4 ECOSYSTEM PROCESS MODELS

Convenors: Dr. Michael Kemp and Dr. Richard Wetzel

Toward a Sustainable Coastal Watershed:
The Chesapeake Experiment. Proceedings of a Conference
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A Comparison of Vegetation and Nutrient Dynamics from Two Marsh-Creek Systems Within the Monie Bay National Estuarine Research Reserve

L. Murray
University of Maryland

Abstract: Marsh vegetation was sampled from two marsh-creek systems within the Monie Bay National Estuarine Research Reserve. The watershed of one system (Little Monie) is predominately agricultural, while the other (Little Creek) is surrounded by natural vegetation. Two sites within each system (one area directly adjacent to the creek and the second 50 m from the creek edge) were sampled seasonally over a 3-year period for plant biomass, species composition, and plant tissue nutrient concentrations. While plant biomass and tissue nitrogen were not significantly different in the two areas, plant tissue phosphorus concentrations increased in the agriculturally influenced system. This increase was more evident in years of higher rainfall. Fertilization experiments conducted in spring and fall resulted in higher above-ground biomass in both marsh-creek systems, but not in below-ground biomass in the agricultural system. Additionally, both nitrogen and phosphorus levels in above and below-ground plant tissues from both systems were elevated with spring fertilization. However, fall fertilization did not increase phosphorus concentrations in plants from the agricultural system, indicating that these plants tend to “store” phosphorus during the growing season. These results suggest that while plant community dynamics are similar in the two marsh-creek systems under "normal" nutrient regimes, the addition of nutrients elicist varying responses from the plants in the two marsh-creek systems.

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THE INFLUENCE OF FLOW ON *ZOSTERA MARINA* SEAGRASS COMMUNITY METABOLIC RATES: IMPLICATIONS FOR SIMULATION MODELS

W. J. Seufzer and R. L. Wetzel
Virginia Institute of Marine Science

Abstract: Today's seagrass simulations include light and temperature as primary physical forcing functions influencing the growth and sustainability of seagrasses. As spatially averaged models (a single model that represents seagrass for an entire region) are augmented into spatially articulated models (an array of replicated models linked together that account for spatial variability and that can include a moving water column), the influence of the overlying water on the *Zostra marina* community may need to be included. Four methods were investigated for measuring *Z. marina* community metabolic rates and their relation to the speed of the overlying water column. Metabolism measurements were based on dissolved oxygen (DO) and were conducted with an array of DO sensors and a current meter. Computational models were built to perform slack, diurnal, and two upstream-downstream methods on the data. Parameters used to compare the methods included net community production, gross community production, community respiration, production-to-respiration ratios, and production versus flow. Findings indicated a measurable relationship on current flow and *Z. marina* community metabolic rates. This paper disscusses how the computational models were implemented and compares results obtained from each of the methods.

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Relationships Between External Forcings and Ecosystem Responses in Chesapeake Bay and A Western Shore Tributary Estuary

W. R. Boynton and J. D. Hagy
University of Maryland

Abstract: Temperate zone, coastal plain estuaries such as Chesapeake Bay and its tributary estuaries are typically exposed to strong interannual and seasonal variations in the magnitude and timing of freshwater inputs, I_w, and associated nutrient loads, I_n. These inputs clearly influence physical processes (transport, stratification) and biological processes (primary production, nutrient cycling, oxygen dynamics), although quantitative relationships have rarely been developed except in the context of complex simulation models. During the last decade, an impressive data base has been developed for Chesapeake Bay and its tributary river-estuaries for a large suite of input, water quality and some biological stock and rate variables. To explore this data base for simpler relationships between external forcings and ecosystem responses, hypothesized cause-effect linkages (and alternative explanations) were developed and tested via regression analysis. For stations in mainstem Chesapeake Bay, significant relationships have been found for I_w, I_n vs algal biomass, I_w vs primary production rates, and I_n vs organic matter deposition rates. For the Patuxent River, significant relationships have been found between I_w and algal biomass, I_w and hypoxic water volume-days, and algal biomass and hypoxic water volume-days. These regressions incorporate volume-weighted spatial averages, thereby maximizing use of the spatial aspects of the data base. These averages were output from software designed to visualize and quantify spatial distributions of water quality variables. Other relationships have also been developed which predict bottom water oxygen decline and sediment nutrient fluxes from the water column flux of organic carbon. All of these linkages appear to function on seasonal to annual time scales, suggesting that long-term "memory" associated with nutrient storage in sediments is minimal. Comparisons are made between input-response relationships observed in mainstem Chesapeake Bay and in Patuxent River, including commentary on the influence of intrusions from the mouth of the estuary.

