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THE EFFECTS OF TAURINE ON THE PRODUION OF HYPOCHLOROUS ACID BY HEMOCYTES OF THE OYSTER, *CRASSOSTREA VIRGINICA*

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Abstract: Hemocytes of the oyster, *Crassostrea virginica*, produce reactive oxygen intermediates (ROIs) to destroy foreign cells. ROI production is enhanced in hemocytes isolated from oysters infected with *Perkinsus marinus*. Mammalian phagocytic cells generate hypochlorous acid (HOCL), a major ROI species. Therefore, the increased quantity of ROIs generated by oyster hemocytes associated with infection may be substantially composed of HOCL. Taurine, a scavenger of HOCL, is normally present in high concentrations in oyster tissues. Therefore, taurine may be a scavenger of the HOCL produced by hemocytes and may regulate its effectiveness as a killing agent.

ROI production by blood cells can be measured by chemiluminescence (CL) augmented with luminol. Oyster hemocytes were incubated with taurine to determine if it inhibited the typical CL response. Extracellular taurine inhibited CL in a dose-response manner. A concentration of 1 mM caused 50% inhibition, while a 5 mM or greater concentration caused 100% inhibition. This suggests that oyster hemocytes generate HOCL as a major ROI component that may be affected by the taurine present in oyster tissues.

The concentration of taurine in the hemocytes, hemolymph, and gill tissue was quantified by HPLC. In comparison to gill tissue, the taurine concentration in the hemocytes was extremely low. The concentration of taurine per milliliter of hemolymph, however, was significant and fell within the range of concentrations observed to inhibit luminol CL. The taurine concentration in the hemolymph corresponded to that which caused a 20% inhibition of CL. This suggests that the amount of taurine in the hemolymph is sufficient to quench some of the HOCL generated by the hemocytes. Therefore, the effectiveness of HOCL production as a mechanism of defense in oysters against parasitic infection is questionable.

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Dairy Systems Integrated for Waste, Crop, Herd, and Water Quality Management

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Abstract: Data and system evaluations support the conclusion that Lancaster County farmers have completed the "greatest production agriculture experiment of the century. From 1960 to 1980, high producing dairy herds evolved that require integrated waste and cropland management items to protect the health of herds, flocks, families, and the Chesapeake Bay. They utilize newsprint and other cellulose wastes to increase the C:N ratio of manures to prevent excess nitrate, N.

While nitrate N leaching and high surface soil P were found for some fields, many others with higher yields were not adding excess nitrogen(N) or phosphorus (P) to ground and surface waters. From 1960 to 1980, dairy farms changed from herds on pasture, silage, grain, and hay produced on the farm to systems with corn silage and alfalfa hay being produced on the farm with feed grains and supplements being purchased. Milk cows in the County increased from 64,000 in 1960 to a high of 114,000 in 1986. Alfalfa acres increased from 39,000 in 1961 to 57,000 in 1988 with other harvested hay acres decreasing from 58,000 in 1961 to a low of 18, 000 in 1992. As cows and liquid manure systems increased, bedding per animal decreased. Over time, cropland received more manure nutrients containing less straw bedding. These changes led to the hypothesis that the C:N ratio of manures decreased as yields increased. Data, however, lead to the conclusion that crop yield increases resulted largely from increased available water holding capacity of the soils induced by manures plus bedding. Recommended additions of nutrients in amounts equal to their removal by crops do not take into account the fact that soil nutrient uptake efficiency by plants is only 50%. Changes should evolve with "operational land management Systems" replacing current emphasis on "best management practices".

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The Challenges of Vegetation Restoration Adjacent to Mechanical Draft Cooling Towers

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Abstract: The restoration of vegetation communities is an arduous task at best. Plant community restoration presents a number of unique challenges when attempting to create a community that truly functions as a natural system as well as adapting to site specific circumstances. A plant community restoration effort was employed at a unique microsite adjacent to the Baltimore Gas and Electric Brandon Shores Power Plant in Anne Arundel County, Maryland. The site is located adjacent to three mechanical draft cooling towers. Water from these cooling towers contains concentrated levels of many elements, including sodium, magnesium, and calcium. This restoration effort was preformed for erosion control purposes along the Patapsco River. In addition, the existing vegetation was showing signs of severe necrotic conditions.

The objectives of this study were to:

1. Assess the reasons involved with vegetation die back.
2. To develop a vegetation restoration plan for the site.
3. To assess the restored community.
4. To make future recommendations concerning projects of this type.

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MONITORING FOR THE PRESENCE OF ZEBRA MUSSELS BY THE STATE OF MARYLAND

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Maryland Department of Natural Resources

Abstract: Since their introduction in the mid 1980s, zebra mussels have spread rapidly throughout and outward from the Great Lakes region. Sightings have already been reported at Binghampton, New York, in the Susquehanna River basin, the largest source of freshwater to Chesapeake Bay.

In response to the potential for a zebra mussel invasion, the Maryland Department of the Environment (MDE), in coordination with the Maryland Department of Natural Resources, began monitoring for adult and larval zebra mussels in 1992. The objectives of this new monitoring effort are to provide early warning of zebra mussel introductions into Maryland's waters and to track the spread and effects of zebra mussels if they become established in Maryland.

Currently, monitoring is occurring monthly at 11 sites for the presence of zebra mussels. At 10 of these sites, benthic multi- plate sampling devices are used to check for the presence of adult mussels. Monitoring for larval zebra mussels occurred at some of these stations in 1993 using bridal veil sampling devices, but this monitoring was suspended because of vandalism problems. At the eleventh site, located at the mouth of the Susquehanna River, MDE monitors for the presence of larval zebra mussels only. All of the zebra mussel stations are located in areas that are considered to have a high probability of being exposed to zebra mussels and that are particularly important to Maryland's largest water users (e.g., water suppliers, industry, utilities). To date, no evidence of zebra mussels has been found in Maryland's waters.

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RESTORATION OF SEAGRASS MEADOWS USING *IN VITRO* PROPAGATED *RUPPIA MARITIMA*

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Abstract: The seagrass *Ruppia maritima* can be rapidly propagated using in vitro tissue culture methods. The best culture conditions for maximal propagation rates are f/2 nutrients or half strength MS nutrients, 3 mg/l 2iP (a cytokinin), 0-5 $^{o}/_{oo}$ artificial seawater and 1% sucrose. Vitamin supplements do not appear necessary. Room temperatures ranging from 20-27 ^{o}C appear satisfactory for growth. Either apical segments or intercalary segments work well for culture inoculation. Cultures can be directly transferred to peat pots and acclimated in a flowing seawater system. After acclimation, cultures can be transferred to the field. In a field trial in North Carolina, survival rate of transplanted seagrasses ranged from 20%-80% in the first year, but was less in the second year when the seagrass *Zostera marina* began to move into the experimental plots. Such cultures may also have value as bioassay indicator organisms that can be used to evaluate stressful environmental factors in the field.

