

PLANKTON PATCH FEASIBILITY EXPERIMENTS

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LONG-TERM GOALS

The 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. This goal can most readily be achieved by directly measuring processes thought to control plankton patch dynamics, experimentally testing their importance, incorporating those processes into mechanistic plankton dynamics models, and then testing the models in the ocean.

OBJECTIVES

Specific objectives this year were (1) to complete development and testing of techniques for field calibration of spectral absorption and attenuation meters; (2) to complete development of the algorithms and programs for rapid post-processing high resolution CTD, current velocity, optical, and acoustical data and combining that data into a common file; (3) to post-process and begin to analyze the results of the 1996 East Sound cruises to identify small-scale physical-biological and biological-biological interactions that could control the initiation, maintenance and dispersion of thin plankton patches; (4) to continue development and testing the new hardware and software needed to facilitate the 4 dimensional sampling required for field testing patch models in the littoral zone; and (5) to continue development of the conceptual and numerical models that can be used to predict critical interactions, guide future experiments, and integrate the resulting biological and physical data.

APPROACH

Our approach has been to combine plankton patch experiments in the 1000 m long Langley tow tank with field observations in littoral marine systems suitable for testing model predictions. In the tank experiments, we initiate a plankton patch in the center section of a 1000 m long tow tank, manipulate vertical and horizontal physical structure to control flow fields along the tank axis, then follow the dispersal of physical and biological tracers of the patch. Mass balance and numerical models based on physical

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and biological data from these experiments are then used to test specific patch hypotheses and identify important physical-biological interactions. Whenever possible, predictions of the resulting models are then tested in the coastal waters by making observations before, during and after natural events (such as storms) in field systems that are sufficiently topographically constrained to allow collection of the required data. An important component of this work has been the development of new techniques for quantifying critical structures and processes in 4 dimensions over a wide range of scales. This approach is highly interdisciplinary and involves close collaboration with physical, chemical, optical and acoustical oceanographers.

WORK COMPLETED

Six tasks have been completed in FY97. First, we completed the development and testing of techniques for field calibration of spectral absorption and attenuation meters. This work has been key to quantifying the fine scale structure of phytoplankton and to using absorption by dissolved material as a water mass tracer. This work has been submitted for publication (Twardowski, et al.). Second, we have developed the algorithms and programs for rapid post-processing high resolution CTD, current velocity, optical, and acoustical data. This program incorporates all the calibration corrections and time lags, merges the data from the many sensors into a common file, then calculates critical derived parameters that incorporate data from one or more of the sensors. The data from our past cruises has been reprocessed using this new program. Third, we have begun to analyze the results of the 1996 East Sound cruises to identify small-scale physical-biological and biological-biological interactions that could control the initiation, maintenance and dispersion of thin plankton patches. This effort has been done jointly with Dr. Holliday at Tracor (our 2 data sets are completely merged and have been shared). We have also met with the other investigators involved in the 1996 cruise and have identified potential overlapping data sets and issues of joint interest. Fourth, we have continued to develop numerical and conceptual models that can be used to predict how physical-biological interactions can control plankton dynamics. These efforts have resulted in one paper in press (Donaghay and Osborn, 1997) and several presentations (Donaghay et al. 1997a,b). These models are being used to guide experiments and field efforts and integrate the resulting biological and physical data. Fifth, we have developed and tested new hardware and software designed to facilitate 4-dimensional sampling in the littoral zone. These new techniques provide us both with extensive real-time control of our bottom-up CTD/optics profilers and with the capability to operate one of them as an autonomous system with or without a data link. These capabilities are essential to planned field efforts. Sixth, we have completed enough laboratory experiments to demonstrate that small-scale mixing processes can directly affect plankton growth and mortality rates. This ongoing work has been presented at the ICES meeting in Baltimore (Sullivan, et al. 1997).

