The Role of Nutrients in the Formation, Maintenance, and Transformation of Phytoplankton Thin Layers

Robert H. Byrne
College of Marine Science, University of South Florida
140 Seventh Avenue South, St. Petersburg, FL 33701
phone: (727) 553-1508 fax: (727) 553-1189 email: byrne@marine.usf.edu

Eric Kaltenbacher
Center for Ocean Technology, University of South Florida
140 Seventh Avenue South, St. Petersburg, FL 33701
phone (727) 553-3959 fax: (727) 553-3967 email: eak@marine.usf.edu

Grant Number: N00014-02-1-0823

LONG-TERM GOALS

This project is a collaboration between Dr. Robert Byrne, University of South Florida, and Dr. Mary Jane Perry, University of Maine. Our long-term objective is to better understand the mechanisms involved in the development, maintenance, and transformation of optically-active, thin layers. Because nutrients play an important role in regulating phytoplankton growth and in maintaining phytoplankton thin layers, our specific goals are to determine how phytoplankton photosynthetic physiology responds to small changes in nutrient flux, how nutrient flux regulates thin layer dynamics, and how changes in pH can be used to infer the net trophic status of a thin layer.

OBJECTIVES

Our research seeks to address how the combination of high-resolution measurement of nutrient concentrations, pH, photosynthetically active radiation (PAR), phytoplankton fluorescence, and scattering can be used to study the physiology of the planktonic community in a specific layer. The objective is to better understand how phytoplankton physiology changes as thin layers grow and dissipate. The specific objective of the University of South Florida's component during the past year was continued development and testing of Spectrophotometric Elemental Analysis Systems (SEAS) for autonomous pH and nutrient measurements, with the long-range objective of incorporating a suite of SEAS sensors into an autonomous Slow Descent Profiler to study thin layers and their associated nutrient fluxes in the field. The specific objective of the University of Maine's component was the measurement and interpretation of pH measurements, with the long-range objective of using high-resolution chemical and optical profiles to assess the biochemical status of a phytoplankton thin layer and to determine if the phytoplankton in a layer are waxing or waning.

APPROACH

Our approach is to combine new, miniaturized optical and chemical sensors that are capable of sampling on the critical space and time scales relevant to the formation and maintenance of optical thin layers. The laboratory at the University of South Florida has the capability to measure phytoplankton nitrogenous nutrient concentrations with nanomolar resolution (Byrne et al., 2000) and pH with 4 ten

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**

4. TITLE AND SUBTITLE **The Role of Nutrients in the Formation, Maintenance, and Transformation of Phytoplankton Thin Layers**	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) **College of Marine Science, University of South Florida,,140 Seventh Avenue South,,St. Petersburg,,FL,33701**	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

14. ABSTRACT
This project is a collaboration between Dr. Robert Byrne, University of South Florida, and Dr. Mary Jane Perry, University of Maine. Our long-term objective is to better understand the mechanisms involved in the development, maintenance, and transformation of optically-active, thin layers. Because nutrients play an important role in regulating phytoplankton growth and in maintaining phytoplankton thin layers, our specific goals are to determine how phytoplankton photosynthetic physiology responds to small changes in nutrient flux, how nutrient flux regulates thin layer dynamics, and how changes in pH can be used to infer the net trophic status of a thin layer.

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

thousandths of a pH unit resolution (Clayton and Byrne, 1993). Additionally, the University of South Florida has developed a capability for *in-situ* measurement of total inorganic carbon (Byrne et al., 2002). The *in-situ* SEAS-pH system developed at USF will be tested at very slow profiling rates in Tampa Bay and in the Gulf of Mexico. For this purpose the University of South Florida will develop a slow descent package for use with the *in-situ* pH and nutrient SEAS systems. We expect to begin this development in November of 2003. The laboratory at the University of Maine has the capability to measure fluorescence and other optical changes associated with photosynthetic physiology and cell growth, as well as the capability to measure 14C-carbon incorporation at 5 dpm above background. Our initial approach has involved use of a suite of chemical and optical measurements in controlled environmental chambers to observe both axenic cultures of phytoplankton and freshly-collected seawater from the Damariscotta River Estuary that contains natural assemblages of phytoplankton, bacteria, protozoan grazers, and individual crustacean zooplankton.