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POTENTIAL FOR CONTROL OF THE ZEBRA MUSSEL, *DREISSENA POLYMORPHA*, BY THE BLUE CRAB, *CALLINECTES SAPIDUS*

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Abstract: Predation is an important controlling factor of community structure in aquatic systems. The success of introduced species like the zebra mussel, *Dreissena polymorpha*, is due in part to the general lack of effective predators in the newly colonized systems. We examined the community composition and measured mortality rates of a *Dreissena* population at a site in the middle portion of the Hudson River estuary, New York. Rocks collected in the field were sampled for density and size structure of the resident mussels. We also sampled along depth transects to determine vertical distribution. Predator exclusion experiments using rocks with a known number of *Dreissena* were used to estimate mortality. We tested the effectiveness of the blue crab, *Callinectes sapidus*, at consuming zebra mussels by presenting similar rocks to crabs in field enclosures. Field sampling in the months of June, July, and August indicated a dense (~30,000 m^{-2}) population composed almost entirely of one-year-old mussels. Mussel densities reached average densities less than two meters below the spring low tide mark. In cage experiments, we found that *Callinectes* caused mortality rates an order of magnitude higher than those measured for the local predator guild, which was primarily composed of finfish. The ability of *Callinectes* to consume large numbers of zebra mussels that we have demonstrated has important implications for areas such as Chesapeake Bay, where blue crabs are abundant and the threat of invasion by the zebra mussel remains high.

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SEDIMENT BOUND CCA-C LEACHATE 10-DAY REPEATED EXPOSURE TOXICITY STUDY TO *AMPELISCA ABDITA* UNDER STATIC CONDITIONS

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Abstract: The objective of this study was to demonstrate the effects of 10-day exposure to sediments mixed with leachate (seawater) from treated (CCA-C) and untreated wood pilings on the benthic amphipod, *Ampelisca abdita*. The biologic endpoints used to establish effects was organism survival during the 10-day exposure period. Leachate obtained during a 28-day (four 7-day intervals) period from CCA-C treated and untreated pilings was dosed onto two sediment types, high and low organic carbon sediments. The carbon characteristics of the sediment types were low OC (< 1% OC) and high OC (> 4% OC). *Ampelisca abdita* were exposed to sediment of each type dosed with one of three concentrations of leachate (i.e., 10%, 50%, or 100% leachate). During this study, the components of the CCA-C treatment, (copper, chromium, and arsenic) were measured during the preparation of the leachate, in sediment mixtures and in overlying and interstitial water in the exposure vessels.

Analyses for copper established that treated pilings released approximately 530mg/m^2 of exposed wood over 28 days. Mixing the leachate with LOC and HOC sediments resulted in absorption of copper in the LOC sediment and to a slightly greater degree in the HOC sediment. Analysis of water in the exposure vessels demonstrated that the copper bound to both the LOC and the HOC sediments remained bound and did not desorb into the interstitial or overlying water.

Analyses for chromium demonstrated that treated pilings generally released little or no chromium over 28 days. Mixing the leachate with LOC sediment resulted in negligible uptake of chromium into sediment and only a minimal amount of chromium absorbed to the HOC sediment. Analyses of the interstitial water in the exposure vessels demonstrated that chromium present in the sediment generally did not move into interstitial water but did move into overlying water from both LOC and HOC sediments.

Analyses for arsenic demonstrated that approximately 60 mg arsenic/m^2 of treated wood surface area leached from the treated pilings. Arsenic did not appear to absorb onto sediment of either type and, in almost all cases, was not observed in interstitial or overlying water.

Comparison of the survival data for the exposures conducted from the untreated and treated wood pilings and the survival of the organisms maintained under control conditions established that leachate from untreated wood pilings adversely affected organism survival while leachate from CCA-C-treated wood pilings did not adversely affect organism survival. The primary constituents of the CCA-C-treated wood pilings were not present in the leachate at concentrations that would adversely affect the survival of the organisms.

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HAYMOUNT: AN ECOSYSTEM APPROACH TO PRIVATE DEVELOPMENT

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Abstract: As the Chesapeake Bay region braces for an explosion of population growth, a private developer has embarked on one of the most environmentally responsible communities ever proposed. Adopting an ecosystem approach, the developer has created an environmental program without borders, a program that takes responsibility for the impact of the community not only within the town boundaries, but on a regional and global scale as well.

Located on Virginia's Rappahannock River, Haymount represents a holistic approach to sustainable design, reaching beyond the project borders into the indirect impacts of the community on the environment. It combines a program for natural resource protection and pollution prevention with a transportation program and a strategy for promoting a vital community life. The project demonstrates that environmental protection can be accomplished proactively in the context of local community goals of economic development, affordable housing, and related issues.

The form of the project, based on cluster planning that develops less than one-third of the site and preserves large areas of natural habitat. Containing development in this manner results in a town density that facilitates pedestrian access to community. Pedestrian life is the paradigm around which the town is designed. Residents' daily needs can be met within a five-minute walk. The town's compactness provides the opportunity for an integral transportation program that assists in further reducing air emissions and rainwater runoff.

Haymount includes advanced applications of environmental technology for wildlife and forest management, wastewater treatment, stormwater management, organic farming, and sustainable development.

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A Research Plan for the Mid-Atlantic Regional Marine Research Program

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Abstract: The Regional Marine Research Program (RMRP) was developed to set priorities for regional marine and coastal research in support of efforts to safeguard water quality and ecosystem health, and to carry out such research through grants and improved coordination. The program established the following nine regions: (1) Gulf of Maine, (2) Greater New York Bight, (3) Mid-Atlantic, (4) South Atlantic and Caribbean, (5) Gulf of Mexico, (6) Southwest, (7) Pacific Northwest, (8) Alaska, and (9) Insular Pacific.

The Mid-Atlantic region extends from Cape May, New Jersey to Cape Fear, North Carolina and includes the Delaware Bay, Chesapeake Bay and the Albemarle-Pamlico Sound system. The research plan for the Mid-Atlantic RMRP was submitted in February 1994 and is available for review. The plan identifies priority research needs for the Mid-Atlantic region such as (1) land-use effects on living resources, (2) euthrophication, algal blooms, and anoxia, (3) fishery yields, recruitment, and trophodynamics, (4) biotic and material exchanges between estuaries and the ocean, and (5) coastal erosion and climatic effects. The plan also includes a discussion of regional management issues, a review of the environmental quality of coastal waters and expected trends in the Mid-Atlantic region, and a review of research being conducted within the region. A comprehensive research inventory database for the 1992-96 time period is available for reference upon request.

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RESPIRATORY RESPONSES OF BLUE CRAB, *CALLINECTES SAPIDUS*, TO AMBIENT HYPOXIA

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Abstract: Blue crabs occur on the East and Gulf coasts of the United States in bays and low salinity estuaries that frequently become hypoxic at temperatures of 25-30° C in the summer. Blue crabs are able to compensate for hypoxia under laboratory conditions, but it is not clear that compensatory mechanisms are effective under natural conditions. The effect of the molting process on respiratory function during hypoxia is of particular concern for natural populations. In addition, most laboratory investigations have used large male crabs. As a result, few data exist on smaller crabs that inhabit the shallow waters where temperature and oxygen vary by as much as an order of magnitude. Respiratory function was measured in blue crabs under moderate hypoxia (50 to 100 mmHg) at 25° or 30° C, low salinity.

