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US GLOBEC NWA/Georges Bank: Processes Controlling Abundance of Dominant Copepods on Georges Bank: Local Dynamics and Large-scale Forcing

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Principal Investigator: Townsend, David W. **Award ID:** 0606612

Organization: University of Maine

Submitted By:

Townsend, David - Principal Investigator

Title:

US GLOBEC NWA/Georges Bank: Processes Controlling Abundance of Dominant Copepods on Georges Bank: Local Dynamics and Large-scale Forcing

Project Participants

Senior Personnel

Name: Townsend, David

Worked for more than 160 Hours: Yes

Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

University of Rhode Island Graduate School of Oceanography

Dr. Ted Durbin

University of Massachusetts, Dartmouth

Dr. Changshen Chen

Woods Hole Oceanographic Institution

Drs. Cabell Davis, Rubao Ji and Robert Beardsley

SUNY at Stony Brook

Dr. Charles Flagg

University of New Hampshire

Dr. Jeffrey Runge

Other Collaborators or Contacts

Colleagues involved in the NOAA/ECOHAB Program-sponsored project: GOMTOX, from Woods Hole Oceanographic Institution

Activities and Findings

Research and Education Activities:
Included in Findings attached file.

Findings: (See PDF version submitted by PI at the end of the report)
In attached file.

Training and Development:
One University of Maine Ph.D. Graduate Student, Mr. Nathan Rebuck, is focusing his Ph.D. Dissertation on the topic of Variability in Water Masses, Nutrients and Biological Productivity in the Gulf of Maine Region, and as such, he is working with me on this project.

Costs for Rebuck's University of Maine assistantship and tuition are being covered by other funding sources.

Outreach Activities:
I have presented portions of these findings at annual workshops of scientists, fishermen and managers, at the Marine Education and Research Program, headed up at the Gulf of Maine Research Institute and funded by NOAA, where I present a morning-long session on the oceanography of the Gulf of Maine and Georges Bank.

Journal Publications

Books or Other One-time Publications

Web/Internet Site

URL(s):
http://grampus.umeoce.maine.edu/nutrients/
Description:
This is where we are serving the main result of this work: A Nutrient Database for the Gulf of Maine and Georges Bank

Other Specific Products

Contributions

Contributions within Discipline:
Results of research funded in part by this grant have been extended to other research programs;
1. the ECOHAB GOMTOX (Gulf of Maine Toxicity) Program which has detected populations of the PSP-causing dinoflagellate, Alexandrium, on Georges Bank (D.M. Anderson, WHOI, et al.)
2. the currently funded NSF grant led by Rubao Ji (WHOI) on Modelling Spring Plankton Blooms in the Gulf of Maine.

Results of this work have led to the submission of an NSF grant to study the effects of Arctic melting on the nutrient regime in the Gulf of Maine.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

This study is forming the basis for one Ph.D. Dissertation at the University of Maine (at no additional cost to grant).

Contributions to Resources for Research and Education:

The nutrient database has been made available to other researchers in the region (and is currently on the web).

Contributions Beyond Science and Engineering:

Conference Proceedings

Categories for which nothing is reported:

Any Journal

Any Book

Any Product

Contributions: To Any Other Disciplines

Contributions: To Any Beyond Science and Engineering

Any Conference

Final Project Report

Project Title: US GLOBEC NWA/Georges Bank: Processes Controlling Abundance of Dominant Copepods on Georges Bank: Local Dynamics and Large-scale Forcing

Principle Investiogator: David W. Townsend

Awardee: University of Maine

Award Number: 0606612

Expiration Date: 04/30/2009

Project summary

This project was a modeling study of the biological oceanography of Georges Bank that was specifically targeted toward understanding the dominant processes that control abundances and population dynamics of herbivorous copepods.

