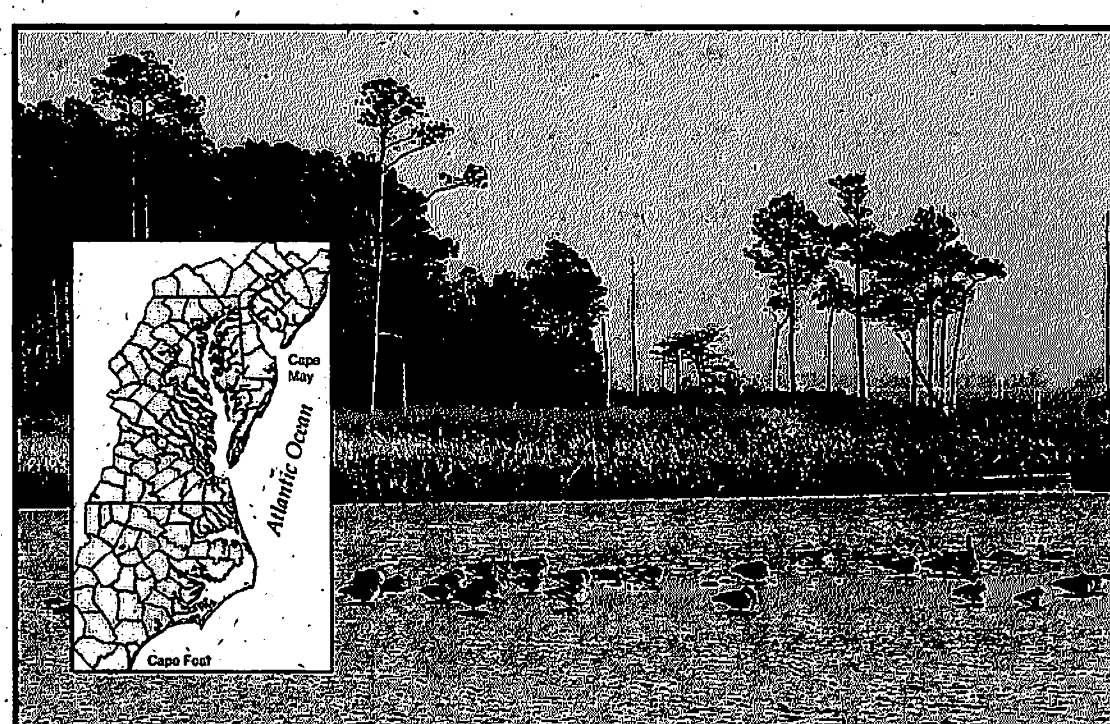
A WORKSHOP REPORT

Land-Use Effects on Water Quality in Mid-Atlantic Coastal Waters and Estuaries

Management and Research Needs



Mid-Atlantic Regional Marine Research Program

A Maryland Sea Grant Publication
College Park, Maryland

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Land-Use Effects on Water Quality in Mid-Atlantic Coastal Waters and Estuaries

Management and Research Needs

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Mid-Atlantic Regional Marine Research Program

A Maryland Sea Grant Publication
College Park, Maryland

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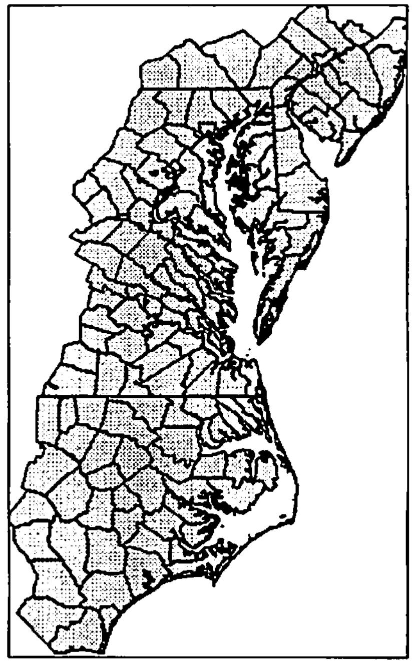

If the ecological health of U.S. coastal waters is to be restored and protected, significant progress must be made in controlling pollutants coming from lands that drain into these waters. Contaminants reaching aquatic systems like Delaware Bay, Chesapeake Bay and the Albemarle-Pamlico Sound in the mid-Atlantic region — whether the result of soil runoff, groundwater intrusion or point source discharges — have been responsible for widespread declines in water quality. While major strides have been made over the last 25 years in cutting direct discharges of wastes, population growth in coastal areas continues. And with that growth comes the clearing of riparian forests and other changes to natural landscapes that serve to buffer aquatic systems from land erosion, nutrient runoff and toxic contamination.

