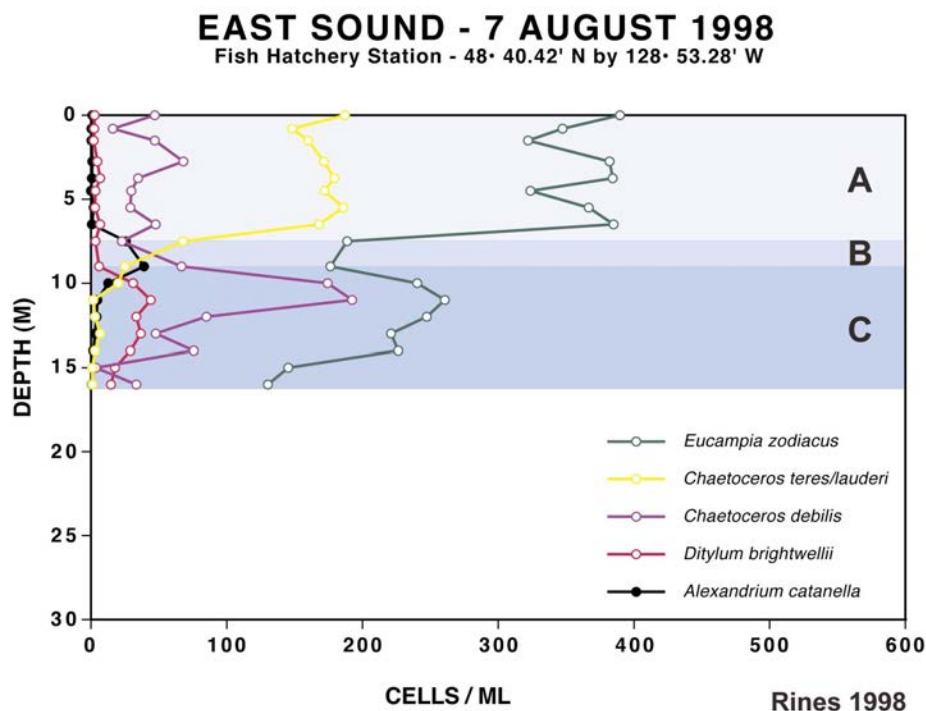
RESULTS

We have previously reported a deep, near-bottom thin layer dominated by the diatom *Pseudo-nitzschia fraudulenta* (May 1996), and a multiple-layered vertical profile containing discrete layers of *Alexandrium catenella* and *Chaetoceros debilis* (June 1997). To date, we have been able to document three kinds of patterns of vertical distribution of diatoms and dinoflagellates in East Sound:

- (1) All phytoplankton species present are distributed throughout the upper mixed layer.
- (2) Phytoplankton occur in thin layers, which are composed of an enhanced biomass of the entire floristic assemblage.
- (3) Phytoplankton occur in thin layers, where individual layers are dominated by a single species. Multiple, species-specific layers may occur. Particular taxa are restricted to certain regions of the water column.

Based on our analyses of 1996, 1997 and 1998 phytoplankton data, we now have evidence that the patterns can be recurrent, and that they are related to physical circulation patterns. A detailed analysis of the biological-physical coupling has been carried out for our 1996 data (Rines et al.). Our next step will be to conduct a similar, collaborative analysis for all other profiles. Based on preliminary information, it appears that the above phytoplankton distribution patterns are related to two types of physical events: regional scale physical forcing involving influx of buoyant Fraser River plume waters into East Sound, and to much finer-scale advective events where interleaved layers of water are moving in different directions. Both patterns (1) and (2) occurred during the June 1998 thin layers experiment. During this time, the net-plankton was numerically dominated by *Chaetoceros socialis*, which forms 500 μm to 2 mm hollow, spherical super-colonies. Their spatial distribution appeared related to the dominance of Fraser River plume water during the period, which is being studied in detail by Dekshenieks et al. An example of pattern (3) is shown below. Regions A, B, and C denote layers of water being advected in different directions, as determined by preliminary ADCP data. Here, *Chaetoceros teres* is primarily restricted to the surface layer. *Ditylum brightwellii* and *Ch. debilis* have peak concentrations in the lower layer, below the pycnocline. The highly toxic PSP dinoflagellate

Alexandrium catenella is restricted to a narrow band of low motion, at ~ 8 m depth. *Eucampia zodiacus* occurs throughout the water column. This pattern is very similar to that recorded in June, 1997, when *A. catenella* and *Ch. debilis* were found in the same relationship to each other, under similar physical conditions. We plan to examine the relationships between biological, physical and optical patterns in far greater detail as Phase I analyses are completed.