Hemolymph oxygen, pH, and carbon dioxide were not maintained, even under modest hypoxia, indicating that these ambient conditions may compromise the oxygen delivery system of blue crabs under these conditions.

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TRENDS IN WATER AND HABITAT QUALITY IN THE CHOPTANK ESTUARY

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Abstract: The Choptank River Estuary, located on the Eastern Shore of Maryland, drains a 700 mi^2 watershed that is approximately 60% agricultural. The Choptank is subject to high nonpoint source nutrient loads from agricultural land as well as point-source loads from two major wastewater treatment facilities. High nutrient and phytoplankton concentrations, along with high turbidity, characterize the upper portion of the estuary. Occasional low bottom dissolved oxygen concentrations characterize the deeper portions of the lower estuary. Near Cambridge, the submerged aquatic vegetation habitat is impacted by high suspended solids and limited light penetration. Aerial surveys have revealed a widely fluctuating distribution and abundance of submerged aquatic vegetation over the last decade.

Trends in total phosphorus, orthophosphate, total nitrogen, dissolved inorganic nitrogen, bottom dissolved oxygen, secchi depth, and chlorophyll were examined at three tidal stations and one nontidal station where regular monitoring has occurred from 1974 through 1993. The data were corrected for freshwater flow and examined using seasonal Kendall's trend analyses. The results indicate that few changes have occurred over the past two decades.

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Use of Grass Carp for Control of Nuisance Aquatic Vegetation in the Chesapeake Bay Watershed: A Chesapeake Bay Program Critical Issue Forum

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Ronald Klauda, Robert Lunsford, and Alan Haft
Maryland Department of Natural Resources

Daniel Terlizzi
Maryland Sea Grant

Abstract: Grass carp (*Ctenopharyngodon idella, Cyprinidae*), native to Asia, were introduced to the United States in 1963 for biocontrol of nuisance aquatic vegetation in freshwater ecosystems. Subsequently, grass carp have established self-sustaining populations in several rivers, most notably the Mississippi and Missouri rivers. By consuming large quantities of vegetation, grass carp can have a direct impact on aquatic ecosystems. In Chesapeake Bay, there is concern that naturalized grass carp could escape from stocking sites and further deplete communities of submerged aquatic vegetation in the upper estuaries. Successful management of aquatic species in large river systems requires a high degree of cooperation among jurisdictions. Of the six states in the Chesapeake Bay basin, Maryland alone does not permit the introduction of grass carp. While the permitting states are unanimous in allowing only triploid fish, there is a high degree of variability among states in the review and oversight of permitted introductions. In January 1994, the Living Resources Subcommittee of the Chesapeake Bay Program sponsored a forum, Pros and Cons of Stocking Triploid Grass Carp in the Chesapeake Bay Basin, to discuss state policies, the federal triploid certification program, stocking protocols and effectiveness, and the potential for grass carp to adversely affect aquatic vegetated communities of the basin. In addition to a common collection of insights applicable to future decisions concerning triploid grass carp, the forum will also result in recommendations for increasing the level of consistency and cooperation among programs that permit grass carp in the basin states.

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WINTER DISTRIBUTION AND ABUNDANCE OF WATERBIRDS IN OFFSHORE WATERS OF THE CHESAPEAKE BAY

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Abstract: From December 14, 1992 through March 3, 1993, we conducted the first comprehensive winter survey of migratory waterbirds using the open waters of Chesapeake Bay. The survey, designed to capture the full extent of habitat use within the Bay, covered over 6% of the Bay's surface based on 160 east-west transects representing over 5,000 kilometers of survey flight lines. Two, sixty meter wide strips were counted on each side of a Cessna 185 aircraft on floats from an altitude of 140 feet. Positions are obtained for each sighting with the use of a global positioning system allowing us to map the distribution of waterbirds.

This survey design allows us for the first time to estimate populations in the mainstem of the Bay. We estimate about 115,000 surf scoters, 90,000 oldsquaw, 80,000 ring-billed gulls, 70,000 herring gulls, 40,000 goldeneye, 60,000 bufflehead, 45,000 red-breasted mergansers, 26,000 black scoters, 15,000 white-winged scoters, and 12,000 red-throated loons inhabiting the Bay. In contrast, recent mid-winter waterfowl surveys counted only 14,000 oldsquaw and 10,000 scoters. The survey is a useful management tool for providing the Chesapeake Bay Program with current geo-referenced information on wintering migratory waterbirds.

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Biological Temporal Trends in the State of Maryland's Core Stations

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Abstract: Benthic macroinvertebrate communities have been sampled at 27 of the state's core monitoring stations since the mid-1970's. In general, the benthic samples have been collected once a year during the spring to summer months at each core station using a surber sampler or Folner modified Hester Dandy multiplate sampler.

With this database of 10-20 years worth of macroinvertebrate community information the temporal trends at each core station were evaluated using four selected parameters: taxa number, Shannon-Weiner diversity index number, modified Hilsenhoff Biotic index number, and percentage of ephemeroptera, plecoptera, trichoptera (EPT). These parameters were analyzed for significant correlations with time utilizing two nonparametric statistical tests. The null hypothesis is that there is no significant change over a certain number of years for each parameter measured.

An in-depth evaluation of the biological temporal trends of the27 core stations using nonparametric statistical analysis in conjunction with the raw, calculated, historical, and field data is included in the discussion. The information is presented using eight different subbasins to group the core stations. Briefly, the results indicate that 18 of the core stations had an improvement (although some were slight improvements), 8 core stations remained relatively the same, and only 1 station had some degradation in terms of benthic macroinvertebrate communities.

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INTRODUCTION AND SPREAD OF A PARASITIC CASTRATOR IN CHESAPEAKE BAY: *LOXOTHYLACUS PANOPAEI* (CIRRIPEDIA, RHIZOCEPHALA) INFECTING MUD CRABS (BRACHYURA, XANTHIDAE)

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Abstract: The parasitic barnacle *Loxothylacus panopaei* provides one of the best documented examples of the introduction and spread of exotic species in Chesapeake Bay. Rhizocephalan infections castrate the host, with major consequences for host population reproductive success. *L. panopaei* was introduced into the lower Bay in 1963-64, when infected mud crabs *(Eurypanopeus depressus)* were coincidentally imported with oysters from the Gulf of Mexico. By the late 1960s, the parasite was common in *E. depressus* (10-70%) and *Rhithropanopeus harrisii (0-87%)* throughout the lower Bay, reaching the Potomac in the mid-Bay but not the upper Bay. By 1983, the parasite had also spread to infect a third host species, *Neopanope sayi* (0-8%), in the lower Bay. Salinity tolerance of the parasite (10°/oo) did not limit parasite dispersal up the Bay, because extensive areas of the mesohaline zone remained uncolonized while the parasite extended to nearly 5°/oo in lower Bay tributaries, and because high salinities during the 1980s drought did not appear to alter the rate of spread. The parasite arrived in the lower mesohaline zone (Rhode River) in 1989, producing outbreak infections of 70-90%. This outbreak reflects a 30 yr lag in parasite dispersal from initial introduction to 200 km up the Bay, with the upper 100 km in mid-Bay taking 20 yr. These epidemic outbreaks in the Chesapeake are compared with our long-term measures of this host-parasite interaction at several spatial and temporal scales along the East coast of North America. Although this parasite has limited larval dispersal, it's inadvertent introduction into the Chesapeake and spread among host species provides a model warning against the continued transport of species among coastal regions.

