Fine-Scale Nutrient Gradients and Thin Plankton Layers in Coastal Waters

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LONG-TERM GOALS

The long-term goal is to understand the mechanistic role that transient chemical plumes and steep nutrient gradients play in the episodic formation and maintenance of productive, thin plankton layers in coastal waters. Thin plankton layers are patches of phytoplankton and zooplankton that range in thickness from a few centimeters to a few meters yet can extend horizontally for kilometers and persist for days. Recent work has shown that thin layers can be sufficiently intense and persistent to affect chemical and biological rate processes and the performance of current and planned Navy optical and acoustical sensors (Hanson and Donaghay, 1998, Dekshenieks et al., 2001). Thin plankton layers have also been shown to be associated with steep nutrient gradients and transient chemical plumes in stratified coastal waters (Hanson and Donaghay, 1998). However little is known about the mechanistic roles that chemical gradients play in the episodic formation and maintenance of productive, thin plankton layers in coastal waters. What are the critical temporal and spatial scales for the interaction of chemical gradients and such plankton patchiness? We need high-resolution observational and experimental data that will help elucidate the role of nutrients in the dynamics of thin plankton layers and contribute to the development of a predictive model for thin plankton layer formation, maintenance and decay in coastal waters. Our longer-term goals include:

1. Continuing to develop and demonstrate a technological capability for autonomous, real-time, *in situ*, fine-scale nutrient profiling.
2. To acquire the high-resolution, spatial and temporal, nutrient data needed for the development and testing of predictive models for the role of nutrients in thin plankton layer occurrence and dynamics in a coastal environment.

OBJECTIVES

The objectives for the FY 2003 effort were to increase our technological capabilities to determine the chemical mechanisms influencing the dynamics and impacts of thin plankton layers. Specific scientific objectives included:

1. Participation in a thin layers field investigation at a coastal site selected by Donaghay, Holliday, and Dekshenieks as part of their ONR thin layers field site evaluation study.
2. To utilize submersible chemical analyzers to document the changes in fine-scale nutrient distributions associated with episodic physical/biological events at that site.

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3. To document and evaluate the influence of steep nutrient gradients on the biological and optical properties of thin plankton layers.

APPROACH

We will participate in experimental studies at coastal sites where thin layers are believed to be recurrent phenomena. These experiments will be done in collaboration with Percy Donaghay, Margaret McManus, Van Holliday, and Jan Rines. We will assist with the deployment of an array of profilers at the coastal site. Within this array we will help Donaghay and co-workers deploy ORCAS IOPC profilers that include a SubChem Systems Autonomous Profiling Nutrient Analyzer (APNA). The APNA will be configured to measure nitrate, nitrite, and iron. The nutrient data will be relayed by telemetry in real time from the array of profilers, shared with the other PIs and used to guide ship-based sampling. The chemical analyzers on the array will be serviced as required during the field experiment. Time series data from this array will allow us to quantify the temporal/spatial variability of steep nutrient gradients and plumes over a long enough period to define their critical role for thin plankton layer formation, maintenance and dissipation at an open coastal site.

We will also use a boat-deployed vertical profiling package that has SubChem Analyzers configured for the determination of nitrite, nitrate, ammonia, phosphate, silicate and iron. The boat-deployed vertical profiling package will have a water sampling system designed for the rapid collection of water samples from multiple discrete depths, with 10 cm scale resolution. These comparative water samples will be used to validate the analytical accuracy and vertical depth resolution of the ship-deployed SubChem Analyzers and IOPC-deployed Autonomous Profiling Nutrient Analyzers.

WORK COMPLETED

During the past year we accomplished a number of important tasks, which have both enhanced and demonstrated our ability to utilize submersible chemical analyzers to obtain high-resolution multi-nutrient vertical profiles in real time. We are testing and utilizing a new class of submersible chemical analyzers for this work that have been developed during the past seven years by SubChem Systems, Inc. with ONR, NOPP, and NOAA funding. These submersible chemical analyzers (Table 1) can be selectively configured to continuously and simultaneously measure the following dissolved inorganic nutrients NO2, NO3, PO4, Si(OH)4, Fe, and NH3.

