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Project Summary

Chesapeake Bay Nutrient Dynamics Study

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This study had two major objectives. The first was to fill gaps in our understanding of important biological, chemical, and physical processes occurring in Chesapeake Bay. This information was required to make the best use of existing data and to develop future data needs to further understand the basic functioning of the Bay system. The second objective was to collect a synoptic data set for the entire Chesapeake Bay to be used in future modeling efforts and to establish the present condition of the main Bay at one point in time.

Field work for the study was conducted by 16 scientists on 13 cruises between 1 May 1980 and 1 June 1981. The synoptic nutrient study was conducted from 8 to 17 July 1980 in conjunction with a circulation study covering the entire Bay from 25 June to 29 July 1980. The process studies were performed at various times and locations dictated by the processes themselves. Subsurface transport of nutrients and phytoplankton were examined in May 1980 in the upper Bay. Sediment nutrient releases and oxygen demand were studied in eight locations in summer 1980 and spring 1981. Nitrogen and silica dynamics were examined in several locations during July, August, and September 1980. Bacterial dynamics were studied in August 1980. The results of these studies added important information to the knowledge about Chesapeake Bay.

This Project Summary was developed by EPA's Chesapeake Bay Program, Annapolis, MD, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Chesapeake Bay is a large, productive, coastal-plain estuary with 64,000 square miles of watershed and about 4,000 miles of shoreline. Nutrients enter the Bay directly from the shore, adjacent urban centers, and the major rivers draining the watershed.

Once in the Bay, nutrients participate in biological and chemical cycles. These cycles, combined with physical circulation, tend to trap the nutrients in the estuary. Thus, the observed nutrient concentrations represent the net result of many interacting processes that comprise the biological and chemical cycles. Estuarine scientists and managers recognize that nutrient concentrations alone do not convey enough information. The related processes must be identified and placed in perspective.

This study was planned and performed to examine several estuarine processes which were known to exist but were not well quantified. It was also designed to provide limited information about fluxes at the Bay mouth and a synoptic data set for future modeling efforts. Time and funds limited the processes which could be studied to those thought to be the most important. The results of the field experiments are summarized in the following sections.

I. Synoptic Data Set

A large body of nutrient and physical data was collected for 8 days in July 1980 from four transects spaced along the axis of the Bay, and from the mouths of the major rivers. The data set is synoptic in the sense that all stations were sampled twice each day with the exception of the mouth transect which was sampled at 3 hour intervals for 36 hours and twice daily thereafter. The purposes for obtain-

ing this data set were: 1) to establish the current condition of the Bay with respect to nutrients; 2) to estimate the transport of nutrients within the Bay and across the mouth for at least one period of time; and 3) to obtain a data set for future use in developing a mathematical model of the entire system. Data collection was conducted within a matrix of continuously recording current meters to enable the transport calculations to be made.

II. Dye Tracing of Deep-Water Flow

A dye tracer experiment confirmed that deep water travelling up the Bay can reach the surface in tributaries, namely the Chester River, and deliver nutrients, phytoplankton, and other organisms from down-Bay. This may be an important mechanism for algal-bloom formation and is significant in bringing larval forms of higher species with their potential food sources into proper nursery areas.

Procedure/Methodology

Rhodamine dye was injected into the center of a subsurface lens of the dinoflagellate *Prorocentrum* near their annual bloom area in the northern Chesapeake Bay. Continuous monitoring of the dye and density structure revealed a net upstream movement of both the dye and the dinoflagellates below the pycnocline.

Hematoxylin stain was used to determine nuclear division rates for the *Prorocentrum* within this subsurface-chlorophyll maximum, showing an actively reproducing population.

Results/Conclusions

The strong pycnocline repressed the vertical advection of the dye and limited the upward, phototactic migration of *Prorocentrum*. A branching of the subsurface dye patch and associated dinoflagellate concentrations were observed at the mouths of two major tributaries. The dye and cells were followed upstream in bottom waters to a shoaling area where increased vertical advection resulted in the breakdown of the pycnocline, the mixing of the dye to the surface, and the appearance of a surface patch of *Prorocentrum*.

III. Sediment-Water Nutrient Exchange

Direct measurements of nutrient exchanges between bottom sediments and overlying water confirmed the conceptual understanding of this interaction in Chesapeake Bay and, for the first time, quantified the exchange rates.

