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BIOLOGICAL PROCESSES IN THE WATER COLUMN OF THE SOUTH ATLANTIC BIGHT: PHYTOPLANKTON RESPONSE

FINAL PROGRESS REPORT

A Final Report Submitted to U. S. Department of Energy

by

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March 10, 1992

PREPARED FOR THE
U.S. DEPARTMENT OF ENERGY
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Project Summary

For logistical and organizational reasons, DOE-sponsored studies of the southeastern U.S. continental shelf were divided into 2 components: (1) shelf-wide processes and (2) nearshore (coastal boundary zone) processes. Coastal boundary zone (CBZ) dynamics involve studies of circulation and of biological and chemical transformations. Continental shelf processes affect the removal of material from the coastal boundary zone into areas where the material no longer interacts with or influences concentrations in the CBZ. The two arbitrarily separate components are, in fact, unified. The CBZ typically extends about 300 km alongshore and about 20 km offshore from its center off Savannah, Georgia, where most runoff occurs. The rates of biological and chemical transformations are controlled by proximity to the bottom and the amounts of fine suspended organic matter originating from rivers and salt marshes. Once material is removed from this zone, either by alongshelf or cross-shelf advection to regions where the materials are no longer in contact with the bottom, the suite of factors governing the rates of chemical and biological transformations changes. The determination of contrasting rates in these two environments was one of the central focuses of the South Atlantic Bight program.

Our research addressed the basic question of how water circulation patterns and related physical processes affect phytoplankton productivity and other biological processes in the water column of the southeastern U.S. continental shelf. Past research emphasized the effects of the Gulf Stream on shelfwide plankton processes. Unlike the situation at more temperate latitudes, pulses in biological production on the S.E.

Continental Shelf are not seasonally dependent but are driven by specific, short term physical events. For example, meanders or eddies of the Gulf Stream often induce the upwelling of sub-surface waters at the shelf break. When these waters are advected onto the shelf proper (intrusions), usually at frequencies of about 2 weeks, primary and secondary production may increase markedly.

During the summer, cold subsurface intrusions are displaced onto the middle and sometimes the inner shelf, when the following conditions occur simultaneously: (1) the Gulf Stream is in an onshore position; (2) there is a frontal eddy at the shelf break; and (3) wind stress is northward. Such intrusions can cover an area of 10,000 km^2, and pronounced patches of phytoplankton and zooplankton may develop within them. Primary production may exceed 2 g/m^2/day in upwelled waters resident on the shelf. Nutrients are usually exhausted within one week. Rapidly growing and reproducing zooplankton increase in abundance at rates of 10-50%/day and remove the phytoplankton within 3 weeks. At the shelf break, where the stability of the water column is weak, zooplankton do not appear to control the standing crops of phytoplankton. Their fate depends on the length of time the intruded waters remain on the shelf. When residence times are short (< 5 days) primary production is stimulated but the time is too short to allow significant response by grazing organisms. In these cases there may be a large export of particles off the shelf. With longer residence times, on the other hand, grazing organisms may consume most of the phytoplankton produced. In these instances much of the material consumed is recycled on the shelf or is deposited to the sediments (e.g., fecal pellets). Long residence times, thus, result in a relatively small loss of particles from the shelf.

During winter, Gulf Stream intrusions are primarily restricted to the outer shelf because shelf waters are relatively dense. Density fronts maintained by convergence delineate the boundary between these water masses. Model results and combined shipboard and moored instrument observations indicate that cold air outbreaks displace the front shoreward, transporting nutrient-rich Gulf Stream water onto the outer shelf. After winds diminish, the excess potential energy shoreward of the front induces offshore advection of water and particles along the bottom. Light and temperature conditions are such that significant primary production is expected if the residence time of the upwelled water is sufficiently long. Our sampling suggests that (1) substantial biogenic production does occur during these events, and (2) much of this production may cascade off the shelf before zooplankton can respond and utilize it. The role of rapidly growing protozoan and gelatinous zooplankton appears critical to the fate of this primary production.

On the inner and middle shelf, studies were conducted to ascertain the effects of wind events on phytoplankton dynamics during the season of maximum river discharge. Other field projects focused on the relation between the nearshore frontal system and the spatial distribution of plankton biomass and production. Yet another major interdisciplinary project studied the fate of the low salinity water (and entrained particles) in the coastal boundary zone which advects south towards the Florida coast during the fall, a principal mechanism removing biotic and abiotic particles from coastal waters of the southeastern continental shelf. A three-year study was also conducted of rates of biological and chemical processes important to the carbon and nitrogen cycle of the inner shelf. These measurements of temporal and spatial variability of phytoplankton biomass and productivity were extended using chlorophyll data derived from satellite (CZCS) imagery.

These investigations show that elevated concentrations of suspended organic and inorganic particles occur in nearshore waters due to the presence of a coastal salinity front which inhibits cross-shelf exchange. Within the front rates of primary production are very high (600-700 $gC \cdot m^{-2} \cdot y^{-1}$), and relatively aseasonal compared to more temperate latitudes. However, interannual variability may be considerable, influenced in part by meteorological effects on nutrient availability. Phytoplankton *growth rate* is limited primarily by irradiance due to high turbidity of inner shelf waters. Dissolved inorganic nitrogen (DIN), which appears to regulate phytoplankton *biomass*, does not vary seasonally, suggesting that (DIN) utilization is proportional to supply rates. The abundance and productivity of protozoan zooplankton imply an important role in regeneration of nutrients to support the high primary production.

The salt marshes and nearshore sediments filter, store, and process materials derived from both river and middle/outer shelf sources. Both import (e.g., heavy radionuclides, inorganic elements) and export (particulate and dissolved organic nitrogen) may occur and rates may vary on seasonal time scales. Intense mixing associated with large tidal amplitudes may be important in flushing nutrients and other materials from salt marsh and nearshore sediments. The organic nitrogen supplied from these sources must be mineralized by heterotrophs to make it available for phytoplankton.

The coastal salinity front increases the residence time of suspended material, thus favoring recycling of nutrients and enhanced primary production. In areas with less extensive marsh development and lesser riverine inputs, such as off Florida, inner shelf production may be influenced more by shelf break upwelling or alongshelf transport of materials derived from adjacent marsh-dominated systems.

All of these projects required an interdisciplinary approach, and they were implemented in collaboration with other investigators in the DOE Southeastern Program. Lists of publications, submitted manuscripts, and presentations which acknowledged this award are attached.

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Students

Garcia-Moliner, Graciela. Ph.D. Thesis: "Phytoplankton dynamics in the Mid-Atlantic Bight as determined from CZCS (ocean color) satellite imagery (1978-1986)."

Postdoctoral Scholars

Stegmann, Petra. Dr. Stegmann investigated coupling between physical circulation patterns, bio-optics, and primary production in the South Atlantic Bight.

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