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DEVELOPMENT OF STRATEGY FOR MANAGING LOW FLOW INTO THE CHESAPEAKE BAY

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Susquehanna River Basin Commission

Abstract: The Susquehanna River Basin Commission has been concerned for some time about the effect of low flows from the Susquehanna River, and changes in low flows, on the salinity, water quality, available habitat, and living resources of the Chesapeake Bay. Previous studies have shown that natural droughts and future consumptive uses will have a significant impact on living resources. However, these studies have not provided sufficient information for the management of low flows. These previous studies recommend additional studies to develop quantify effects of low flows and changes in low flows on the Bay. These effects need to be quantified in order to accomplish goals of the Chesapeake Bay Agreement, the Commission's comprehensive plan, and the Commission's consumptive use makeup regulation. At present there is no clear strategy for studying and managing the effects of low flows and modifications of low flows. The Commission has obtained funding from the Chesapeake Bay Program to develop a strategy.

The study procedures are described and a progress report is included in our paper.

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USE OF A THREE-DIMENSIONAL TRANSPORT MODEL TO PREDICT THE DISTRIBUTION OF A CANDIDATE VIRAL INDICATOR (FRNA COLIPHAGE) OF FECAL POLLUTION FROM A LARGE POINT SOURCE OF SEWAGE EFFLUENT: INITIAL STUDIES TO COMPARE MODEL PREDICTIONS WITH FIELD DATA

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Abstract: Discharges from sewage treatment plants (STPs) represent the largest potential inputs of pathogenic human enteroviruses to shellfish waters. Accordingly, buffer zones contiguous with STP discharges are required within which shellfish harvesting is not permitted. These closures represent the largest proportion of harvest-limited acreage, ranging from 67% in the Northeast to 44% in the Middle Atlantic. Despite the significance of this closure type, the size and shape of buffer zones are usually not based on either physical processes or microbiological data, and certainly not on health risk. These facts and the inadequacies of the fecal coliform indicator stimulated efforts to study a bacteriophage indicator of enteric viruses and to utilize a fully three-dimensional circulation and transport model to (1) predict the distribution of the pollutant field from an STP in the James River, (2) to compare the predicted distribution with field densities of the target viral indicator, and (3) to calibrate the model based on these data. Field samples collected along a gradient from the STP under seasonal conditions consisted of water, sediment, and deployed shellfish. A rapid recovery method was developed for enumeration of FRNA coliphages in water. Densities of fecal coliforms were also determined. First year results suggest the bacteriophage indicator does not behave as a conservative element, and its observed absence or low densities in the water column and sediment "downstream" of the STP may not necessarily reflect reduced health risk because FRNA coliphages were recovered along this gradient in caged shellfish deployed as biomonitors.

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Submerged Macrophyte Transplant Success in Upper Chesapeake Bay and Prospects for Future Applications

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Abstract: Throughout the world, submerged macrophyte populations are disappearing where water quality declines, habitats are degraded, and sea levels rise. Increasingly, the feasibility of using restoration ecology as a means to rectify these conditions is being explored.

Between 1984 and 1989, nearly 350,000 submerged macrophytes were planted or transplanted into the waters of upper Chesapeake Bay, utilizing six different species. Over 60 sites in three major river systems were tested, and water quality analyses were included for four of those years. Techniques evaluated included type of stock (root stocks versus actively growing plants or seed), fertilization, season of transplant, origin of plant stock, species of preference, exclosure performance, sediment requirements, planting densities, and site selection criteria. Of the 60 sites utilized, short-term success was achieved at 15 and long-term success (three years or more) at 8 of the sites.

The species of choice was *Vallisneria americana*, with *Heteranthera dubia* and *Ceratophyllum demersum* doing well under more restricted conditions. Success was achieved only near the mouths of rivers where water quality was the best available or where some form of sheltering influence reduced wave or current energies. Ideal depth profiles were from 0.5 to 1 meter MLW and the best sediments were sandy silts with approximately 5% organic matter. Secchi depths averaged >0.8 m (Kd < 2.0), *chlorophyll a* values were <15 µgm/l, and orthophosphate concentrations were generally < 0.02 mgm/i where transplant success was highest.

As sea levels continue to rise and such needs as dredge spoil disposal require attention, it may be possible to modify bottom regimes to accommodate establishment of submerged macrophytes. The information and criteria described here should assist in making such determinations in fresh and oligohaline waters.

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Hierarchical Modeling of Groundwater in Support of Nonpoint-Source Pollution Assessment in Chesapeake Bay Ground/Watersheds

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U.S. Environmental Protection Agency

L. Joseph Bachman
U.S. Geological Survey

Abstract: Groundwater enters the Chesapeake Bay through two major pathways: (1) as base flow in streams and nontidal tributaries; and (2) as direct seepage to tidal coastline and bottom-sediment interfaces. Monitoring of the tributary load of nutrients and toxic substances is feasible yet expensive. Measurement of direct seepage along the entire tidal coastline is not technically or economically feasible at this time. A stepwise and progressive groundwater modeling approach is demonstrated using the analytic element method (AEM). The ARC/INFO Geographical Information System (GIS) is used to organize spatial data and to create coverages that include AEM model results. The groundwater flow models incorporate steady state and average groundwater conditions, regional estimates of recharge, and average hydraulic conductivities. The models represent a range of scales and resolutions, based on supraregional (1:250,000), regional (1:100,000), and local (1:24,000) map data. The supraregional scale assessment separates the Chesapeake Bay drainage basin into two provinces at the Fall Line: (1) the Piedmont province, characterized by lithified and fractured rock aquifers; and (2) the Coastal Plain province, characterized by unconsolidated water table aquifer. The regional-scale model of the Patuxent River basin compares the surface-watershed boundary, which is topographically defined, to the groundwatershed boundary, which is water-table defined. The local scale model compares AEM water-table contour maps to observed static water levels at the U.S. Geological Survey's Jefferson Patterson Park research site in the Patuxent River basin, Calvert County, Maryland. Future research will focus on interfacing the AEM groundwater modeling with a hydrogeomorphic landscape classification that will relate concentrations in the groundwater to land-use.

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BIOLOGICAL PERFORMANCE OF *CRASSOSTREA GIGAS* IN MESOHALINE WATERS OF MARYLAND

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Abstract: Seasonal growth, meat condition, mortality, disease prevalence, and disease intensity of *Crassostrea gigas*, and *C. virginica* placed into an ambient-flowing water system at Deal Island, Maryland (Tangier Sound) was described for four summers, 1989-1993. Oyster hatchery conditioning tanks received ambient Tangier Sound water ranging from 11 to 21 ppt and 80 to 300C that was chemically treated prior to discharge into a sand pit. Three groups of *C. gigas* were from west coast hatchery-reared stocks, and one group from a genetically altered population deployed in Virginia and New Jersey waters. *Crassostrea virginica* were from populations in the upper Potomac River, and hatchery-reared stocks from Maine. Samples of *C. virginica* and *C. gigas* tested negative for Dermo and MSX prior to deployment.