Procedure/Methodology

Oxygen and nutrient fluxes across the sediment-water interface were measured with bottom chambers in four zones of Chesapeake Bay (turbidity maximum, mesohaline, near-marine, and several tributaries) during two distinctive seasons.

Results/Conclusions

Sediment oxygen demand (SOD) ranged from 1.04 to 4.15 g $O_2 m^{-2} d^{-1}$ in summer and from 1.41 to 3.45 g $O_2 m^{-2} d^{-1}$ in spring, and was quite uniform in time and space. Calculations indicate that SOD is a large loss term in oxygen budgets (32 to 50 percent), at least in the mid-Bay where low oxygen concentrations are often exhibited during warm periods of the year. Ammonium fluxes ranged from 102 to 669 μg at $m^{-2} h^{-1}$ in August and from 32 to 110 μg at $m^{-2} h^{-1}$ in May and were significantly lower in the upper Bay and lower Bay than in other areas in August but not in May. Sediment flux ratios of O:N averaged 14.0 in August, closely approximating that expected for aerobic plankton decomposition but were much higher (95.1) in May when NH_4^+ fluxes were low. Evidence suggests that a substantial fraction of the remineralized NH_4^+ was denitrified in the sediments in the spring but not in the summer. Nitrate fluxes were generally small during the summer but were directed into sediments and proportional to NO_3^- concentration in the water column during the spring, again suggesting denitrifying activity. Phosphorus fluxes were erratic in summer (-4 to 40.2 μg at $m^{-2} h^{-1}$) and consistently near zero in the spring.

Sediment nutrient fluxes represent a substantial nutrient source during the summer, when phytoplankton demand is high and water column nutrient reserves are low, and a potential sink in the spring when phytoplankton demand is lower and fluvial nutrient inputs are high. Additional calculations indicate that (1) a small percentage of the particulate nitrogen and phosphorus delivered to the sediment surface is sequestered in the sediment column and (2) most of the observed sediment nutrient flux is supported by remineralization occurring very close to the sediment surface rather than by diagenic processes deeper in the sediment column.

IV. Relative Nutrient Contributions from Water Column Recycling and Sediment Release

A model was developed to ascertain, from vertical nutrient and salinity profiles, the relative contributions of nutrients derived from sediment release and recycling within the water column.

Procedure/Methodology

A data set from the lower Potomac estuary comprised of 43 hourly vertical profiles of nutrients and salinity was analyzed and employed to develop a model based on transport equations. The model is applicable during periods of relative steady-state flow such that vertical distributions of properties do not change during the course of measurement. The model output consists of a dimensionless parameter which indicates the relative proportion of nutrient in the observed profile from water column recycling versus release from the sediments.

Results/Conclusions

During a summer period of deep water anoxia in the Potomac, the model indicated that water column recycling was primarily responsible for the observed profiles while release from the sediments had a secondary role. The technique can be used in other situations to ascertain the relative importance of these two nutrient processes for limited time periods.

V. Sources and Sinks of Nitrite

Direct measurements with heavy isotopes quantified, for the first time in the Chesapeake, the rates of nitrogen transformation between ammonium, nitrite, and nitrate in the water column.

Procedure/Methodology

The transformations of inorganic nitrogenous nutrients that are responsible for the frequently observed high levels of nitrite in Chesapeake Bay and York River were investigated using a combination of ^{15}N tracer techniques and assays of chemical properties (NH_4^+, NO_2^-, NO_3^-, O_2, N_2O, and CH_4).

Results/Conclusions

During a destratification event in the York River, uptake and remineralization of NH_4^+ followed a diel cycle, but nitrification was not as closely coupled to the light regime. In addition, the observed distributions of N_2O, NO_2^-, and CH_4 in the York River suggest that the source of N_2O and

NO_2^- (both produced during nitrification) was not in the river sediments. Rates of nitrification inferred from N_2O gas flux calculations are consistent with measured *in situ* rates.

Experiments conducted at a series of stations in mid-Chesapeake Bay were designed to look at N-transformations among N pools and to measure the yield of N_2O-N per unit NO_2^--N during nitrification. Yield values ranged from 0.2 percent to 0.7 percent in agreement with laboratory results.

Our ^{15}N data indicate that oxidized N can be formed within the water column of the Bay when physical events cause the mixing of NH_4^+-rich bottom water with more oxygenated surface layers. Surface waters showed unexpectedly rapid rates of NO_3^- reduction to NH_4^+.