WORK COMPLETED

Developmental work at University of South Florida in the past year has considerably improved the performance of the SEAS-pH sensor. The accuracy of the *in-situ SEAS-pH* sensor is equivalent to that which has been obtained in the laboratory (Clayton and Byrne, 1993; Clayton et al., 1995) using state of the art procedures developed at University of South Florida. Importantly, measurements can be obtained with a frequency of approximately 1 Hz. The SEAS-pH sensor is currently being tested to depths on the order of 250 m in the Central Pacific Ocean. Growth and respiration experiments at the University of Maine have demonstrated that pH is measurably altered by phytoplankton photosynthesis and respiration in light/dark cycles on a diurnal time scale. The ability to see repeatable changes in pH, consistent with photosynthesis (increased pH) and respiration (decreased pH), for phytoplankton concentrations on the order of 3 – 4 mg chlorophyll *a* m^{-3} suggest that measurements of pH in thin layers will provide considerable insight into their net growth rates. For measurements with bacteria and zooplankton, the pH consistently decreases due to respiration.

RESULTS

The expected outcomes of the proposed work will be better understanding of phytoplankton physiology at low nutrient concentrations, better tools to study the dynamics of phytoplankton thin layers, and finer scale observations of optical and chemical changes in thin layers.

Figures 1 and 2 show the changes in pH and chlorophyll for samples collected from the Damariscotta River Estuary, Maine, and incubated at ambient temperature (17^{o}C) for 24 hours. Initial chlorophyll concentration was 2.97 mg m^{-3}. Estuarine samples were collected in the morning and incubated for 24 hours in the dark (blue) or light (yellow). Please note that the cold room lights were turned off at 2000; hence, photosynthesis in the "light" samples ceased at night. Controls (pink) were filtered upon collection and incubated in the dark. Each measurement was made in quadruplicate; error bars are plotted but are difficult to see (very small error). Figure 1 demonstrates that we are able to see very small changes in pH and that the trends in pH over the 24-hour period are consistent with our predictions: i.e., that pH increases during the day for a photosynthesizing system and that pH decreases in a system dominated by heterotrophic processes (the sample kept in the dark for 24 hours). Because the pH of the "light" sample exhibited a net increase over the 24-hour period, we conclude that this sample from the Damariscotta Estuary was net autotrophic. The chlorophyll concentration at the end of the 24-hour incubation was 6.64 mg m^{-3}, confirming that the net growth of phytoplankton in the sample was indeed positive (Figure 2).

