Plankton Patch Feasibility Experiments

Percy L. Donaghay
Graduate School of Oceanography
University of Rhode Island
Narragansett, Rhode Island 02882
Phone: 401-874-6944
Fax: 401-874-6240
e-mail: donaghay@gsosun1.gso.uri.edu
Award # N000149510225

LONG-TERM GOALS

My long-term goal is to increase our understanding of the biological - biological, physical - biological and chemical - biological interactions that control the initiation, maintenance and dissipation of plankton patches.

OBJECTIVES

Efforts this year focused on testing our model of the effects of episodic increases in current shear on the dynamics and impacts of thin layers of phytoplankton and zooplankton. Thin layers are plankton patches that range in thickness from a few tens of centimeters to a few meters, yet can be sufficiently intense to affect biological rate processes and the performance of current and planned Navy optical and acoustical sensors. Although there is increasing evidence that thin layers can occur in a variety of stratified coastal systems, we know little about their temporal/spatial extent or the mechanisms that control their dynamics. Our primary objectives this year were to (1) quantify the temporal and spatial scales of thin layers of phytoplankton and zooplankton, (2) test our model of the effects of episodic increases in current shear on thin layer formation, maintenance and dissipation, (3) test the hypothesis that zooplankton aggregate into thin phytoplankton layers, and (4) obtain a qualitative picture of circulation in East Sound and its response to large scale forcing.

APPROACH

We conducted three major cruises in East Sound as part of the 1998 Thin Layers experiment. Our approach during each cruise is summarized below.

In the first cruise, we collaborated with Margaret Dekshenieks (URI), Tom Osborn (JHU), and Alan Weidemann (NRL) in an effort to obtain a qualitative picture of circulation in East Sound and its response to large scale forcing. Prior to the start of this experiment, we installed a weather station and a wave/tide gauge in upper East Sound and assisted Alan Weidemann in installing bottom mounted Acoustic Doppler Current Profilers (ADCPs) on either side of the mouth of the Sound, at mid Sound and at the site of the time series moorings in upper East Sound. Between May 24 and June 3, we used our ship mounted 1200 khz ADCP to map currents along the Sound and across the upper, middle and lower Sound. These transects were collected near ebb and flood tide during calm periods and periods of winds from the north and south. Vertical profiles of temperature, salinity, density, oxygen, total absorption and scattering were rapidly collected at the end of each transect.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Plankton Patch Feasibility Experiments**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Rhode Island,Graduate School of Oceanography,Narragansett,RI,02882**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**6**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

In the second cruise, we collaborated closely with Van Holliday (Tracor) in collecting the combination of time series and transect data needed to address our primary objectives. At the beginning of this cruise, we assisted Van Holliday in deploying his Tracor Acoustic Profiling Systems (TAPS), and then deployed our underwater winch CTD/optics profilers adjacent to the TAPS. Both types of profilers were powered from shore and transmitted data to shore in real time. These profilers were deployed adjacent to Weidemann's ADCP at the time series station in the upper Sound. This arrangement gave us simultaneous fine scale measurements of phytoplankton and zooplankton structure along with currents and physical structure. Once installed, we used our underwater winch CTD/optics profilers to collect hourly profiles of temperature, salinity, density, oxygen, spectral absorption and spectral transmission at the location of the array. These data were collected for the 2 week intensive sampling period. During this same period, we used our transect boat to simultaneously collect high resolution profiles of currents, temperature, salinity, density, oxygen, pH, Eh, spectral fluorescence, spectral absorption by dissolved material, and spectral absorption and scattering by particulate material. High resolution profiles of zooplankton were collected from the transect boat using a side looking TAPS provided by Van Holliday. The transect boat was also used to collect discrete depth samples for microscopic analysis of phytoplankton by Jan Rines (URI). Profiles from the transect boat were collected at varying distances from the time series station in order to map the spatial extent of layers. Following the completion of the intensive sampling period on June 25, we pulled our underwater winch profilers, re-calibrated the sensors and made repairs as needed.