In recent years, our understanding of the linkages between land practices and aquatic health have increased immeasurably. New research has increasingly focused on detailing the mechanisms of contaminant transport in specific coastal watersheds and, at different scales, modeling these mechanisms. There are obvious general relationships between land effects and aquatic systems, and there is a consensus among scientists and managers that without effectively managing the patterns of land development, the health of coastal ecosystems will continue to decline. However, are there measurable similarities among watersheds and estuaries? If there are, is it possible to extrapolate findings on land-patterns and effects from one estuary to another? If not, what are the factors that account for differences and how can that understanding contribute to more effective management?

With population continuing to increase in watersheds throughout the mid-Atlantic region, what are the projected impacts of land-use changes? Can the effects on water quality of one aquatic system affect, through coastal transport mechanisms, other aquatic systems? Are there rational methods for planning land development that can minimize the impact on water quality and living resources while accounting for economic needs? These are only some of the questions that the Mid-Atlantic Regional Marine Research Program raised in a workshop in December 1994 of scientists, resource managers and policy makers.

The aim of the workshop was to assess our scientific understanding about the impact of land-use and population growth on the health of near-shore waters in the mid-Atlantic region; the goal was to reach a consensus on the current state of knowledge and the kind of information researchers and managers must have to more effectively manage land development for protecting the integrity of aquatic systems. Workshop members were in agreement that all watersheds and coastal waters in the region have been affected by land use changes over time, including changes that result from population increase, development and deforestation. In addition, they were in agreement over the following and other specific issues:

Land-Use Effects

- Not all estuaries and coastal waters respond to land use changes in the same way. Differences are related to geology and geomorphology of the drainage basins, sediments, ground water input, hydrology and residence time. These differences also relate to how each system will respond to sea level rise and other climatic influences.

- Estuaries in the mid-Atlantic are linked in terms of near coastal Atlantic ocean circulation patterns. Living resources that move between estuarine and near coastal waters are shared, and there are exchanges of nutrients and toxic materials.

- If differences between systems can be quantified, then local and/or subsystems may be used as models for other or larger systems. There is a need for more interdisciplinary work combining upland, estuarine and coastal research, as well as economic and policy interests.

Management Information Needs

- Strong evidence that demonstrates specific successes and failures of scientifically-based regulatory practices.

- Predictive models that can relate land-use patterns and population density with the impact on ecological functioning of aquatic systems, for instance, water quality and fisheries.

- Economic models that can be employed to predict land-use and development patterns.

- Integrated ecological and economic models to explain how, under different regulatory regimes, land-use decisions are made and the consequence of those decisions on the ecological functioning of aquatic systems.

Research Recommendations

As an element of specific research recommendations to support management information needs, research will benefit from the synthesis of existing data across varied research disciplines, for example, in terrestrial ecology, aquatic science, and economics. Research will need to include the following:

- Link studies of upland terrestrial and aquatic habitats to estuarine and coastal waters.
- Quantitative models that link landscape, land-use patterns and population density to their effects on coastal environments.
- Quantitative studies on the contribution of urban and suburban development to water quality.
- Interdisciplinary studies that link terrestrial and aquatic research with economic and policy issues.

Regional Planning and Cooperation

- Regional workshops to synthesize existing data and review case studies.
- Focused workshops that bring together upland and coastal scientists (with data) and managers (with examples) to address specific issues.

If research-based findings on environmental and economic policy are to make a difference, there must be effective communications among researchers in widely different fields of study and decision makers — policymakers, regulators, resource managers, legislators, environmentalists and citizens concerned about the health of coastal habitats. Such communications cannot be an afterthought — they must be part of the process from the beginning, so that research can play an active role in helping to design practical ways for influencing such a very diverse public.

Mid-Atlantic Regional Marine Research Program

Introduction

The Mid-Atlantic Regional Marine Research Program — one of nine coastal regional programs established by Congress to support management-driven research on water quality and ecosystem health — encompasses coastal waters from Cape May, New Jersey to Cape Fear, North Carolina.