The modeling team was led by Cabel Davis (Woods Hole Oceanographic Institution) and included: Rubao Ji and Robert Beardsley (WHOI), Edward (Ted) Durbin (URI), Charles Flagg (Stony Brook Univ.), Changshen Chen (UMass Dartmouth) and Jeffrey Runge and myself (UMaine).

My role on this team of specialists was to encompass two areas of inquiry, each of which dealt with data input to *(i)* the formulation of biological models, as well as working with the biological modeling team members (Davis, Ji, Durbin and Runge) in coupling the dynamics of the zooplankton to nutrient and phytoplankton dynamics, and *(ii)* the physical oceanographic models and working with the physical oceanographic team members (Beardsley, Flagg and Chen) to model nutrient fluxes.

My Ph.D. graduate student (Mr. Nathan D. Rebuck), while supported with University of Maine funding, was instrumental in meeting our project goals, which were:

1. Locate and compile all data on dissolved inorganic nutrients collected in the Georges Bank – Gulf of Maine region, for use in setting initial conditions in driving a lower trophic level plankton ecosystem simulation model.

2. Provide data on nutrient concentrations and distributions associated with the various water masses and water types that contribute to primary productivity of the Gulf of Maine and Georges Bank region, locally and, especially, upstream in order to interpret NAO-related interannual variability.

Activities:

Specific activities to date for this project included:

1. Attendance at Principal Investigator Workshop in Woods Hole, MA (October 29, 2007), and three informal PI meetings, also in Woods Hole, in November, 2007 and January and June of 2008.

2. Compilation, refinement, and analysis of a new nutrient database for the Gulf of Maine – Georges Bank region.

3. Posting of a Nutrient Database for the Gulf of Maine on the web.

The Georges Bank – Gulf of Maine Nutrient Database:

The data archive that we have assembled for the Gulf of Maine region is available online at *http://grampus.umeoce.maine.edu/nutrients/*. The subset of data assembled for purposes of this project includes all data from the region defined as 40°N to 45.5°N and 71°W to 65°W, as shown in Figure 1, with sample station locations color coded for the year of collection. It is intended as a macronutrient (inorganic nitrogen, phosphate, and

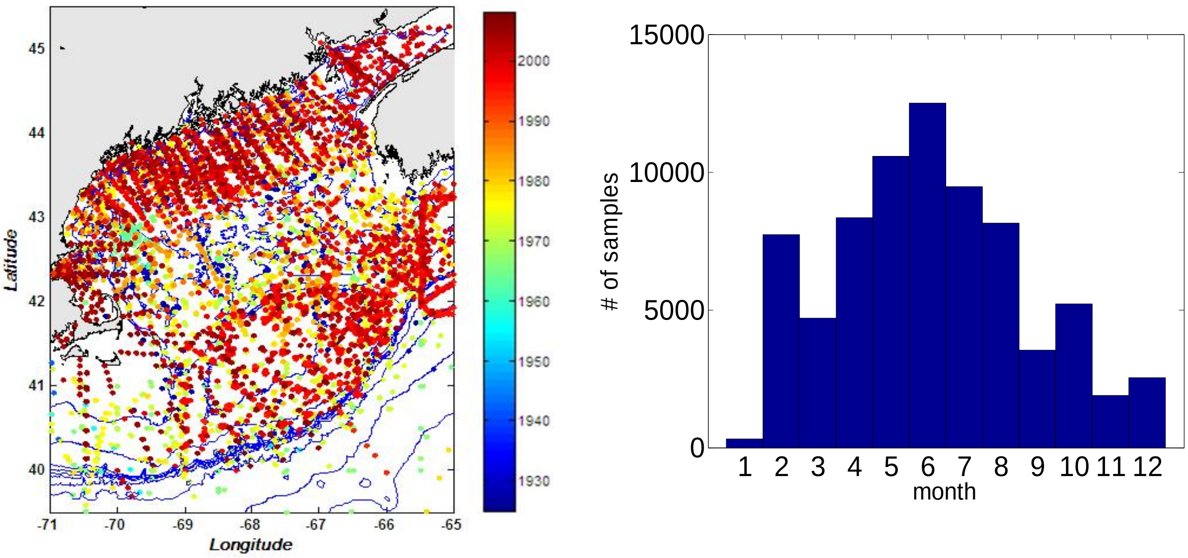

Figure 1. Station locations for nutrient data, with corresponding temperature and salinity, for the Gulf of Maine region, colored by year of collection, and bar graph of month of collection for samples shown in map.