We conducted a third cruise in conjunction with the hyper-spectral overflights by Curt Davis (NRL). At the beginning of this mid-summer cruise, we re-deployed our underwater winch profilers adjacent to Holliday's TAPS and Weidemann's ADCP at the time series station. As during the intensive sampling period, we used the underwater winches to collect a time series of hourly CTD/optics profiles while the transect boat was used to collect high resolution CTD/optics/current profiles throughout East Sound. This gave us a second opportunity to examine the effects of episodic increases in current shear on thin layers. The transect boat was also used to collect discrete depth plankton samples for microscopic analysis by Jan Rines (URI) and Dian Gifford (URI). Whenever possible, we coordinated our sampling with the hyper-spectral overflights of Curt Davis (NRL) and the CTD/optics profiles being collected by Alan Weidemann on a second transect vessel.

Near the end of the third cruise, we replaced the CTD on one of the two underwater winch profilers with a Sontek Acoustic Doppler Velicometer (ADV). We then used this combination to obtain estimates of mixing during a quiescent period followed by strong south winds that gradually mixed the pycnocline down from 2 to 7 meters. Currents were measured by our shipboard 1200 khz ADCP and Weidemann's nearby bottom mounted ADCP. The underwater winch profilers were manually controlled during this period to optimize sampling and coordinate it with high resolution optical/physical profiles being collected by Weidemann and ourselves on separate boats anchored nearby. In addition, we used the siphon sampler to collect phytoplankton and microzooplankton samples from discrete depths for real-time video analysis and later counting by Jan Rines and Dian Gifford. After sampling near us for several hours, Alan Weidemann used his boat to collect a transect of optical and physical structure.

WORK COMPLETED

In addition to completing the three cruises described above, we completed a series of other efforts before the cruises. These are summarized below.

First, we completed the development of a technique for field calibration of spectral absorption and attenuation meters (WET Labs ac-9), and then applied this technique to quantifying the microscale distribution and dynamics of colored dissolved organic matter (CDOM). This work has been included in Mike Twardowski's Ph.D. thesis (Twardowski, 1998), and a paper on the calibration method is in press in the Journal of Oceanic and Atmospheric Technology (Twardowski, et al, in press). A paper on the spectral signature associated with the photobleaching of CDOM absorption was published in the extended abstracts for Ocean Optics 98 (Twardowski and Donaghay, 1998). Two additional papers have been prepared for submission. Following the completion of the method development (and its acceptance), we have used the revised methods to recalculate absorption data collected in 1995-7. This has greatly improved the accuracy of our estimates of microscale structure of absorption by dissolved substances and the absorption and scattering of particulate material.

Second, we completed a series of efforts designed to increase the visibility of the thin layers issue. We co-edited with Tim Cowles a special issue of Oceanography (fall, 1998). We co-authored the front piece to the issue (with Cowles) and co-authored a paper with Al Hanson that appeared in the issue (Hanson and Donaghay, 1998). We collaborated with Holliday in organizing a special session on thin layers at the 1998 AGU/ASLO Ocean Sciences meeting . We presented a paper at the session and were a co-author on several others. Finally, we have collaborated with Dian Gifford in organizing a thin layers special session for the 1999 ASLO meetings.

Third, we took the lead in a series of efforts needed to insure the success of the field experiment. These efforts included writing the original Thin Layers Program Plan with Van Holliday, and then revising it to reflect input from the other PI's. We also assisted in development of plans for the circulation experiment and the hyper-spectral overflights. Once the plans were finalized, we negotiated the contracts for the RV Henderson (the ship used as a floating lab), the Treker (used for deploying moorings by Holliday and us), and the Tyee Moon (our transect vessel). We also worked with Holliday to obtain a site for our shore station, and then installed the cables and breakers needed to power it. Prior to the experiment, we modified most of the components of our underwater winch profilers so that they could be powered and controlled from shore and provide real time data. During the experiment, we assisted in deployment and recovery of the moorings by Holliday (TAPS), Weidemann (ADCPs), and MacIntyre (thermister chains).