Both species experienced relatively high mortality (15% to 90%) each summer. Mortality in *C. gigas* appeared to be mediated by nonspecific disease entities, with the exception of 1990 when an epizootic of *Nocardia* occurred in west coast oysters. Growth of C. *gigas* was poor, exhibiting 5% to 40% increase in shell height. Meat quality of surviving *C. gigas* was poor and inner surfaces of shells were fouled with mud deposits and heavy infestations of *Polydora*, rendering the oysters unmarketable. *Crassostrea virginica* contracted epizootic levels of *Perkinsus marinus* each year, and MSX invaded *C. virginica* in the hatchery system in 2 out of 4 years.

MSX was not detected in *C. gigas* and Perkinsus infections were at low prevalence and low intensity when observed. Based on the performance of *C. gigas* in the mesohaline waters of Tangier Sound, the species is not recommended for commercial aquaculture or rehabilitation of natural oyster beds in Maryland waters.

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The Productivity/Biomass Index-A Quantitative Method of Qualitatively Ranking Sampling Stations in the Chesapeake Bay Water Quality Monitoring Program

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Academy of Natural Sciences

Abstract: Chesapeake Bay is a complex system, composed of a number of subestuaries, each of which has unique chemical and physical characteristics that ultimately cause different biological reactions. Two important differences are the loadings and species of nutrient and the amount of light (reflected by the suspended particle loading) available to the phytoplankton assemblage for photosynthesis. In an attempt to rank the various regions within Maryland's portion of Chesapeake Bay for the Maryland Department of the Environment, from the standpoint of phytoplankton enrichment, an index has been developed. Estimates of integrated primary productivity, *chlorophyll a* and phytoplankton carbon are utilized in this ranking index for the fourteen primary sampling stations. Results from 1992 data indicate that (1) two stations heavily impacted by nutrient additions (Baltimore Harbor and tidal fresh Patuxent River) rank the highest in the productivity/biomass index, (2) five sites in the mesohaline mainstem Bay or Western Shore tributaries were ranked slightly behind the aforementioned stations, and (3) stations located in the oligohaline regions of the Bay and its tributaries were characterized by the lowest phytoplankton enrichment in the P/B index. Further analyses will focus on temporal and spatial changes in the ranking system during the study period, 1984-1993. These results will be useful in assessing phytoplankton response to changing nutrient concentrations between and within subestuaries over time in Chesapeake Bay.

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INTER- AND INTRA-ANNUAL VARIABILITY IN PHYTOPLANKTON SPECIES COMPOSITION IN THE PATUXENT RIVER ESTUARY

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Abstract: From 1982 to the present, phytoplankton samples and physical data (temperature, salinity, and pH) have been collected approximately weekly from the Patuxent River, a subestuary of Chesapeake Bay, at Benedict, Maryland. Compiled data of cell densities in the Patuxent River from 1982 to 1993 show an overall yearly pattern of phytoplankton distribution, with a winter peak of cell density generally occurring in January and February, caused by dense blooms of the dinoflagellate *Katodinium rotundatum*, in conjunction with cryptophytes. A spring bloom consisting mostly of diatoms usually appears in April and May. During summer and early fall, extended blooms of centric diatoms, flagellates, and cyanophytes occur. Superimposed upon this general pattern, however, is great inter-annual variability in the extent and timing of these blooms, often with the absence and then appearance of certain species from year to year. For example, the usually predictable winter bloom of *Katodinium* did not occur in 1983, 1984, 1985, and 1991, and the bloom in 1992 was smaller and displaced downriver. Although there is a spring bloom every year dominated by *Skeletonema costatum*, other diatoms vary greatly in cell density for any given year, such as *Rhizosolenia fragilissima*, which only bloomed in 6 of the 12 years sampled, and *Cerataulina pelagica*, which bloomed in 4 years. The extent and timing of these blooms can be attributed to changes in river flow, temperature, and salinity that are common within a dynamic estuarine system, but may also be affected by biological variability or other unknown factors.

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Management of Chesapeake Bay Resources: Governmental Organization and Interest Group Interaction

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American University

Abstract: This paper reviews current programs and issues while attempting to highlight emerging strategies to deal with future problems. In particular, it analyzes the programs of the Chesapeake Bay Foundation and the organization's interactions with Federal, State, and local governments.

Based on research done during my recent sabbatical as well as ongoing observations, I present an overview of the Chesapeake Bay Program organization and the key actors, including U.S. Environmental Protection Agency, other federal agencies and the four states, local governments, and other government entities, such as the Maryland Critical Areas Commission. The unique nature of the Chesapeake Bay Program Office is explained as well as the three key government levels—career staff on the Implementation Committee, political appointees on the Principals Staff Committee, and elected officials on the Chesapeake Executive Council.

I also look at the influential Chesapeake Bay Foundation and its evolving role, from watchdog to outside partner, as it has recently adopted a more cooperative stance with the Chesapeake Bay Program. Finally, I assess the current agreements and accomplishments as well as future challenges.

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Enhancement of Wet Deposition Estimates to the Chesapeake Bay Watershed Using Modeled Precipitation Inputs

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Environmental Resources Research Institute

Abstract: Accurate determination of spatial patterns in the chemical composition of wet deposition is essential for assessing the impacts of wet deposition on the Chesapeake Bay and its tributaries. Limited spatial density of national and regional monitoring networks requires that point estimates of wet deposition be extrapolated to describe their distribution over the entire watershed. Application of spatial interpolation algorithms have yielded nitrate deposition estimates that differ from field observations by more than 35% in mountainous terrain in the eastern United States. Such errors might actually obscure surface deposition features across much of the Bay's watershed. Because the distribution of precipitation in mountainous terrain is influenced by topographic features, incorporating topographic information into models describing the spatial distribution of precipitation should improve their accuracy. A three-dimensional interpolation model that allows for the estimation of precipitation volumes at any point for any month or seasonal summary period has been developed for Pennsylvania utilizing digital elevation data and measured precipitation volumes at 135 National Oceanic and Atmospheric Administration and 62 U.S. Geological Survey monitoring sites. The "topographically-refined" estimates of precipitation, when combined with estimates of nitrate concentrations in precipitation interpolated from regional and national network sites, yielded a 53% reduction in mean absolute error and a 55% and 79% reduction in mean percent error and mean squared error, respectively, in nitrate deposition for seven monitoring sites not included in model construction. Application of this modeling approach to the Chesapeake Bay watershed would increase significantly the spatial resolution of wet deposition estimates into this valuable estuary and subsequently enhance environmental impact assessments.

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Onshore-Offshore Pattern and Variability in Distribution and Abundance of Bay Anchovy, *Anchoa mitchilli*, Eggs and Larvae in Chesapeake Bay.