silicate) dataset, but temperature and salinity are also included, and were necessary variables for inclusion. The archive is a combination of publicly available data and more recent unreleased data. The majority of data in the Gulf of Maine archive comes from two public sources: the World Ocean Database (WOD; *http://www.nodc.noaa.gov*) maintained at the National Oceanographic Data Center, and data assembled at the Marine Environmental Science Division at the Bedford Institute of Oceanography and the Marine Environmental Data Service in Ottawa, both a part of the Department of Fisheries and

Oceans Canada (http://www.dfo-mpo.gc.ca/science/data-donnees/subjects-sujets-eng.asp?sub=nutri).

The two public sources were supplemented with additional data that have remained in provisional or unreleased status. Much of the new and unreleased data come from samples collected by our group at the University of Maine (DWT). In addition, recently acquired data were provided by the GOMTOX Program (Dynamics of *Alexandrium fundyense* distributions in the Gulf of Maine; http://www.whoi.edu/gomtox/), the Atlantic Zone Monitoring Program (AZMP; http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/azmp-pmza/index-eng.html), the University of New Hampshire Coastal Ocean Observing Center (UNH-COOA; http://www.cooa.unh.edu/index.jsp), data collected on recent survey cruises by D. McGillicuddy at the Woods Hole Oceanographic Institute (WHOI), the Massachusetts Water Resource Authority (MWRA), and the Marine Monitoring and Assessment Program at the Northeast Fisheries Science Center of NOAA (MARMAP). The number of contributions from each source to the Gulf of Maine archive is given in Table 1. Data Quality Control and Quality Assurance techniques that have been applied are described in detail on the above referenced website.

Table 1. Number of samples and dates of collection for component datasets aggregated into the Gulf of Maine dataset (Fig. 1) that contain matching observations of temperature, salinity, nitrate, and silicate. Subset names and sources are described on the referenced website.

Data Source	Number of Samples	Period
WOD	8,348	1961-2003
Petrie	9,027	1969-2005
DWT	11,216	1998-2007
MWRA	29,673	1992-2008
WHOI	6,299	2003-2006
MarMAP	3,500	1969-1981
GoMTox	5,532	2007-2008
GlobEC	3,428	1997-1999
UNHCOOA	815	2004-2007
AZMP	636	1999-2005
Total	**78,474**	**1961-2008**

Analyses:

A scatter plot of nutrient data in Figure 1 (nitrate plus nitrite versus phosphate) reveal several clusters of points, as shown in Figure 2. In Figure 3 we have isolated the exceptionally low N:P ratio data from Figure 1 (blue data points) and compared them with station location, depth of collection and corresponding salinity. That analysis

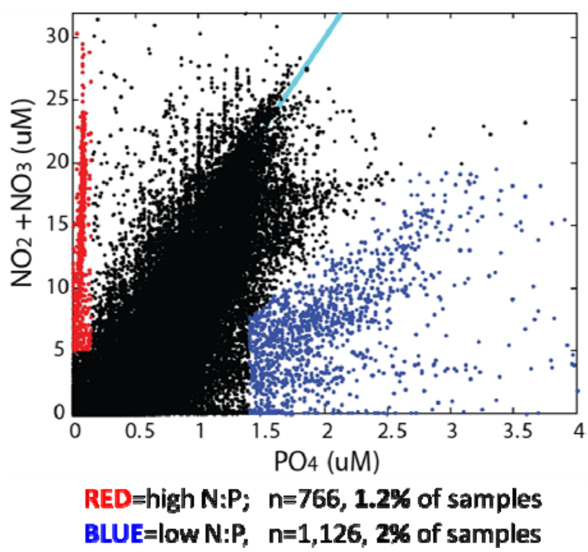

Figure 2. Scatter of plot of Nitrate plus Nitrite versus Phosphate for Georges Bank. The Redfield Ratio line (16:1) is given.