The magnitude and duration of high concentrations of N_2O and NO_2^- in these estuarine waters during mixing events might be expected to increase if anthropogenic loading of nutrients causes anoxic conditions in the Bay to become more widespread.

VI. Ammonium Recycling by Micro-Zooplankton

Rapid nutrient recycling within the euphotic zone of Chesapeake Bay is a major process that supports high rates of production at times when nutrient concentrations are low. Zooplankton, especially those which graze directly on the phytoplankton, must be closely involved in recycling. Previous work has shown that the potential to recycle nutrients increases with decreasing size in zooplankton. Therefore, this study focussed on the micro-zooplankton which is comprised of ciliates, rotifers, and other organisms similar in size to the phytoplankton themselves.

Procedure/Methodology

Because of the difficulties involved in making the necessary measurements, the isotope dilution technique was selected as the most suitable way to measure ammonium release in the presence of phytoplankton uptake.

Two basic questions were asked by the experiments: 1) At what rates and with what significance was ammonium being recycled *in situ* in surface waters? and 2) What deductions could be made as to the size of the organisms responsible for any measurable ammonium release?

Results/Conclusions

Results indicate that the rate of ammonium nitrogen recycling from natural samples was 0.034 to 0.129 μg at $NH_4N\ L^{-1}h^{-1}$. Further, virtually all recycling activity was contained in the less than 35 μm fraction, suggesting that micro-zooplankton had a major role in the recycling rate.

VII. Biogenic Silica Cycle

An annual silicon budget was developed for the Chesapeake Bay in this study.

Procedure/Methodology

The major external source of dissolved silicon is river input into the Bay. A smaller amount probably enters from the seaward boundary. Silicon in surface waters is utilized by organisms, primarily diatoms. When they die or are eaten, the siliceous components dissolve. The rate of dissolution of this amorphous silicon is quite rapid relative to that for mineral crystalline forms (sands and clays). Some of the particulate silicon sinks to deeper waters below the pycnocline. Some reaches the bottom where continued dissolution enriches the sediment interstitial water producing a concentration gradient favoring diffusion toward the overlying water. If the system is in a long-term steady-state; that is, annual sinking is about equal to annual sediment release, then silicon release from the sediments sets the lower limit for its uptake in the overlying waters.

Measurements of benthic fluxes were used to focus on the role of sediment dissolution processes in resupplying the water column with dissolved silicon. The budget is in the form of a box model which specifically excludes pools and fluxes of mineral silicon which do not participate in the rapid turnover affecting biological processes.

Results/Conclusions

Calculations made from field measurements indicate that sediment release of silicon exceeds river and ocean inputs by a factor of two to five on an annual basis. Thus, the silicon cycle within the Bay is of major significance relative to the external inputs.

VIII. Bacterial Biomass and Production During Estuarine Destratification

Bacterial abundance, biomass, and ^3H-thymidine incorporation rates were studied during spring tidal destratification of the York River, Virginia estuary.

Procedure/Methodology

Samples were collected by pump at the York River mouth for bacterial abundance, by acridine orange direct counts for biomass measurements, and by Niskin bottle with ^3H-thymidine for production measurements. Amino acid uptake was estimated with a tritiated amino acid mixture.

Results/Conclusions

In this system, monthly high spring tides cause destratification of the moderately stratified estuary, which oscillates between stratified and vertically homogeneous conditions on a time scale of 1 to 10 days. Bacterial abundance and carbon biomass ranged from one to eight x 10^9 cells L^{-1} and 20 to 100 μg C L^{-1}. Thymidine incorporation into cold TCA insoluble fractions ranged from 1 to 10 nano-moles L^{-1} d^{-1} and bacterial carbon production rates and specific growth rates were seven to 75 μg C L^{-1} d^{-1} and 0.2 to 1 L^{-1} d^{-1}, respectively. Biomass increased steadily during the destratification process while production remained constant. Production then increased two- to three-fold in twelve hours during the period of maximum water column homogeneity. Increased vertical mixing and possible stimulation of phytoplankton production are hypothesized as the major cause of this bacterial response to destratification.

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The complete report, entitled "Chesapeake Bay Nutrient Dynamics Study," (Order No. PB 84-190 982; Cost: $25.00, subject to change) will be available only from:
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