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Center for Environmental and Estuarine Studies

Abstract: The spatial pattern and daily variability of the onshore-offshore distribution and abundance of bay anchovy, *Anchoa mitchilli*, eggs and larvae were determined from four days of repetitive ichthyoplankton sampling on a transect in mid-Chesapeake Bay during July 1988. Ichthyoplankton samples were collected at eight stations in two depth strata with a 60-cm bongo net sampler. Abundances of anchovy eggs and larvae differed greatly among stations on the transect. Eggs and small larvae (< 5.5mm SL) were 30-200 times more abundant offshore than at inshore and frontal regions. The offshore region, near the Bay channel, was the primary bay anchovy spawning region. Mean larval lengths and relative (but not absolute) abundances of large (> 5.5mm SL) larvae increased in an offshore-to-inshore direction. Mortality rates for both small and large larvae were highest offshore. A simulation model was unable to demonstrate that these distributions resulted from the transport of larvae inshore. Biovolumes of gelatinous predators which may consume anchovy eggs and larvae, and densities of zooplankton that could serve as larval anchovy prey, tended to increase in the frontal region, although not significantly so ($P > .05$). In view of the offshore region's immense volume, its standing crop of anchovy eggs and larvae was as much as 69 times higher than in the other two regions. Consequently, possible favorable transport of anchovy larvae to the inshore and frontal regions, or possible growth enhancement there, may have little overall effect upon Baywide recruitment.

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GEOGRAPHICAL DISTRIBUTION OF A WESTERN PACIFIC BRACHYURAN CRAB, *HEMIGRAPSUS SANGUINEUS*, ALONG THE EAST COAST OF THE UNITED STATES

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Abstract: An ovigerous female of this Asiatic grapsid crab, *Hemigrapsus sanguineus*, was discovered in 1988 in the upper intertidal of a rocky location along the coast of New Jersey. Research since then has shown that it is well-established and breeding prolifically along this coast, where it occupies a vertical niche that has not been exploited by other native brachyurans. Recent studies have shown that it extends at least to Woods Hole, Massachusetts, south into Delaware, and also inside the entrance to Chesapeake Bay. Thus the species has a latitudinal distribution of at least 675 kilometers. In Chesapeake Bay, two mature crabs (male and female) were collected in the middle of June 1993, along a rock jetty leading into the harbor of Cape Charles, Virginia. This was the only site explored in the Chesapeake. Rocky locations in the inner estuaries have not yet been investigated, but it is likely that *H. sanguineus* has invaded such areas, because studies in Japan and my own studies have shown that it is capable of survival at salinities at least down to $10\ ^{0}/_{00}$. The possible implications of this exotic introduction, especially with regard to the Chesapeake Bay, are discussed.

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DEVELOPMENT OF EPA'S PESTICIDE ECOLOGICAL TOXICITY DATABASE: APPLICABILITY, PROBLEMS, AND PRESENT STATUS

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Abstract: In 1991, initial plans were developed with the Chesapeake Bay Program to create a computerized database of acute and chronic toxicity values contained within OPP ecological effects data files. The terrestrial and aquatic organism data include plant data as well as vertebrate and invertebrate studies. The pesticides were originally prioritized according to the most recently collected pesticide use surveys for Pennsylvania, Virginia, and Maryland counties within the Chesapeake Bay watershed. The need for such a comprehensive and current source of scientifically reviewed toxicity studies has become readily apparent with increased requests from other government agencies for information contained within the database. As a result, the Ecological Effects Branch sought and has received additional funding to continue this effort. The present database contains over 5,500 individual study reports on over 240 registered pesticides which comprise a major component of the nation's present agricultural and industrial pesticide use. Eventually the database is expected to expand to over 12,000 toxicity records for up to 600 pesticide active ingredients and formulations. Nationwide access through a Pesticide Information Network operating on existing computer networks is envisioned within two years.

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HEAVY METAL INPUTS INTO THE CHESAPEAKE BAY: WHAT THE SEDIMENTS TELL US

Michael Owens and Jeffrey Cornwell
Center for Environmental and Estuarine Studies

Abstract: Studies using dated cores have shown a large increase in metal concentrations and input fluxes during the early part of the 20th century. Cores collected in the mid-1970s showed that heavy metals such as lead, zinc, and copper had their highest concentrations close to the sediment-water interface. In the intervening decades, one goal of environmental regulation has been to decrease the amount of trace metal deposited in Chesapeake Bay. Cores from mid-Bay marsh and subtidal sediments were dated with ^{210}Pb and analyzed for iron, manganese, copper, lead, cobalt, zinc, and nickel. Lead profiles showed large increases in metal concentration from the beginning of the century to the 1970's, and a large decrease in more recent years. The copper and zinc profiles are similar to the lead profiles, with peak concentrations occurring several years prior to the lead peak. All other metals analyzed showed relatively constant inputs. This study shows that significant progress has been made in decreasing trace metal contamination in the mainstem of Chesapeake Bay.

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Evaluation of Manure Management Policies on Virginia Dairy Farms: Identifying Cost/Nutrient Abatement Trade-offs

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Abstract: Efforts to reduce nitrogen and phosphorus loadings from concentrated livestock operations to ground and surface water supplies suffer from lack of information on farm costs and abatement effectiveness of proposed policies. This research explores cost/abatement trade-offs of manure management policies for dairy farms in Rockingham County, Virginia, the state's most important dairy and poultry production county.

Possible manure management restrictions that have been suggested or implemented in some states include (1) restrictions on nitrogen and phosphorus amounts added to soils by manure and commercial fertilizer applications; (2) restrictions on timing of manure applications; and (3) farm manure storage requirements. In this analysis, each alternative manure management policy's impacts on field-level nutrient losses and crop yields are estimated under representative weather conditions with the Erosion Productivity Impact Calculator (EPIC) simulation model. Baseline and policy-affected financial performance are estimated for representative farms of 60, 100, and 150 dairy cow herd sizes and with/without poultry enterprises using the Farm Level Income and Policy Simulator (FLIPSIM) simulation model. Financial performance is evaluated through changes in net returns, net asset value, and probability of economic survival over the simulated period.

Comparative farm-level adjustment costs are related to nitrogen and phosphorus nutrient abatements in order to estimate cost/abatement trade-offs for each farm size. Dairy industry and broader regional economic impacts are estimated from aggregated farm-level impacts.

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PERKINSUS MARINUS: TRIGGERING MECHANISMS FOR EPIZOOTICS

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Center for Coastal Physical Oceanography

Abstract: *Perkinsus marinus* is one of the crucial factors controlling population abundance and productivity of oyster (*Crassostrea virginica*) populations. A computer model was used to examine the factors which trigger *P. marinus* epizootics. Epizootics are triggered by three general classes of environmental and biological perturbations: factors affecting food supply, factors affecting environmental characteristics, and factors affecting the supply of juveniles in the populations. Most simulated epizootics followed a typical time course. The conditions triggering the epizootic occurred and disappeared well before (as much as 18 months before) the initiation of mortality in the population. Once started, most epizootics progressed more or less rapidly toward population extinction. No internal mechanism was available to limit their time course. Stopping an epizootic required reducing the infection intensity in the submarket-size adults and subadults in the population.