The goal of the Mid-Atlantic Regional Marine Research Program (MARMRP) is to foster integrative research to distinguish between natural forces and human impacts that affect the functioning, integrity and health of marine and estuarine ecosystems in the region. MARMRP emphases include the analysis of past effects for improved understanding of system dynamics in order to project how changes in human demography and land use will affect receiving waters, marine resources, and ecosystem integrity in the region.

In 1994, the Program produced a comprehensive research plan (Cooper and Lipton 1994) that (1) summarized environmental conditions in the region, (2) characterized regional problems and resources, (3) inventoried existing research efforts and (4) targeted priority research methods and priority areas for research.

Methods of research considered priority include:

- Data management, synthesis and interpretation
- Ecosystem modeling and comparative studies
- Presentation and application of regional research to regional management
- Economic and social considerations

Five priority areas of research have been identified as critical to the mid-Atlantic region; they are:

- Historical and contemporary effects of land-use on living resources in the context of ecosystem structure and function
- Eutrophication, algal booms and anoxia

- Fishery yields, recruitment and trophodynamics of the mid-Atlantic Bight

- Parameters of materials (including nutrients, sediments and contaminants) and biotic exchanges between estuaries and the coastal ocean

- Coastal erosion and climatic effects

Land-Use Effects on Water Quality: A Critical Issue

A survey of MARMRP board members and others identified land use effects on water quality as an issue in which a synthesis of our understanding would be a direct benefit to researchers and managers in setting out scientific goals to aid policy making and resource management. Towards these ends, a two-day workshop was held on December 1-2, 1994, to synthesize our scientific understanding about the impact of land-use and population growth on the declining health of coastal waters and estuaries and to reach a consensus on the kind of information researchers and managers must have to more effectively restore and protect these waters. The workshop brought together scientists, resource managers and policy makers (see Workshop Participants, p. 31) to address the following questions:

1. What are the major similarities and differences among watersheds and estuaries in the mid-Atlantic, what are the interactions with other regions and within the region in terms of land-use and its impacts, and to what extent can we extrapolate from one estuary to another?

2. What are the projected impacts of land-use changes and increasing population on the mid-Atlantic coastal waters, and what kind of information do management communities in the region need?

3. What are research recommendations and priorities for the mid-Atlantic region over the next four to ten years related to land-use effects on coastal ecosystems and water quality?

4. How can a regional perspective be used to implement land-use strategies for protecting the mid-Atlantic coastal ecosystems?

The following sections summarize the consensus response to these questions, including our current scientific understanding on how land use can affect coastal waters, and the research and policy directions we must pursue if the integrity of these waters is to be restored and maintained in the future. Nearly all land in the region is under some kind of management — how can that land be used, while taking into account economic and social factors, so that its impact on coastal waters is minimized? The answers are complex and will require collaboration across many disciplines in science, economics, policy, social science, communications and education.

Land-Use and Mid-Atlantic Coastal Waters

Major land use changes throughout the mid-Atlantic coastal region began with and continue to be influenced by the impacts of population growth, including the extensive clearing of forests and the cumulative, interactive effects resulting from agriculture, industrialization and urbanization. In general, problems related to land use and the consequent effects on water quality and living resources include the following:

- Current patterns of land development consume large amounts of natural habitat, resulting in nonpoint source pollution and fragmentation of that habitat. Alternative development patterns could significantly reduce these inputs.

- Habitat alterations and fragmentation have stressed the ecological integrity of many systems, affecting survival and reproductive success of living resources that depend on specific habitat types and impairing the system's ability to buffer pollutant impacts. In particular, loss of freshwater wetlands continues in areas of estuary watersheds.

- Heavy use of surface and groundwater threatens the long-term water supply for industrial and domestic use, and for maintenance of habitats and living resources.

What do we know about land-use effects on the mid-Atlantic region's estuarine and marine water quality and ecosystems?

- All watersheds and coastal waters in the region are affected by land use changes over time, including population increase, development and deforestation.

- Not all estuaries and coastal waters respond to land use changes in the same way. Differences are related to geology and geomorphology of the drainage basins, sediments, ground water input, hydrology and residence time. These differences also relate to how each system will respond to sea level rise and other climatic influences.

- Estuaries in the mid-Atlantic are linked in terms of near coastal Atlantic ocean circulation. Living resources that move between estuarine and near coastal waters are shared, as well as some exchange of nutrients and toxic materials.