indicates that those samples were from near-surface depths and coastal (but not estuarine) salinities, and were clustered about a set of stations confined to the western coastal Gulf of Maine. We believe that those data represent waters depleted in DIN relative to P, in that P is recycled faster that N, which in those waters, has been lost via vertical particulate fluxes out of the water column. As such, we would expect the cluster of stations to be in the western Gulf, downstream in a productive coastal current system.

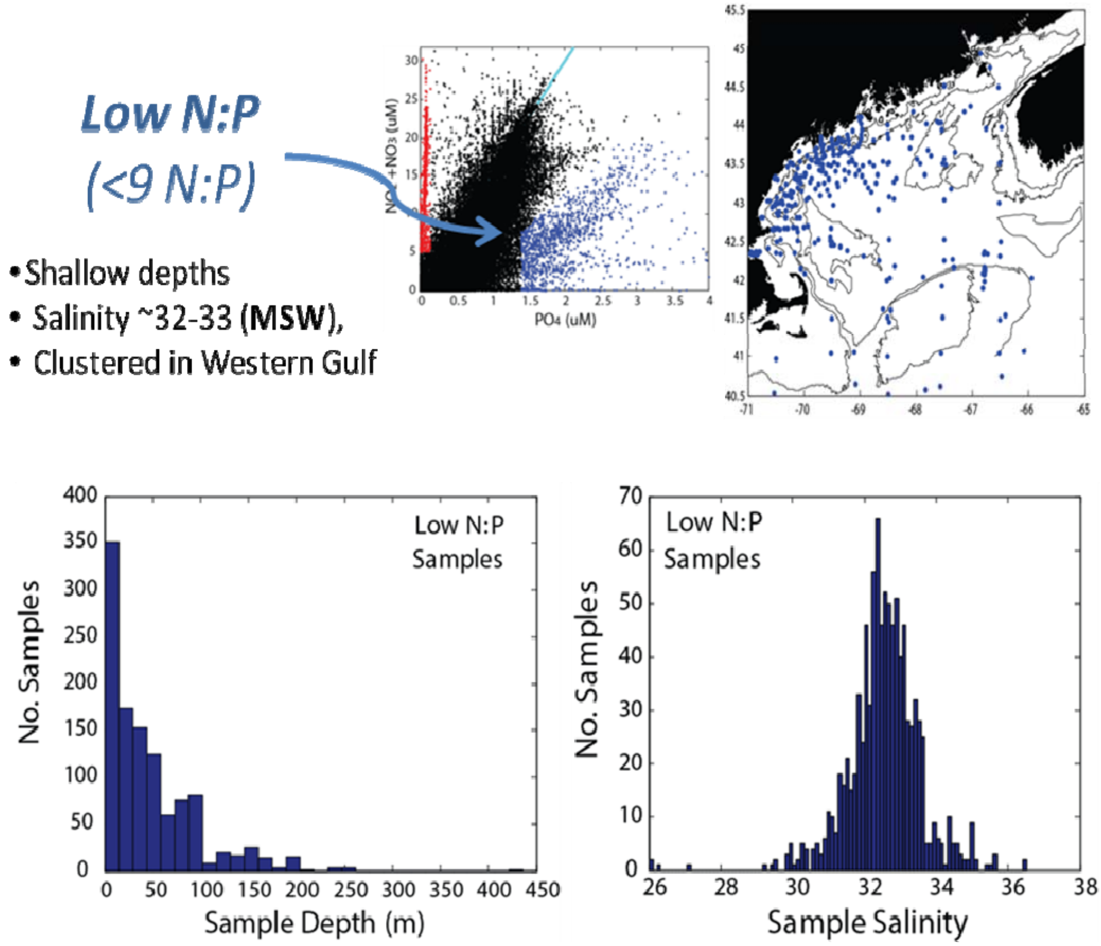

Figure 3. Geographic locations, depths and corresponding salinities of the exceptionally low N:P data (blue data points from Figure 2).