Our simulations suggest that a principal mechanism is a large recruitment event that would dilute *P. marinus* in that portion of the population, although it would not affect the infection intensity of the market-size adults, which is maintained at a relatively stable level by the death of heavily infected individuals. Infection intensity of the market-size adults does not need to be reduced to stop an epizootic nor does it need to be raised to start one. Reducing the rate of replacement of market-sized individuals that die is sufficient. In the common case where prevalence exceeds 60% and infection intensity rises to 3% or more during the summer months, most oyster populations suffer adult mortality due to *P. marinus*. Stability is maintained by an adequate rate of replacement of adults to minimize the effect of these losses on adult density and population fecundity. Accordingly, our simulations suggest that the key to triggering an epizootic is to raise the infection intensity in the subadult and submarket-size adult portion of the population, and the key to stopping an epizootic is to reduce infection intensity in that same portion of the population.

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Geographic Variations in Nitrogen Loading within the Patuxent River Basin, Maryland

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Abstract: Excessive nutrient loading continues to threaten the water quality and economic vitality of Chesapeake Bay. Efforts to reduce fluvial nutrient loading have emphasized the reduction of point-source loads, but further reductions may require emphasis on nonpoint-source (NPS) loads. Because of concern over NPS nutrient loading, the U.S. Geological Survey, in cooperation with the Maryland Department of the Environment, began a study of the Patuxent River watershed. The purpose of the study is to quantify nutrient loads from various subbasins and to gain additional insight into the relation between land use and water quality. To achieve these goals, an intensive data collection effort has been established that includes the compilation of hydrologic, meteorologic, geographic, and water quality data for the Patuxent River watershed.

Water quality sampling locations are representative of subbasins with specific predominant land uses in the Piedmont and Coastal Plain physiographic provinces. Preliminary evaluation of the data collected so far reveal significant differences in the amount and form of nitrogen in subbasin streams. Total nitrogen concentrations were highest at stream sites in the Piedmont, and nitrate was the predominant form of nitrogen. Dilution of nitrate during periods of runoff implies that groundwater may be the primary source of nitrate in streams at two of the Piedmont sites. Land use in the Piedmont is largely agricultural, and nitrate concentrations in groundwater can be elevated because of agricultural activity. Total nitrogen concentrations, and the percentage of total nitrogen in the form of nitrate, were lower in the Coastal Plain streams than in the Piedmont streams. Land use in the Coastal Plain subbasins is largely forested and nitrate dilution during storms was not as apparent as it was in the Piedmont. Thus, groundwater is a less significant source of nitrogen in the Coastal Plain subbasins than it is in the Piedmont subbasins.

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Long-Term Changes in the Acidity of a DeKalb Forest Soil in the Mid-Region of the Susquehanna River Watershed

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Abstract: Forest soil acidification has been reported to result in reduced forest productivity and forest decline. Soil acidification and forest decline may trigger changes in nutrient cycling in forest ecosystems, with important consequences for drainage water chemistry and aquatic biota. In an attempt to determine whether or not Pennsylvania forest soils are becoming more acidic, soil samples were collected at six forested sites in Clinton County, Pennsylvania, in 1993. Soil chemistry data obtained through two previous studies conducted in 1957 and 1961 were available for each of these sites. Soils were analyzed for pH and exchangeable calcium (Ca) and magnesium (Mg), and the results were compared to the results obtained in the earlier studies. Soil analysis methods were evaluated to ensure that values obtained in the 1993 sampling were comparable to those of the original investigators. Results indicated significant decreases in pH and exchangeable Mg content at all sites. Exchangeable Ca decreased on the undisturbed sites and increased on the disturbed sites. Significant acidification of these soils has taken place over the past 32-36 years. Comparisons of disturbed and undisturbed sites indicated that at least part of the observed increase in acidification was the result of acid deposition.

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MANAGING CHEMICAL RELEASES: WHY CURRENT METHODS DO NOT GUARANTEE SUSTAINABLE ECOSYSTEMS

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Abstract: Current methods of managing chemical discharges and emissions employ statistical and toxicological information; however, they disregard critical toxicological concepts and, as a result, do not provide adequate protection for aquatic ecosystems. Although the concentration of a chemical in the water column is the most immediate threat to aquatic organisms, the total mass loading of persistent and bioaccumulative chemicals dictates the overall potential for the chemical to pose effects to the system. Because the effects of long-term buildup of persistent chemicals in sediments and the dangers of bioaccumulation are not factors in criteria development, existing criteria and standards protect only against the immediate effects of discharge. Furthermore, issues such as degradation of chemicals into more toxic constituents, and additivity of toxic effects have not begun to be addressed in the regulatory framework. Existing plans for sediment criteria do little to improve this situation. In addition, the development of site-specific criteria further constricts the protective ability of water quality criteria. These issues and other aspects of current regulatory methods are discussed, and recommendations are made for more sustainable approaches to managing chemical discharges.

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The Effect of Nutrient Delivery Form on a Mesohaline Submersed Macrophyte Community: A Comparative Study

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Abstract: A long-term mesocosm study was conducted at the Horn Point Environmental Laboratory to investigate the effect of the mode of nutrient delivery on the submerged aquatic macrophyte, *Potamogeton perfoliatus*. Plants obtained from experimental submerged aquatic vegetation ponds located at the Horn Point Environmental Laboratory were placed in experimental microcosms and exposed to three different forms of nutrient delivery: dissolved pulse, particulate pulse (heat-killed phytoplankton), and dissolved continuous. Nutrients were added to each treatment at the same nutrient input rate (38 μM N l^{-1} and an N:P ratio of 10:1). Water column nutrients remained relatively low in the dissolved continuous treatments and were highly variable in the pulse treatments, but disappeared rapidly after addition. Water column chlorophyll and macroalgae biomass were found to be significantly higher in the continuous treatment when compared to the control. Initially, there was a greater increase in plant growth rate in the dissolved nutrient treatments during the first 5 weeks of the experiment as compared to control. However, during the last 4 weeks, plants in these treatments exhibited a significantly greater decline in growth rate. Other measurements of plant health (such as root-to-shoot ratio, shoot length, and number of leaves per length of shoot) also indicated stress in the treated chambers. These results suggest that, over a relatively long time scale, dissolved nutrient additions decrease plant "health," while particulate additions do not. Furthermore, these data show the relationship between nutrient loading and water column concentrations and depict the rapid utilization of nutrients by microalgae.

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Development of a Regional Policy for the Prevention and Control of Non-Indigenous Aquatic Species: The Chesapeake Basin Experience

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Abstract: The discovery of zebra mussel veligers in the upper Susquehanna River, the major tributary to Chesapeake Bay, the increased use of triploid grass carp in some states of the Chesapeake basin and the initiation of *in situ* experiments with the nonindigenous oyster *Crassostrea gigas* were major factors stimulating the development of a basin-wide policy for the prevention and control of nonindigenous aquatic species. We present the policy developed by the Exotic Species Workgroup of the Chesapeake Bay Program in response to the environmental threat posed by nonindigenous aquatic species. Workgroup members include scientists, policy staff, and resource managers from the Chesapeake Bay Program jurisdictions (Maryland, Pennsylvania, Virginia and the District of Columbia), with representation from the nonsignatory basin states (Delaware, New York and West Virginia).