Table 1. Submersible chemical analyzers available from SubChem Systems for use in this research.

SubChem Analyzers	# Units	# Channels	Cabled or Remote	Deployment modes & platforms
Autonomous Profiling Nutrient Analyzer (APNA)	2	4	both	ORCAS Array IOPC profiler Vertical and towed profilers
REMUS Chemical Analyzer	1	4	remote	REMUS AUV
SubChemPak Analyzer	1	4	cabled	Vertical and towed profilers
SubChemPak NH3 Analyzer	1	2	cabled	Vertical and towed profilers

The work completed during FY2003 involved the continued development and testing of the Autonomous Profiling Nutrient Analyzer (APNA) that was developed with NOPP funding for deployment on the ORCAS IOPC profiler. The two APNA instruments are presently configured for the simultaneous determination of dissolved nitrate, nitrite and iron. A third instrument, a modified APNA, has also been successfully deployed on the REMUS AUV on multiple occasions for the determination of dissolved nitrite and iron. When an appropriate thin layers site is identified, we will collaborate with Percy Donaghay and co-workers to deploy the APNA on the ORCAS IOPC profiler at the chosen location. We expect this APNA-IOPC field test will be conducted during May-June 2004.

We have also successfully developed and demonstrated new *in situ* instrumentation and methodologies for obtaining real-time high resolution vertical profiles for two additional nutrients: phosphate and ammonia. Whereas the phosphate method uses spectrophotometric detection, the ammonia detection is fluorometric. These new profiling analytical capabilities were demonstrated during two field expeditions conducted during 2003. The first field expedition was a research cruise along the southern California coastline aboard the R/V Pt. Sur in collaboration with Ken Bruland (UCSC). The experimental plan involved both surface horizontal and vertical profiling for nutrients (nitrate, nitrite, phosphate, and ammonium) from the ship. The second field expedition was conducted in collaboration with Percy Donaghay and Van Holliday during May 2003 at a coastal site off Santa Barbara. We collected a four-day time series of high-resolution vertical nutrient profiles (nitrate, nitrite, ammonia, phosphate and iron) from a small boat using Donaghay's vertical profiling package with SubChemPak Analyzers (Figure1) while an array of two IOP profilers and TAPS were operational in the area.