The exceptionally low N:P-ratio stations in Figure 3, we should point out, do not reflect low salinity waters from Maine rivers, as indicated in Figure 4, which is an analysis of the nutrient loads and N:P ratios of waters in two of Maine's largest rivers, both of which empty into the western Gulf of Maine.

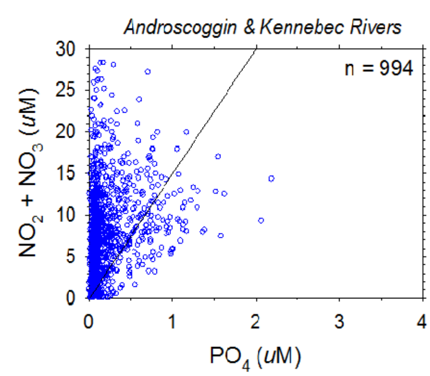

Figure 4. Pot of Nitrate plus Nitrite versus Phosphate for the Androscoggin and Kennebec Rivers in Maine.

The data cluster with high N:P ratios, the red coded data points from Figure 2, are replotted in Figure

5, and compared with station location, depth of collection and corresponding salinity. As can be seen in Figure 5, those high N:P-ratio data were sampled from below the surface and in relatively higher salinity waters (Gulf of Maine Bottom and Intermediate Water layers). We interpret those high N:P rations as being the result of internal nitrification in the Gulf's interior waters, as has been suggested earlier (Townsend, 1998).