- If differences between systems can be quantified, then local and/or subsystems may be used as models for other or larger systems. There is a need for more interdisciplinary work combining upland, estuarine and coastal research, as well as economic and policy interests.

- Elevated levels of toxic substances have been detected in some sediments, the water column and in tissues of organisms dependent on these waters. Fish consumption advisories are issued periodically.
- Deforestation and population growth continue to be associated with increases in sediment runoff, and nonpoint and point sources of nutrients and toxics, causing eutrophication and hypoxic waters in many estuaries.

Deforestation

The clearing of forest stands in coastal areas began in earnest with European settlement and has progressed steadily, though at different rates, throughout the region. In the Chesapeake Bay region, for example, 20 to 30 percent of the land was cleared in the late 1600s to mid-1700s; by the late 1800s to 1920s, 60 to 80 percent of the land was under cultivation, while the next twenty years saw extensive areas of wetland drained for arable land. As a result of declines in farming, about 40 percent of the Chesapeake Bay's 64,000 square mile watershed is now forested. In Delaware's Inland Bays, some 44 percent is forested, while in the Albemarle-Pamlico Sound, the nation's second largest estuarine system, forests account for approximately 28 percent of land cover.

The loss of forests is occurring again: the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (C-CAP), a comprehensive standardized information system for assessing changes in land cover and wetlands in coastal regions, showed more than a 2% net loss of forests in the Chesapeake Bay estuarine drainage area between 1984 and 1988-89 (Dobson and Bright, in press). Reports by the National Estuary Programs in the region report similar trends in their respective estuarine watersheds (see Resources section of this report).

With the clearing of riparian forests, which serve as shoreline buffers and filters, coastal aquatic systems have been less protected against the climatic perturbations of storms and hurricanes and natural fires. Even without the effects of human activities on the land, such extreme perturbations still affect the normative functioning of these aquatic systems. For example, naturally-occurring fires that cause the loss of tree cover and root growth lead to greater soil runoff, higher loading of nutrients and toxicants, greater permeability of groundwater, increased water velocities during rainstorms and loss of evapotranspiration effects. Such natural climatic impacts, however, are episodic, and terrestrial ecosystems eventually recover as do aquatic systems (Brush 1986). However, with the effect of population growth in the mid-Atlantic region permanently altering many riparian landscapes, aquatic systems have been less able to recover their normative functioning.

Although a great deal of progress has been made in reducing "point source" nutrient and toxic discharges from waste treatment plants, the consequences of land clearance on the health of coastal waters have continued as more land is developed. Examples include the massive runoff of soils and the resulting sedimentation of many coastal waters, the consequent increasing nutrient enrichment of these waters as well as higher levels of toxicants.[1] In the Chesapeake Bay tributaries, pre-European sedimentation rates averaged 0.09 cm/yr as compared with post-European averages of 0.30 cm/yr (Brush 1989). Of course, sediment loading cannot easily be separated from the loading of contaminants: the nature of the sediments themselves have contributed to problems with toxic and nutrient cycling within the coastal ecosystems (i.e., sediment quality is important to water quality). Nutrient enrichment and toxic loading — from agricultural lands (animal waste, fertilizers), in direct discharges (waste treatment plants, industrial plants), in airborne deposition, in runoff from impermeable surfaces, in groundwater — are all related to deforestation in different ways.

Land Cover and Anthropogenic Inputs

There is evidence that before European settlement, the ecology of aquatic ecosystems like the Chesapeake Bay were impacted by episodic stresses from natural climatic conditions. The "Medieval Warm Period," ca. 1000-1200 A.D., is an example: according to stratigraphic records, climatic warming led to fires and a loss of forest cover (Brush 1986), which appears to have promoted changes in phytoplankton speciation (Cooper and Brush 1991) and exacerbated hypoxic and anoxic conditions, which the Bay may have a natural tendency for because of its flow patterns (Smith et al. 1993). However, because human activities were relatively limited, riparian and other forests returned naturally, with the effect of trees once more serving as shoreline filters of runoff and groundwater intrusion. The Chesapeake

[1] There are other stresses to ecosystem health such as widespread overharvesting of fish and shellfish and, more recently, protozoan diseases. In Maryland's Chesapeake Bay, for example, oyster harvests averaged some 10 million bushels in the late 19th century. From the 1920s through the mid-80s, harvests ranged between 2 and 3 million bushels, while in the last several years they have declined to under 200,000, largely the result of MSX and "Dermo"disease. In addition to the cropping of phytoplankton, extensive pre-Colonial oyster reefs played a number of other ecological roles, including the trapping of sediments.

appears to have "rebalanced" itself before European settlement began effecting irreversible changes to the system. (These changes include extractive fisheries, changes to benthic habitats through harvesting, etc.) Paleoecological studies show that since European settlement of the watershed, the Chesapeake Bay ecosystem has shifted from a more benthic system to a more pelagic system with increasing anthropogenic influence (Cooper 1995), probably due to a host of factors, including increased sedimentation, eutrophication, turbidity and hypoxic bottom waters.