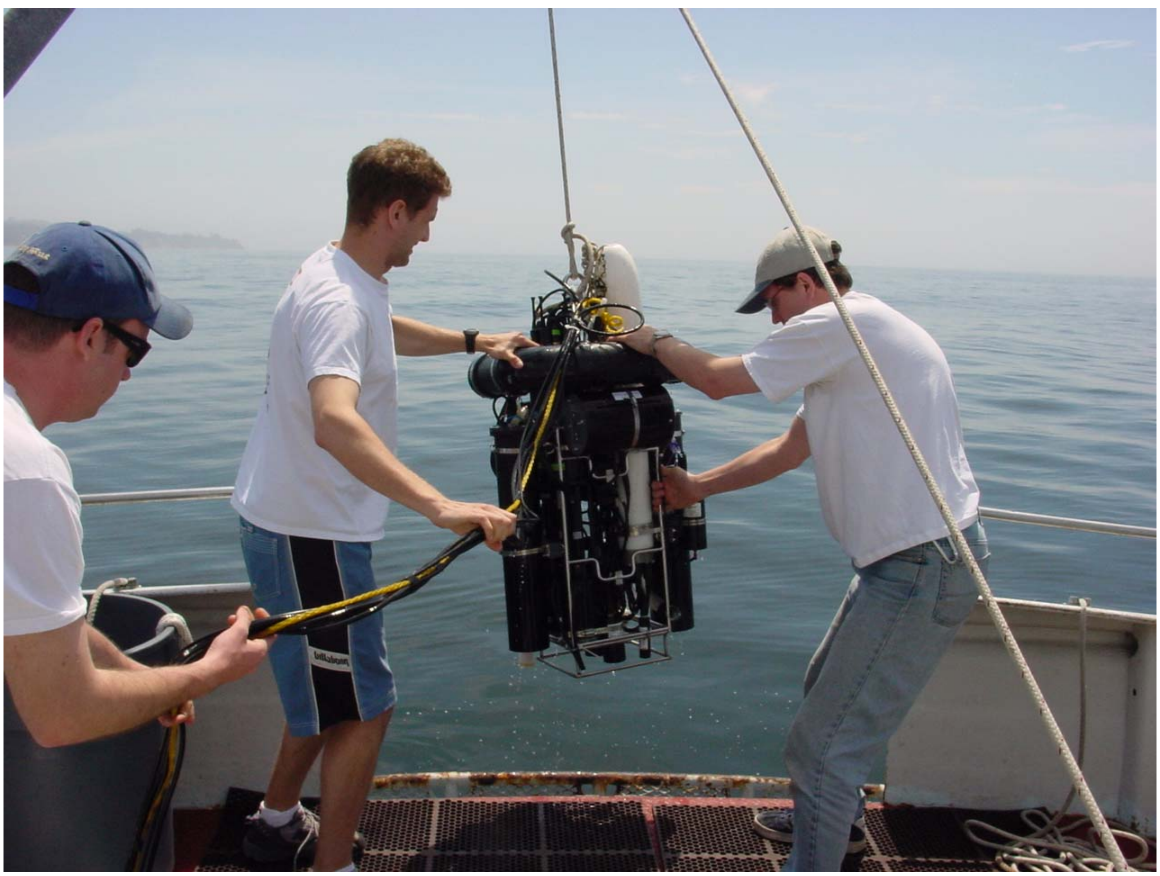

Figure 1. High resolution vertical profiling package being deployed from the stern of a small boat off Santa Barbara, CA in May 2003. The profiling package included a CTD-O2, sensors for spectral IOP and two SubChemPak Analyzers configured for the determination of dissolved nitrate, nitrite, phosphate, iron and ammonia.

RESULTS

The development of the *in situ* ammonia and phosphate methodologies represent a substantial advance in our real-time profiling capabilities. During this time period WET Labs, Inc. also developed a miniature dual-channel fluorometer that can be configured as an ammonia detector for the SubChemPak Analyzer and APNA instrumentation.

The field research conducted off the coast of Santa Barbara, CA developed into an interesting experimental observation of a major episodic event. During the course of a three day time period we documented dramatic changes in vertical nutrient distributions (nitrate, nitrite, ammonia, phosphate and iron) that were correlated with significant changes in optical clarity, phytoplankton biomass and dissolved oxygen levels. Some of the vertical profiles collected that depict these rapid changes are shown graphically in Figure 2. During a two-day time period water clarity went from very clear to turbid as the phytoplankton biomass increased substantially (>10X). Nutrient levels progressively decreased and oxygen levels increased over the three-day time period, in response to the dramatic changes in phytoplankton biomass. Although fine-scale nutrient gradients were detected and documented with the high-resolution chemical profiling system, distinct thin plankton layers did not develop during the time period of observation. We are collaborating with Donaghay and Holliday to analyze and interpret the data from this field experiment and to develop a theory to explain the observations.

IMPACT/APPLICATIONS

This on-going research is giving us the opportunity to continue to improve our autonomous chemical profiling technologies and allow us to continue our investigations of chemical plume and thin plankton layer dynamics. We are obtaining important data on how fine-scale chemical gradients and nutrient plumes may vary in an open coastal system and influence plankton patchiness. The data collected will eventually contribute towards the development of a predictive model for the role of nutrients in thin plankton layer formation and productivity in coastal waters.