RESULTS

Although we are still in the process of analyzing our data, several conclusions are already evident. First, intense, thin plankton layers are a re-occurring phenomena in

coastal waters that have long gone undetected because of sampling problems. Application of new sensors and deployment techniques now allow their detection in a variety of coastal waters. Second, layers of phytoplankton, microzooplankton and macrozooplankton can be sufficiently intense to alter optical and acoustic properties of the water. Third, although these layers can be sufficiently intense to potentially influence trophic transfer processes, the direction of those effects are almost certainly dependent on the degree of co-occurrence and the behavioral responses when they co-occur. Fourth, current shear can play a critical role in the formation, maintenance and dissipation of thin plankton layers. These effects need to be measured and modeled in order to understand and predict layer dynamics in most coastal systems. Simultaneous measurement of plankton layers, currents, shear, and density gradients are essential to understanding layer dynamics.

IMPACT

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 tow tank and 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 Dr. Zaneveld(OSU) and Western Environmental Technology Laboratories (WET Labs) in the development and field testing of both new sensors and the protocols for calibrating them. For example, we have worked closely with WET Labs during the past year in (1) developing and testing the calibration protocols for the ac-9 spectral absorption and attenuation meter, (2) field testing of the HiStar spectral absorption meter, (3) development of a protocol for correcting SAFire spectral fluorescent data for UV absorption, and (4) testing the effectiveness of a new filter combination proposed by Dr. Perry (UW) for estimating photosynthetic activity. 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 provided an ac-9 to Dr. Levine at NUWC for incorporation in a large diameter underwater vehicle test. We also provided pre- and post-cruise recalibration, and at sea

ground-truth during field trials. In a separate case, we have collaborated with Dr. Weideman (NRL) both in transitioning the ac-9 calibration protocols and in field testing high spectral resolution sensors being developed for him at WET Labs. Third, I have collaborated with scientists at NUWV, NAV OCEANO and the industrial members of the URI Ocean Technology Center in developing an underwater winch system for deploying instruments and communication systems from the bottom-up in coastal waters. This work has also involved collaborating with WET Labs in developing a controller/data logger that could control the winches and record the resulting data. Finally, I have collaborated with Dr. Oeschger at NRL in testing and applying new acoustic techniques for measuring turbulence and particle trajectories.

RELATED PROJECTS

Collaboration with other investigators has become an increasingly important part of this project as it has moved toward field testing of models. First, I am continuing my long-term collaboration with Dr. Zaneveld(OSU) in developing and applying new optical sensors to quantifying the optical and biological structure of marine systems. This collaboration has been critical both to our efforts to understand fine scale biological structure and his efforts to quantify and understand optical structure. Second, continued collaboration with Dr. Hanson (URI) in interpreting the high resolution chemical profiles collected during our 1995 East Sound cruise has resulted in a paper on the control of iron II and nitrite fine structure (Hanson and Donaghay, 1997). Third, continued collaborations with Dr. Osborn (JHU) has resulted in a joint paper on bio-physical control of harmful algal blooms (Donaghay and Osborn, 1997). Fourth, I have started a joint ONR project with Dr. Rines (URI) on the role of small-scale mixing processes in controlling the dynamics of non-spheroid diatoms and a joint ONR project with Dr. Gifford (URI) on grazing control of thin phytoplankton layers. Fifth, I am collaborating with Dr. Holliday (Tracor) in his ONR supported measurement of fine scale zooplankton distributions and migration patterns. I am working closely with Dr. Holliday in interpreting the joint data set from both biological and acoustic perspectives. Sixth, I have begun to collaborate with Drs. Alldredge and MacIntyre in examining their East Sound data on the role of marine snow and small-scale mixing in controlling layer dynamics. Seventh, I have collaborated with Dr. Perry (UW) in testing a new technique for use of spectral fluorometers for in situ estimation of photosynthetic parameters. Finally, I am continuing to work with Dr. Katz in a NSF supported joint effort to develop a motion sensing holocamera for measuring particle characteristics and motions. Field tests of this instrument in East Sound have complemented and extended our ONR supported research at this site.

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