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PAST, PRESENT, AND POTENTIAL DISSOLVED OXYGEN CONDITIONS AND NUTRIENT BUDGETS

Carl F. Cerco
U.S .Army Corps of Engineer

Abstract: A eutrophication model package was recently completed for Chesapeake Bay. The package included a three-dimensional hydrodynamic model, a model of water column eutrophication processes, and a model of diagenesis in benthic sediments. The primary purpose of the model was to evaluate dissolved oxygen response to nutrient load reduction strategies. The mass conservation basis of the model and flux algorithms incorporated in the code make it useful, as well, in the creation of nutrient budgets and in quantification of memo transfers. The model was employed to examine Bay budgets under three conditions: existing, limit-of-technology nutrient control, and all-forested watershed. Results derived from the model indicate:

1. Under present conditions, the Bay is a net exporter of nitrogen to the continental shelf. The Bay is a net importer of phosphorus. In fact, the shelf is the largest single source of phosphorus to the Bay.
2. Under all-forest conditions, minimum summer-average dissolved oxygen was roughly 2.7 gm m^{-3}. Incidence of dissolved oxygen of less than 1 gm m^{-3} was a rare event induced by extreme stratification.
3. Introduction of limit-of-technology nutrient controls will increase minimum summer-average dissolved oxygen to roughly 0.75 gm m^{-3} volume of water and dissolved oxygen less than 1 gm m^{-3} will be reduced by 40% from present conditions.
4. Under present conditions, 30% of nitrogen deposited to bottom sediments is lost through denitrification. Under limit-of-technology nutrient controls, the proportion will increase to 37%. Under all-forest conditions, the proportion was 63%. The proportion lost increases as a proportion of dissolved oxygen in overlying water.

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Chesapeake Bay Plankton-Benthos Ecosystem Process Model: Feedback Effects on Nutrient-Oxygen Relations

W. M. Kemp and R. Bartleson
University of Maryland

Abstract: An ecosystem simulation model was developed and calibrated to analyze plankton/benthos interactions and feedback processes for mesohaline Chesapeake Bay. Simulation experiments were used to investigate how changes in fish predation and benthic suspension-feeding (BSF) influenced food chain structures and bottom-water oxygen (o_2) concentrations. Decreased anchovy predation stimulated copepod growth causing a 10% decline in mean bottom-water (o_2) levels, while increased menhaden herbivory led to larger (20%) improvements in bottom water. o_2 When confined to the littoral zone, increased BSF resulted in higher bottom o_2 (because of algal cropping); however, enhanced BSF over the whole bottom (littoral plus profundal) caused decreased bottom o_2 (because of stimulated nutrient recycling). Increased nutrient recycling also made BSF less effective under conditions of reduced nutrient loading to the estuary. Similar ecosystem feedback effects were analyzed for interactions between dissolved inorganic nitrogn (DIN), algal growth, o_2 depletion. and coupled nitrification-denitrification (ND). By doubling ND rates. modest decreases in lower-layer DIN and phytoplankton biomass were induced. causing a 20% increase in bottom o_2 Conversely. when summer bottom water o_2 levels were forced to remain above 2.0 mg 1^{-1} via vertical diffusion, summer ND rates were significantly increased, resulting in higher DIN and algal pools. While the changes in bottom-water oxygen resulting from altered denitrification rates or predation by planktivorous fish and benthic invertebrates were relatively small, most were similar to those expected from expensive nutrient input reduction management scenarios.