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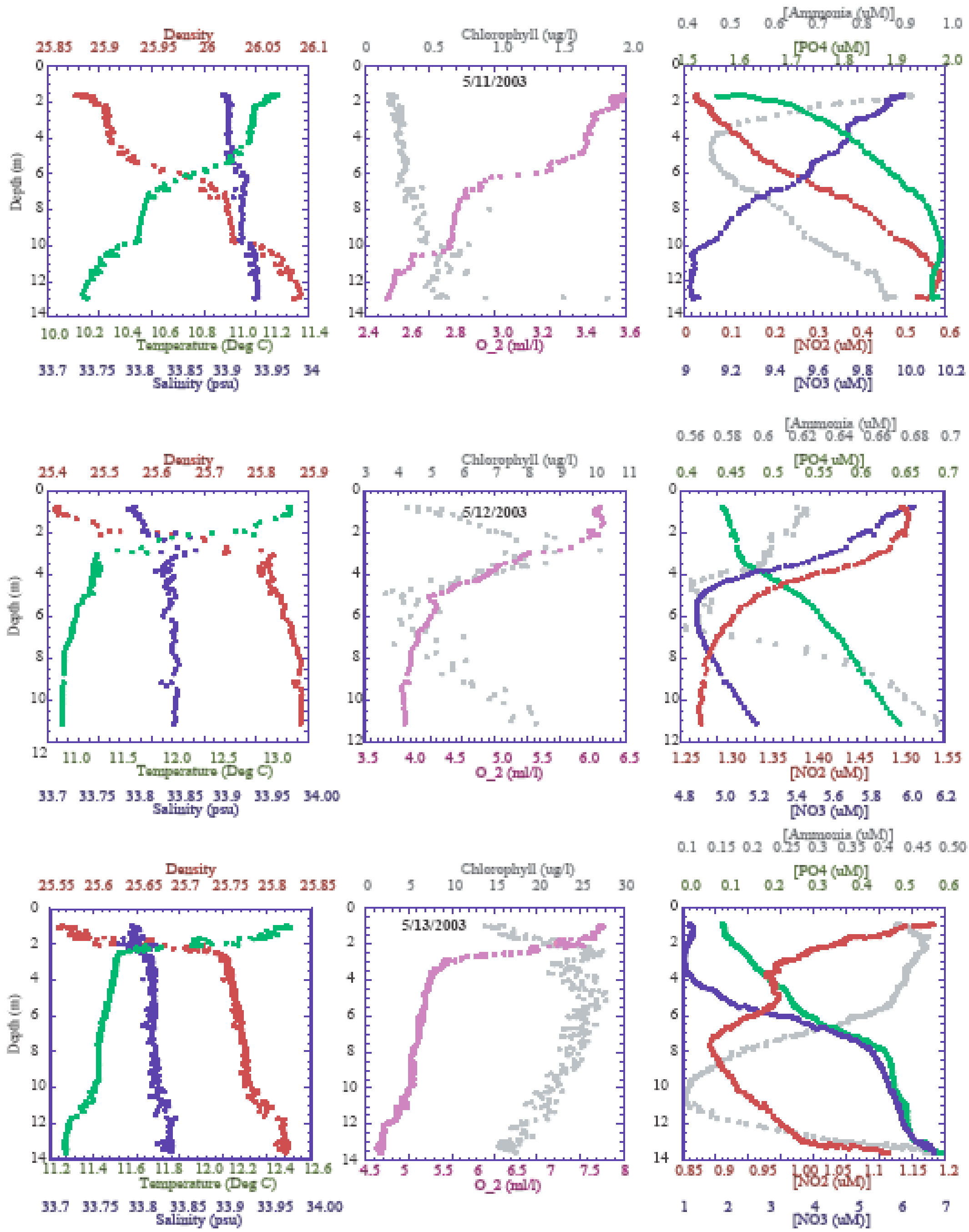

Figure 2. Time series of selected high resolution vertical profiles for salinity, temperature, density, oxygen, chlorophyll, and the nutrients; nitrate, nitrite, ammonia and phosphate collected off Santa Barbara California on May 11 (top), May 12 (middle) and May 13 (bottom) 2003.