RESULTS

Although we are still too early in the process of analyzing our 1998 field data to draw conclusions about the questions asked, we are very excited by the results of the field experiment. First, and foremost, the underwater winches provided the time series of fine scale profiles of physical and optical structure that we will need to address our primary objectives. When combined with the ADCP data, the winch density data will allow us to calculate current shear and Richardson numbers and use the results to evaluate the effects of increases in current shear on patch dynamics. When combined with the transect data, the winch optical data will help quantify the temporal and spatial extent of thin layers. Likewise, when combined with the TAPS data, the winch optical data will help test the overlap of phytoplankton and zooplankton layers. We are looking forward to working with Holliday, Sullivan, Dekshenieks and Weidemann in analyzing this exciting data set.

The development and application of our technique for microscale profiling of absorption by dissolved substances ($a_g(\lambda)$) has provided important insights into the fine scale structure and dynamics of colored dissolved organic matter. First, accurate estimates of fine scale CDOM structure are dependent on careful application field calibrations, and making corrections for temperature, salinity and flow through the filter. Second, $a_g(\lambda)$ frequently shows considerable fine structure that cannot be directly related to salinity. In near surface waters, photo-oxidation reduces $a_g(\lambda)$ and changes the spectral slope over time. In deeper waters, $a_g(\lambda)$ appears to be quite conservative except in regions of high primary production associated with thin layers of phytoplankton. In such cases, $a_g(\lambda)$ values are elevated as might be expected if organic matter is released by rapidly photosynthesizing cells.

IMPACT/APPLICATIONS

One of the central paradigms in biological oceanography has been that small scale mixing processes in the upper ocean are sufficiently strong and equal in all directions that sub-meter scale biological, chemical and optical structures will be rapidly dispersed and thus can be ignored in both sampling and modeling upper ocean dynamics. Our field experiments clearly challenge the generality of this paradigm by demonstrating such features can persist for more than 24 hours and extend horizontally for kilometers. Our field results and theoretical analyses indicate that biological-physical, biological-chemical and biological-biological interactions occurring at these scales may control not only the development of blooms of toxic and/or bioluminescent phytoplankton, but also the extent to which zooplankton are able to exploit phytoplankton production. Equally importantly, our field observations indicate that the fine-scale biological layers can be sufficiently intense to alter optical and acoustical characteristics of these waters.

TRANSITIONS

An important component of our research has involved close collaboration both with industry and Navy labs. First we have collaborated with Ron Zaneveld (OSU) and Casey Moore (WET Labs) in the development and field testing of both new sensors and the protocols for calibrating them. These collaborations have accelerated the development of both the instruments and the calibration protocols essential to their use by the research community and the Navy. Second, we have collaborated with Navy scientists and engineers in incorporating these sensors and calibration protocols. For example, we have collaborated with Alan Weidemann (NRL) in transitioning the ac-9 calibration protocols and in field testing high spectral resolution sensors being developed for him at WET Labs.

RELATED PROJECTS

1. Van Holliday (Tracor) and I have worked very closely in planning and executing the 1998 Thin Layers experiment. We have merged our joint data sets from the 1986 experiment, and plan extensive data sharing and joint analyses of the 1998 experiment.