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EUTROPHICATION EFFECTS ON SAV RELATIVE TO HABITAT RESTORATION GOALS: A MODELING STUDY

C. J. Madden and W. M. Kemp
University of Maryland

Abstract: A numerical simulation model was developed and calibrated for the lower Patuxent River shallow littoral zone. The region, formerly inhabited by a thriving submerged aquatic vegetation (SAV) community of *Ruppia, Potamogeton, Zostera, and Zannichellia* sp., has recently lost virtually all submersed macrophyte cover. The purposes of the model were to elucidate ecosystem processes responsible for the decline of SAV; determine effects of eutrophication on SAV survival; and predict results of nutrient input management strategies. The present model, with 16 state variables, realistically simulates the effects of suspended particulates and phytoplankton on PAR attenuation and Kd, reduction of PAR by epiphytic colonization on SAV leaf surfaces, and nutrient kinetics of SAV, phytoplankton, and epiphytes. When forced with nutrient conditions extant in 1968, the model successfully reproduced observed seasonal cycles and distributions of SAV, with maximum standing crop peaking at ~ 150 g C m^{-2} in August. Small incremental increases in DIN loading resulted in steep reductions in SAV biomass and growing season length; 50% DIN increase to current levels essentially extinguished SAV. Both phytoplankton and epiphytes responded to increased nutrient loading, amplifying nonlinear feedbacks in the system, and reducing PAR below the SAV compensation level. The magnitude of phytoplankton blooms in spring determined SAV growing season onset, while epiphyte density controlled mid-summer productivity and standing crop of SAV. The model predicts that a reduction of 33% DIN loading would restore *chlorophyll a*, DIN concentrations, and Kd to approximately Tier I habitat restoration criteria, resulting in re-establishment of a robust SAV community.

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Model Results to Test Nutrient Limitation and Their Role on Chesapeake Bay Anoxia

Arthur J. Butt
Virginia Department of Environmental Quality

Robert V. Thomann
Manhattan College

Abstract: The nation's largest estuary has fallen victim to excess nutrients causing eutrophication. Phytoplankton overproduction has resulted in depressed oxygen levels, making bottom waters unsuitable, sometimes lethal, to aquatic resources. Controlling excessive nutrient (nitrogen and phosphorus) loadings is the most widespread and serious problem facing Chesapeake Bay and its watershed. Improving water quality in the Bay through nutrient reduction is seen as a major goal of the 1987 and 1992 Chesapeake Bay Agreements. The Chesapeake Bay Three-Dimensional Water Quality Model (Model) was the principal tool used in the 1992 Reevaluation of the Nutrient Reduction Strategy. It successfully tracked mainstem Bay dissolved oxygen concentrations over time, providing a better understanding of the factors influencing its water quality and improving our ability to "predict" the consequences of various nutrient management scenarios.

Model results show that the decline in anoxia is approximately linear to TN load reductions, but is insensitive to TP reduction. This is counter to spring phytoplankton blooms in the middle region of the Bay that is phosphorus controlled. The purpose of this paper is threefold. First, to describe the fundamental processes of eutrophication in the Bay and discuss the contribution that excessive nutrients make to dissolved oxygen levels. Second, to discuss the importance of nutrient reduction location and its impact on the Bay's dissolved oxygen levels. For example, mid-Bay tributary nutrient reductions (Back River to the Potomac River) results in significant improvements to mainstem oxygen conditions but lower Bay tributary (Rappahannock to James River) nutrient reductions result in minimal mainstem oxygen change. Final discussion is directed toward management of water quality in the Bay through both phosphorus and nitrogen load reductions.