Our findings to date raise several new questions. Why are different taxa found in different locations? Is their morphology related to the physical characteristics of the water they are located in? Do these factors influence the optical patterns? We plan to address these issues in the future.

IMPACT/APPLICATIONS

An important component of our team's research is investigation of the concept of 'critical scales'. Critical scales are the spatial and temporal scales over which data must be collected in order for patterns (e.g. the pattern of vertical distribution of phytoplankton) to emerge. Once the pattern is evident, we next look for the process responsible for creation of that pattern. In the sea, there are many biological and physical processes, operating along horizontal and vertical axes, and over different time and space scales, which influence the observed patterns. Our goal is to identify the critical process(es) — the one(s) actually controlling the pattern — which in turn will lead us to a better understanding of the dynamics of the system. Our work to date is an important step towards our long term goal of building models which predict the species specific distribution of phytoplankton, as well as impacts on phytoplankton and zooplankton ecology, ocean optics and acoustics, and Navy systems.

TRANSITIONS

- (1) Education: I have received positive correspondence regarding the usefulness of the East Sound Phytoplankton Web Site from co-workers, students, professors, periodical writers, environmental consultants and Navy personnel. On-line information on the life-history stages of *Noctiluca scintillans* has proven useful to Holliday's investigation of factors influencing the return of an acoustical signal from this organism.
- (2) We anticipate that the Thin Layers Web Site will also be useful to a diverse scientific and government community.
- (3) Researchers at NUWC (Newport, R.I.) have expressed interest in collaborating to obtain data on the size and shape of phytoplankton present in the water column during NUWC instrument tests at a site off the Coast of California.

RELATED PROJECTS

- (1) Phytoplankton data collected in the field under this funding is interpreted within the context of physical, chemical, optical and ADV data collected under Donaghay's (URI) funding. In turn, phytoplankton data collected by this project will be used to help interpret Donaghay's optical profiles.
- (2) Our data is also interpreted within the context of physical circulation in East Sound studied by Dekshenieks, Donaghay and Osborn (URI & Johns Hopkins).
- (3) Species-specific phytoplankton data will be compared to zooplankton distributions inferred from acoustical profiles by Holliday (Marconi).
- (4) Rines has received DURIP funding to acquire instrumentation to equip a plankton imaging and analysis laboratory. This facility will be heavily utilized as we analyze data, conduct future experiments and prepare manuscripts.
- (5) Our August 7, 1998 data set was collected at the same time Alan Weidemann (NRL, Stennis Space Center) collected profiles with his optical instrumentation. Our phytoplankton data will be used to help interpret that information.
- (6) Field data on the vertical distribution of dinoflagellates, especially *Alexandrium catenella*, is being used by J. Sullivan (URI) in his dissertation work, which examines the effects of small-scale turbulence on growth and morphology of dinoflagellates. In turn, this project benefits from sharing of ADV data Sullivan collected in East Sound.
- (7) In August 1998, we collected samples to quantify the spatial heterogeneity of phytoplankton in surface waters during the hyperspectral overflights conducted by C. Davis/J. Rhea (NRL, Washington). Our data is available to aid in the interpretation of those images.
- (8) We expect to collaborate in the future with other Thin Layers PIs.

PUBLICATIONS

Rines, J.E.B., P.L. Donaghay, M.M. Dekshenieks and J.M. Sullivan (submitted) – Thin Layers and Camouflage: Hidden *Pseudo-nitzschia* populations in a fjord in the San Juan Islands, Washington, USA. Marine Ecology Progress Series.