The document developed, *The Chesapeake Bay Policy for the Introduction of Non-Indigenous Aquatic Species*, was approved by the policy advisers to the jurisdictional leaders and forwarded to the jurisdictions for signature on 2 December 1993. Key features of this policy are (1) Species approved by individual jurisdictions at the time of adoption for aquaculture or stocking are "grand fathered" by the policy; (2) applications for first-time introductions into a jurisdiction will be submitted to an *ad hoc* technical review panel consisting of one representative each from the signatory jurisdictions plus two additional members appointed by the Exotic Species Workgroup after consulting with the Chesapeake Bay Program's Scientific and Technical Advisory Committee(STAC); (3) jurisdictions agreed to participate in development of an Implementation Plan to be completed by the Exotic Species Workgroup by 30 September 1994. The Implementation Plan will develop specific protocols to address each of the introduction pathways; aquaculture, fisheries management, biological controls, research, ballast water discharge, and the issues of prevention, education, and control.

Implementation has been addressed through the development of research protocols for the handling and containment of *Dreissenid* mussels. Protocols contain a list of information items that a researcher should provide to the appropriate jurisdiction agency as part of the permit process. A risk assessment questionnaire should be completed by the jurisdiction to determine if the introduction has an acceptable risk level. Research protocols were recently used in the permit process in Maryland to approve two university laboratory research facilities for zebra mussel research. Components of the research protocols may now be modified for applicability to other nonindigenous aquatic species.

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An Analysis of Nutrient Management in the Lower Susquehenna River Basin

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Abstract: This research utilizes a unique, survey-based data set from Pennsylvania's lower Susquehanna River basin to analyze farmers' observed manure and commercial nitrogen fertilizer applications. These data were collected as part of USDA's Water Quality Initiative, Area Studies project, a federal inter-agency effort. The Area Studies collect multi-year, field-level data at a subsample of National Resource Inventory (NRI) sample points. Thus, the database links agricultural production characteristics to soil and environmental characteristics. Information about production technologies, cropping systems, and agricultural practices are collected at both the field and whole farm levels.

These data are used to determine the extent to which producers adjust commercial nutrient applications to account for manure nutrients. If producers coordinate application of both manure and commercial fertilizers, the potential for farmers applying excessive quantities of nutrients for agricultural production is limited. The analysis is presented in two stages. In the first stage, data on manure and commercial fertilizer application in the lower Susquehanna basin loaded into a Geographic Information System (GIS) are used to show the pattern of spatial variation in nutrient applications over the basin. Nutrient applications are mapped for polygons resulting from overlay of county, major land resource, and hydrologic unit boundaries. Contributions to total nitrogen and phosphorus applications from chemical fertilizer and manure sources are compared and contrasted. The second stage of the analysis uses both nonparametric and parametric statistical tests to quantify potentials for coordinating application of these two nutrient sources in agricultural production.

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Distributed Hydrologic Modeling of a Small Coastal Plain Watershed (Sawmill Creek, Maryland)

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Abstract: A distributed (grid-cell) hydrologic model is being used to assess the relative impacts of landuse and well-pumping practices in the Sawmill Creek watershed in Maryland's coastal plain. The landscape simulation model provides high spatial disaggregation (4,900 cells of about 2 acres) and dynamic analysis of watershed conditions. We used a mass-balance, process-based approach to model water movement between surface, unsaturated, and saturated zones and across the landscape. The dynamic nature of the model allows us to analyze such variables as runoff and evapotranspiration over short time scales to understand the dynamic water budget. The Maryland Department of Natural Resources provided funding and GIS data of land use, soil type, and river routing and other data types. Supplemental data were gathered from many sources.

The approximately 8.5 mi^2 Sawmill Creek watershed links to the Furnace Creek watershed before the creek empties into Curtis Bay, an estuary near the mouth of the Patapsco River. Sawmill Creek is under scrutiny in part because of decreasing base flow, presumably due to well-pumping. Although well-pumping has been decreased, the relationship between pumping and base flow is clouded by the variability of rainfall, seasonal factors, and land use changes. This modeling effort examines the interactions between these sources of variability.

This project will contribute to a larger effort to model ecosystem processes at the watershed scale. Results will be used to understand how spatial aggregation influences hydrologic model processes in relation to field processes.

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Microbial Degradation of 2,4-Dichlorophenol in Baltimore Harbor Sediments under Sequential Anoxic and Oxic Conditions

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Abstract: Microbially mediated reductive dechlorination may be an important first step in the degradation of chlorinated aromatic hydrocarbons in anaerobic sediments. Removal of chlorine may facilitate complete mineralization under subsequent aerobic conditions. Temporal anoxia in surficial sediments, as found seasonally in Chesapeake Bay, may provide enhanced conditions for mineralization of these compounds. To test this hypothesis, the microbial degradation of 2,4-dichlorophenol (2,4-DCP) was investigated in surficial sediments under varying redox conditions. Baltimore Harbor sediment slurries were dosed with 14C-labeled 2,4-DCP and incubated anaerobically for 1, 2, or 4 months followed by aerobic incubation. Live and killed controls were held either strictly aerobic or anaerobic for this 245 day experiment. Mineralization, as measured by evolved $^{14}CO^2$, occurred in all live treatments after a lag period of about 50 days, regardless of the redox conditions employed. Treatments initially incubated under anoxic conditions, then later switched to oxic conditions showed biphasic mineralization patterns with a distinct increase in rate upon aeration. The fastest rates of mineralization were observed in treatments held anaerobically 1 or 2 months followed by aerobic conditions. However, these increased rates were not significantly different ($p = 0.05$) from a control treatment held entirely oxic. Reductive dechlorination of 2,4-DCP was monitored in an anaerobic batch sediment slurry incubated in parallel with radiolabeled assays. Degradation of 2,4-DCP began within one month, with rapid loss (84%) occurring within 2 months. Substantial concentrations of the metabolite, 4-chlorophenol, were first detected at 2 months, and persisted at this level for at least 2 additional months.

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Protection Role of Riparian Forest Buffers

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Abstract: Although riparian forest buffers play a critical role in protecting water quality and aquatic habitat, many landowners are reluctant to plant or protect them. Forest buffers and other stream protection measures such as grassed buffers, stream fencing, and watering troughs for cattle are integral parts of Maryland's Tributary Strategies to reduce nutrient pollution in the state's ten major Bay watersheds. Yet, at public meetings held to discuss the strategies with the public, the agricultural community and local governments, concerns were repeatedly expressed that these measures are often unacceptable to farmers. While many urban stream protection measures are regulatory—such as erosion and sediment control, stormwater management, and buffer ordinances—protection in agricultural areas relies more heavily on voluntary approaches.

To identify the barriers to stream protection in rural areas, the Departments of Natural Resources and Agriculture held meetings for landowners and federal, state, and local staff involved in resource protection and agricultural technical assistance. Through a collaborative brainstorming process, the following issues were identified as real or perceived obstacles for farmers: (1) loss of productive land and income; (2) lack of flexibility in practices; (3) bureaucratic hurdles such as delay in necessary permits and cost-share reimbursements; (4) maintenance of buffers and invasive weeds; (5) lack of persuasive evidence of the benefits of buffers; (6) concern that forest buffers may become habitat for protected species, bringing lands under regulatory control; and (7) the need for coordinated, interdisciplinary delivery of technical assistance.

The paper briefly discusses efforts in other states and watersheds to protect riparian areas.