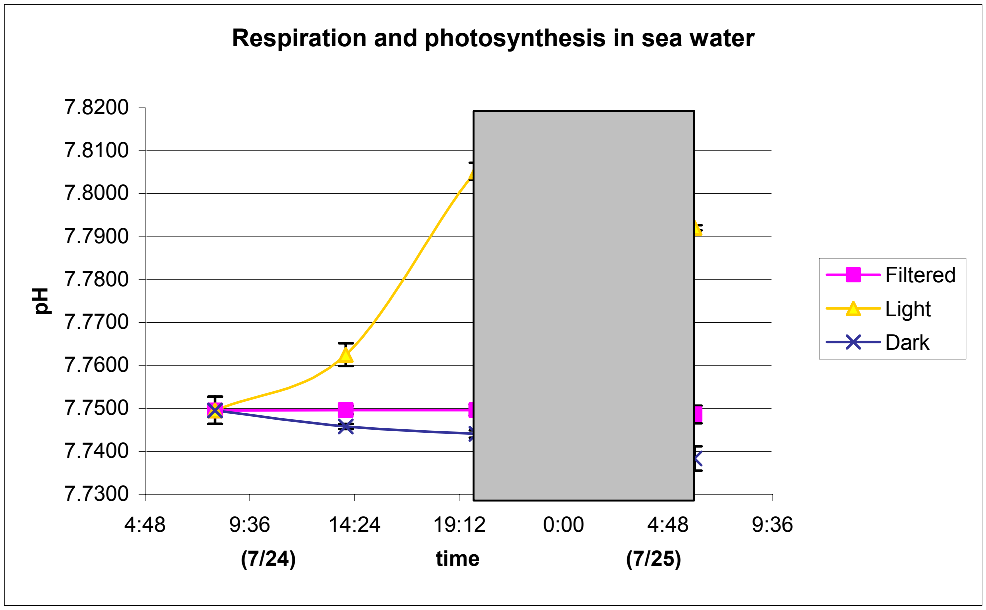

Figure 1: Changes in pH induced by phytoplankton photosynthesis and respiration are shown in light/dark experiments.
[Photosynthesis produces easily observable increases in pH (Light). In the absence of light, respiration lowers the pH (Dark), and very little pH change is observed in the absence of phytoplankton (Filtered).]

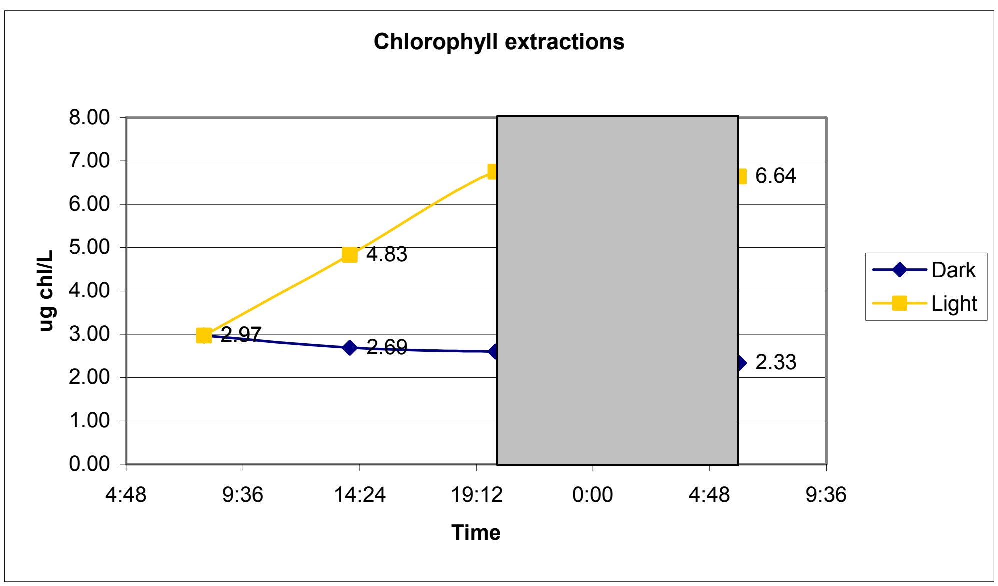

Figure 2: Phytoplankton chlorophyll content corresponding to the light/dark experiments shown in Figure 1.
[Chlorophyll content markedly increases during photosynthesis and slowly declines during respiration.]

Figure 3 highlights pH data obtained from a research cruise onboard the NOAA vessel Ka'imimoana in the Central Pacific Ocean. These in-situ data were obtained during a deployment of University of South Florida's SEAS instrument on September 3, 2003. SEAS was configured to measure pH every 4s and was lowered at a rate of 6 meters per minute. This gives a spatial resolution of approximately 0.4 meters. During the downcast, a strong current (measured by the ship's ADCPs) was present between 80 and 100 meters. Data from the SEAS instrument clearly show the effect of the current moving the instrument away from the ship causing SEAS to rise in the water column.