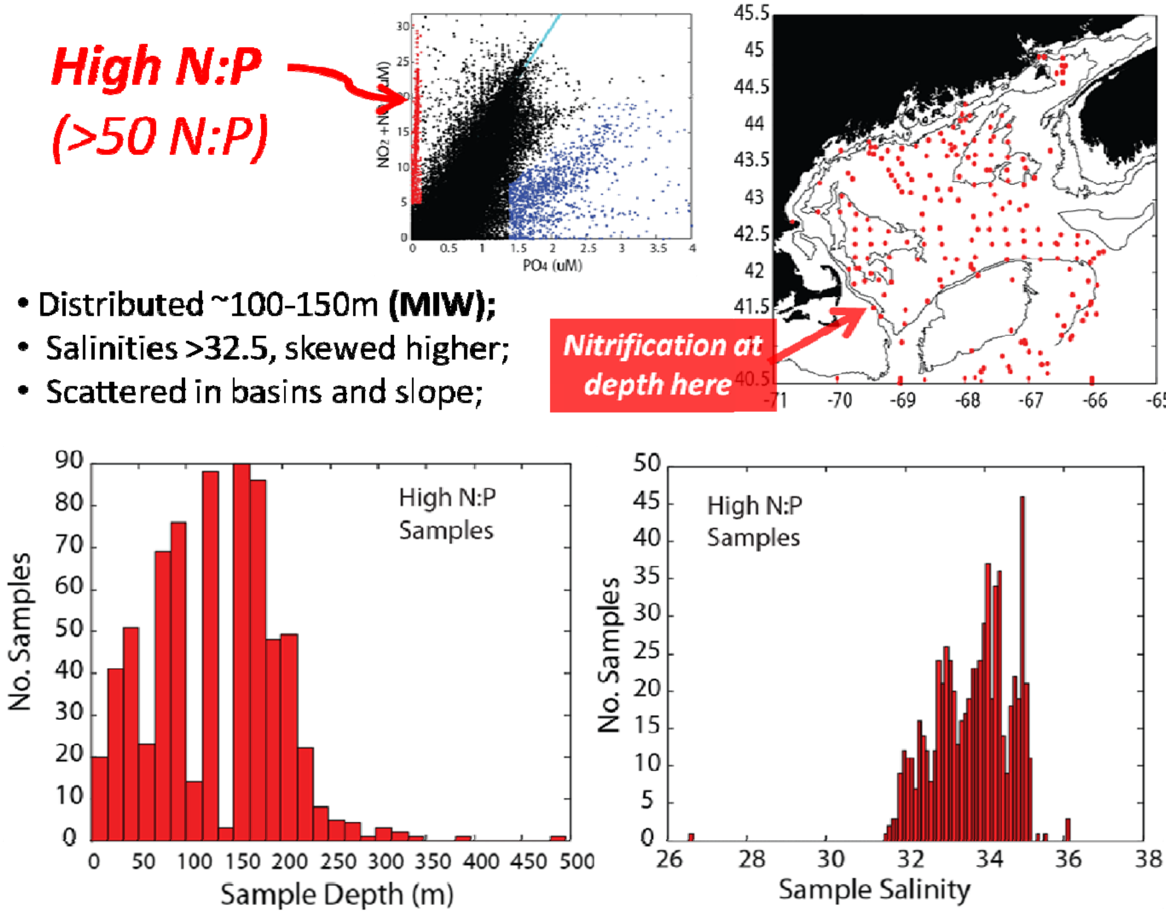

Figure 5. Geographic locations, depths and corresponding salinities of the exceptionally high N:P data (red data points) from Figure 2.

The details of this nutrient dataset and its use in compiling a nutrient climatology for the Gulf of Maine region, are the subject of a Ph.D. dissertation by Nathan D. Rebuck at the University of Maine, and are presently in preparation for publication (Rebuck *et al.*, in prep.).

Focusing in on the nutrient regime on Georges Bank, based solely on data collected in more recent years (Figure 6), we see that the high and low N:P ratio data sort themselves into a coherent pattern in the Gulf of Maine and on Georges Bank. That is, the green data (high N:P) reflect waters originating in intermediate depths in the interior Gulf of Maine, and which have been mixed upward and onto the Bank (as well as having been mixed upward in the two other areas on the interior Gulf of Maine known to exhibit vertical nutrient fluxes driven by tidal mixing). The Black data (low N:P) are the oldest surface waters sampled during this single research cruise in 2007, and as such are analogous to the data cluster noted above for the western coastal Gulf of Maine.