2. Margaret Dekshenieks (URI), Tom Osborn (JHU) and I are investigating physical forcing of thin layer dynamics using physical data collected in East Sound in 1996.
3. Margaret Dekshenieks (URI), Tom Osborn (JHU), Alan Weidemann (NRL), Don Johnson (NRL) and I are quantifying the circulation in East Sound and its response to physical forcing.
4. Jan. Rines (URI), Jim Sullivan (URI), and I are using a combination of lab experiments and field measurements to investigate the role of small-scale mixing processes in controlling the phytoplankton dynamics and the composition of thin layers.
5. Dian Gifford (URI) and I are examining the role of microzooplankton grazing in controlling thin layers of phytoplankton.
6. Alan Weidemann (NRL Stennis), Jan Rines (URI) and I are collaborating in the analysis of the optical, biological and physical data our groups collected during the summer 1998 East Sound experiment.
7. I collaborated with Curt Davis (NRL) this summer by collecting data on fine scale physical and optical structure during the hyper-spectral overflights in East Sound
8. Eileen Hoffman (ODU) is using physical and biological distribution and rate process data I collected during my tow tank experiments to test techniques for assimilating biological data into coupled bio-physical models.
9. I have collaborated with the other Thin Layer PIs in design and execution of the 1998 experiment in East Sound. I expect that these collaborations will increase as we analyze the data from the experiment.

REFERENCES

Hanson, A.K., Jr. and P.L. Donaghay, 1998. Micro to fine scale chemical gradients and layers in vertically stratified coastal waters. Oceanography, 11(7): 10-17.

Twardowski, M. S., J. M. Sullivan, P. L. Donaghay, and J.R.V. Zaneveld, in press. Micro scale quantification of the absorption by dissolved and particulate material in coastal waters with an ac-9. J. Atmos. Ocean. Tech.

Twardowski, M., and , P. L. Donaghay, 1998. The spectral signature associated with the photobleaching of cdom absorption. Extended abstracts, Ocean Optics 98.

PUBLICATIONS

Hanson, A.K., Jr. And P.L. Donaghay, 1998. Micro to fine scale chemical gradients and layers in vertically stratified coastal waters. Oceanography, 11(7): 10-17.

Twardowski, M. S., J. M. Sullivan, P. L. Donaghay, and J.R.V. Zaneveld, in press. Micro scale quantification of the absorption by dissolved and particulate material in coastal waters with an ac-9. J. Atmos. Ocean. Tech.

Twardowski, M., and , P. L. Donaghay, 1998. The spectral signature associated with the photobleaching of cdom absorption. Extended abstracts, Ocean Optics 98.

PRESENTATIONS

Donaghay, P. L., M.M. Dekshenieks, J.E.B. Rines, J.M. Sullivan, M.S. Twardowski, and D.V. Holliday. "Physical and biological control of the formation, maintenance and dissipation of thin phytoplankton layers in the pycnoclines of stratified coastal waters", EOS 79(1): OS175.

Dekshenieks, M.M., P.L. Donaghay, J.M. Sullivan, M.S. Twardowski, and J.E.B. Rines. "Spatial and temporal occurrence of thin phytoplankton layers in relation to environmental forcing", EOS 79(1): 176.

Twardowski, M.S., P.L. Donaghay, J.M. Sullivan, M.M. Dekshenieks, and J.E.B. Rines. "Finescale production of chromophoric DOM associated with a persistent phytoplankton thin layer", EOS 79(1): OS175.

Rines, J., J.M. Sullivan, P.L. Donaghay, M.M. Dekshenieks, and M.S. Twardowski, "Physical mixing processes and phytoplankton species composition of fine scale bio-optical structures in coastal waters" Abstracts, 1998 Ocean Sciences Meeting, EOS 79(1):OS147

Sullivan, J.M., J. Rines, E. Swift, and P.L. Donaghay, "The effects of small-scale turbulence on the growth of marine dinoflagellates", EOS 79(1):OS147

Merrell, J.R., D. Gifford, P.L. Donaghay, M.M. Dekshenieks, M.S. Twardowski, and J.M. Sullivan. Fine-scale vertical distribution of microplankton in thin layers, EOS 79(1): OS186.

Gifford, D.J., P.L. Donaghay and J.R. Merrell "Grazing by microzooplankton on thin layers of phytoplankton", EOS 79(1): OS186.

Hanson, A.K. Jr., and P.L. Donaghay "Micro to fine-scale chemical gradients and layers in stratified coastal waters, EOS 79(1): OS186.