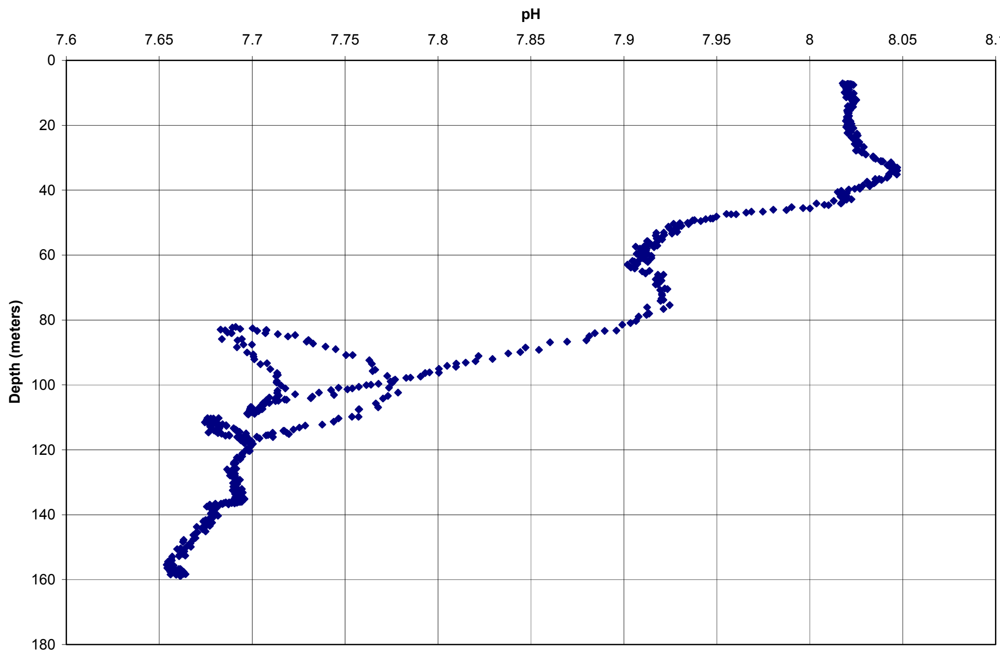

Figure 3: A plot of in-situ pH measured using USF's SEAS-pH instrument on September 3, 2003 in the Central Pacific Ocean (125° W, 2° N).
[This graph shows in-situ pH data measured in the Central Pacific Ocean by USF's SEAS instrument. The pH value is nearly constant at 8.02 between the surface and 40 meters deep. Below 40 meters, the pH decreases sharply to a value of 7.65 at a depth of 160 meters.]

IMPACT/APPLICATIONS

Two major impediments to modeling the formation, maintenance, and demise of phytoplankton thin layers have been a lack of nutrient measurement in thin layers and a poor understanding of the short-term physiological responses of phytoplankton to nutrient fluxes. New sensors that provide high-resolution measurement of nutrient concentrations *in situ*, as well as recent improvements in optical approaches for determining phytoplankton physiological responses, will both aid in removing those impediments. By applying new chemical and optical sensors to the study of thin layer dynamics, we can substantially improve our understanding of phytoplankton growth in thin layers as nutrients become exhausted.

RELATED PROJECTS

This project is coordinated with N00014-02-1-0824 under the direction of Dr. Mary Jane Perry at the University of Maine.

REFERENCES

Byrne, R.H., Liu, X., Kaltenbacher, E.A. and Karen Sell (2002) Spectrophotometric Measurements of Total Inorganic Carbon in Aqueous Solutions Using a Liquid Core Waveguide. *Analytica Chimica Acta,* 451: 221-229. [refereed]

Byrne, R.H., Yao, W., Kaltenbacher, E. and Waterbury, R.D. (2000) Construction of a Compact Spectrophotometer/Spectrofluorometer Using a Flexible Liquid Core Waveguide. *Talanta*, 50:1307-1312. [refereed]

Clayton, T.D. and Byrne, R.H. (1993) Spectrophotometric seawater pH measurements: Total Hydrogen Ion Concentration Scale Calibration of m-cresol Purple and At-Sea Results. *Deep-Sea Research 40*:2115-2129. [refereed]

Clayton, T.D., Byrne, R.H., Breland J.A., Feely, R.A., Millero, F.J., Campbell, D.M., Murphy, P.R. and Lamb, M.F. (1995) The Role of pH Measurements in Modern Oceanic CO2 System Characterizations: Precision and Thermodynamic Consistency. *Deep-Sea Research* 42: 411-429. [refereed]

PUBLICATIONS

Due to the recent start date, no publications are directly attributable to this project at this time.