Estuaries Vol. 17, No. 4, p. 729–731 December 1994

Introduction to the Dedicated Issue

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This issue of *Estuaries* is devoted to papers that describe results from the Nutrient Enhanced Coastal Ocean Productivity (NECOP) Program. The NECOP study was initiated by the Coastal Ocean Program of the National Oceanic and Atmospheric Administration (NOAA) in 1989 to address the effects of nutrient discharge in the coastal waters of the United States (Wenzel and Scavia 1993). The basic hypothesis posed for NECOP is that the addition of anthropogenic nutrients from sewage, agriculture, industrial sources, and suburban runoff have contributed to the development of eutrophication in coastal waters with significant impacts on water quality.

The coastal waters of the northern Gulf of Mexico were selected as the initial study site for NECOP based on a set of criteria developed by NOAA scientists and their academic colleagues. The criteria for the location of study include:

(1) A clear anthropogenic signal,
(2) A resultant nutrient-enhanced productivity of significant magnitude,
(3) A demonstrable impact of enhanced production on coastal environmental quality, and
(4) Renewable resources of significant value.

As described in several of the following papers, the influx of nutrients to the coastal waters of the northern Gulf is dominated by the freshwater discharge of the Mississippi River. The watershed of the Mississippi covers more than one-third of the continental United States, including the heavily fertilized Midwest. The river discharges approximately 30% of its total flow through Atchafalaya Bay with the remaining 70% flowing through the distributaries of the delta. Previous research efforts in this region have linked anthropogenic nutrient inputs to the development of hypoxia in the nearshore waters of Louisiana (e.g., Turner and Rabalais 1991). Hence one of the major goals of the NECOP study was to quantitatively relate the input of riverborne nutrients in the Mississippi River discharge to the development of hypoxia on the shelf. Toward this end, a series of interdisciplinary programs concentrated on selected physical, geological, chemical, and biological aspects of the Louisiana shelf ecosystem. The papers in this issue

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0160-8347/94/040729-03$01.50/0

present the most relevant observations and conclusions from the first 2 yr of the NECOP program.

The historical record of hypoxia in the sediments of the western Louisiana shelf was examined to describe the time course over which nutrients inputs have potentially altered productivity. This retrospective approach is summarized in two papers in this issue, the first by Nelsen et al. They have assessed biogenic, lithogenic, and authigenic indices of hypoxia in the sediments in relation to the historical record of commercial fertilizer use in the United States. Both mineral (glauconite) and biogenic (benthic foram species) indicators appear to be reliable markers of the occurrence of hypoxia. The distribution of these indicators strongly suggests that increased fertilizer loading within the watershed of the Mississippi River has altered the nutrient flux to the northern Gulf of Mexico within the past few decades. Additionally, the organic carbon content, organic constituents (lipids and lignin), and the stable isotope signatures of the sedimentary record are interpreted in cores from both the hypoxic and oxic regions in Eadie et al. The time-dependent changes in organic matter and stable isotopes all support the hypothesis that nutrient loading has had a significant impact on the productivity of the shelf. The largest changes observed coincide with a doubling of nutrient loading in the river between 1960 and the mid-1980s.

Four papers have addressed the role of river discharge on the water-column property distributions on the Louisiana shelf. The history of freshwater and nitrate discharge from the Mississippi and Atchafalaya rivers has been examined for the past few decades by Bratkovich, Dinnel, and Goolsby. They report that the annual cycle, and shorter periods, dominate variability in the system, with a relatively weak covariability between water discharge and nitrate concentrations. They conclude that skilled forecasts of nitrate concentrations in the discharge are possible within well-defined limits.

The variability in the salinity of the inner shelf waters is reported by Wiseman and Kelly for spring 1982. This report examines the sources of variability influencing the salinity signal associated with the Louisiana Coastal Current (LCC). Knowledge of this current is important as it links the discharge of the Mississippi to the shelf waters. The time scales of variability in the LCC correspond to river discharge, synoptic winds, and tidal forcing. The flux of particulate organic carbon to the northern Gulf from the Mississippi River system has been assessed by Trefry et al. They found that river flow is a dominant factor influencing the distribution of particulates and POC. Additionally, the distribution of organic carbon and $\delta^{13}C$ values suggest that significant quantities of terrigenous and marine organic carbon fuel the hypoxia on the inner shelf.