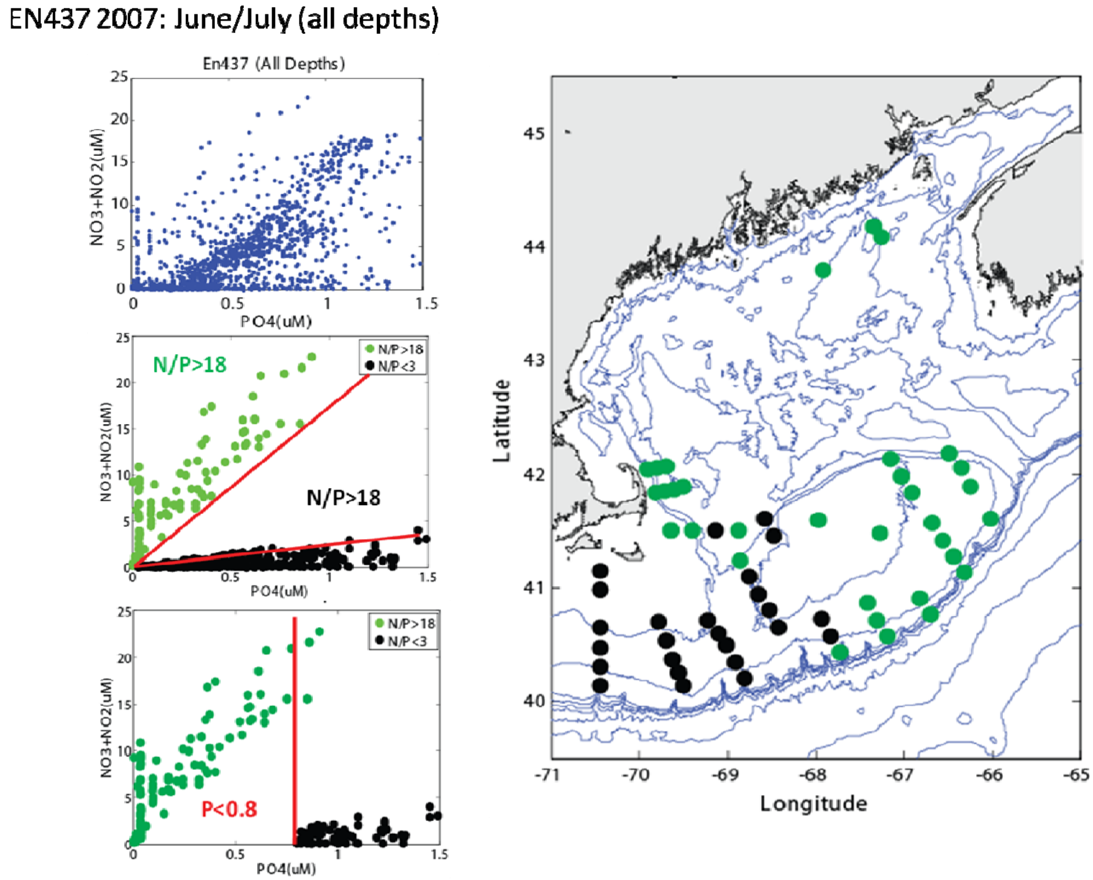

Figure 6. Georges Bank data, based only on data collected in 2007 (*R/V Endeavor* cruise No. EN437), and divided into high (>18) and low (<3) N:P ratios, and plotted geographically as either high N:P (green) or low N:P (black).

Most recently, we have begun to analyze temporal trends in our nutrient and hydrographic database, and have discovered a change in the nutrient loads of source waters to the Gulf of Maine since the 1970s. We believe that we have uncovered a significant change over the past 40 years in the water properties, and especially, the inorganic nutrient loads, in the Gulf of Maine, which, as we have shown earlier (Hu *et al.,* 2008) are the nutrient source waters for Georges Bank. We suspect that this change is the indirect result of additional melt waters in the Arctic since the 1970s, which has enhanced the transport of the coastal geostrophic current in the Northwest Atlantic and Labrador Sea such that it now brings a greater fraction of deep continental *shelf* waters into the Gulf, than deeper continental *slope* waters, which in the past has been the primary source of nutrients. The shelf waters are different in that nitrate loads are lower (because of sediment denitrification on the shelf prior to entry into the Gulf), and silicate loads are greater (from both regeneration on the shelf and from terrestrial river sources). These nutrient changes are reflected in the abundances and distributions of diatoms (which require both nitrogen and silica) and dinoflagellates (which do not require silica).

This most recent finding could mean that the Georges Bank spring phytoplankton bloom, once thought to be silicate-limited (Townsend and Thomas, 2002) is now nitrate-limited, which could hold important implication for structure of the Georges Bank (and Gulf of Maine) planktonic ecosystems. Those findings are being prepared for publication (Townsend *et al.*, in prep).

References:

Hu, S., D.W. Townsend, C. Chen, G. Cowles, R.C. Beardsley, R. Ji, R.W. Houghton. 2008. Tidal Pumping and Nutrient Fluxes on Georges Bank: A Process-Oriented Modeling Study. *Journal of Marine Systems* 74: 528–544.

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