López-Veneroni and Cifuentes' analysis of dissolved organic nitrogen (DON) in the near-surface waters of the shelf reveals that this fraction accounts for the major fraction of total dissolved nitrogen in the Mississippi River plume. The DON signal can be traced along the shelf west of the delta, with an inverse relationship apparent between DON and salinity near the mouths of the major distributaries. Mixing analyses based on riverine and oceanic endmembers suggest that the plume waters may act as a sink of DON, while nonplume waters are a potential source of the labile fraction of DON.

Four separate manuscripts describe the functioning of the planktonic ecosystem on the shelf. Lohrenz, Fahnenstiel, and Redalje have described the spatial and temporal variability in primary productivity and algal biomass on the shelf. Relevant parameters of the photosynthesis-light intensity response were evaluated in order to assess their use in future models of productivity. The relationship between integrated productivity and the vertical export of particulate carbon is discussed by Redalje, Lohrenz, and Fahnenstiel. They find that the vertical flux of POC from the euphotic zone displays a seasonal signal, although the proportion of exported carbon was highly variable. It appears to depend on factors such as phytoplankton species composition and herbivore grazing.

The role of specific nutrients influencing the potential limitation of phytoplankton growth was assessed by Smith and Hitchcock. Their results from algal bioassays with laboratory cultures and natural populations suggest that phosphate and silicate potentially limit phytoplankton in the winter-spring, particularly at lower salinities. In late summer, however, nitrogen could potentially limit growth of phytoplankton at higher salinities. The remineralization rates of dissolved and particulate organic matter has been examined by Gardner et al. Their report shows that particle consumers played an important role in the recycling of organic matter, with the heterotrophic processes strongly coupled to phytoplankton production.

Three papers in this issue concentrate on the hypoxic conditions that characterize the Louisiana shelf in summer and the benthic communities. Dortch and co-workers measured respiration rates in the water column and at selected benthic sites across the shelf in summer 1991. Respiration rates were high in the planktonic and benthic communities, although the values were comparable to other coastal and estuarine waters. The combined res-

piration of both water-column and benthic communities could, however, deplete bottom-water oxygen within a month, thus some mechanism(s) must re-aerate the subpycnocline waters on the highly stratified shelf. Continuous records of near-bottom oxygen concentrations have been analyzed by Rabalais, Wiseman, and Turner from two locations during summer 1990. Hypoxic conditions were weaker at a station close to the Mississippi River delta than at a station near the mouth of Terrebonne Bay. Coherence existed between bottom pressure records and oxygen near Terebene Bay, suggesting that dissolved oxygen concentrations in bottom waters may be controlled by advection by tidal currents. Rates of oxygen consumption were also measured in relation to benthic nutrient flux by Miller-Way et al. A comparison of in situ and shipboard samples indicated no significant difference between the methods in terms of respiration or nutrient flux (NH_4^+, NO_3^-, NO_2^-, PO_4^{3-}, and $SiO_2/Si(OH)_2$). The only exception was found when bottom communities from hypoxic waters were briefly re-oxygenated; these results support the use of shipboard chemostats for reliable estimates of benthic respiration and nutrient flux rates.

The above papers all describe individual components of the shelf ecosystem. A model has been developed by Bierman et al. and employed to examine relationships between various environmental parameters and the dynamics of dissolved oxygen concentrations. The phytoplankton, nutrients, and consumers on the western Louisiana shelf have been modelled in a deterministic, mass balance model that has been calibrated to field data collected in July 1990. For example, subsurface irradiance is apparently more important than nutrient limitation in regulating primary productivity on the shelf, while chemical and biological processes are more significant than advective or dispersive processes in controlling oxygen concentrations in bottom waters. Nutrient remineralization also appears to have a significant effect on the maintenance of chlorophyll biomass.

Finally, a short communication by J. Hendee describes the data management scheme of the NECOP program. The approach of the data management for the program and the capabilities of the NECOP bulletin board are outlined. The information available through the bulletin board is extensive, and it is accessible to outside investigators.

To summarize, the following papers provide an initial description of the accomplishments of the NECOP program during the first 2 yr. We believe they provide a significant contribution to furthering our understanding of the effects of anthropogenic nutrients in the coastal waters of the United States. It has been our privilege to serve as the Guest Editorial Committee during the review process.

Literature Cited

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