Quantitatively, how does land-use and the changes they effect in sediment and nutrient runoff affect coastal systems? Long-term studies in the Rhode River watershed, on the inner Coastal Plain portion in Chesapeake Bay (Correll et al. 1992), and in other areas (e.g., Patuxent River, MD; South River, NC) are providing the kind of information that predictive landscape modeling requires. This research is demonstrating how different types of ground cover and use, coupled with physiographic factors, affect sediment and nutrient runoff. According to Correll (pers. comm.), comparisons of nitrate runoff from cropland, pastures and forests show that 6 times as much nitrate was discharged from croplands as pastures and nearly 28 times as much from cropland than from forests. At the same time, annual discharges for the same land use can vary greatly. For instance, a pasture area on the Rhode River discharged nitrate concentrations between 100 and 200 ppb during 1989-1991 but during 1982 and 1992, mean nitrate concentrations ranged between 1,000 and 1,300 ppb. These wide variations are the result of temporal variability, (for example, interannual differences in rainfall), as well as spatial variability in similar-use landscapes.

Another factor controlling rates of nutrient discharge from a watershed is the distribution pattern of the land use within that watershed. For example, riparian forests buffer and filter nutrient discharges from row crops — therefore, nutrient discharges from a mixed land use watershed will differ significantly if the croplands are in uplands and the forest is along the stream than if the converse is the case (Correll et al. 1992).

Hydrology and Aquatic Systems

Water quality and living resources in mid-Atlantic estuaries and coastal waters respond differently to land clearance and to other perturbations that result from human activities. Each watershed and its subwatersheds is unique in its hydrology and geology, while each aquatic system's geometry affects complex flow and circulation patterns. It is the dynamic characteristics of hydrology and soil transport mechanisms that influence the movement of these land-borne contaminants and the impact they will eventually have on the health of each aquatic system. The Chesapeake Bay system, for example, responds to nutrient enrichment with extensive algal blooms — given the Bay's geometry, flow regimes and other factors, its mesohaline region is characterized by widespread hypoxia and anoxia in spring and summer. Delaware Bay, on the other hand, is not subjected to algal blooms and anoxia as much as to the more direct impacts of toxic contamination on the biological health of the system. It is the uniqueness of each aquatic system that will also condition how each is likely to respond to sea level rise and other climatic influences.

In addition, these waters are also linked by coastal circulation patterns, though to what extent is not clear. There is some evidence, for instance, of the exchange of nutrients and toxic materials by way of coastal currents. Phosphorus is apparently imported to the Chesapeake Bay from shelf waters that travel along the eastern seaboard of the United States. These waters also share living resources, anadromous species as well as invertebrates like blue crabs. For example, striped bass spawned in rivers that make up the Chesapeake Bay and Albemarle-Pamlico Sound systems, feed in coastal waters between Maine and North Carolina for a number of years before returning to their natal waters to spawn. Blue crab larvae spawned at the mouths of estuaries in the mid-Atlantic are swept out to shelf waters where they may be transported by coastal currents into systems other than those they were spawned in. Menhaden, one of the most abundant fish in the Chesapeake Bay, are plankton feeders and, therefore, a significant source of nutrient removal through commercial harvests and through the food web as a major prey of striped bass and blue fish. These examples are to suggest that natural and human impacts on one aquatic system can affect another, directly through water circulation patterns, and indirectly, through naturally-occurring processes such as fisheries recruitment.

Patterns of Population Growth

Despite the site-specific uniqueness of all these coastal systems, their water quality and other measures of ecosystem health depend on the natural landscape and alterations or development of that landscape. NOAA's C-CAP program, using LandSat TM satellite imagery, measured a 4% increase in developed land in the Chesapeake Bay estuarine drainage area from 1984 to 1988-89 (Dobson and Bright, in press). While our understanding of the relationship is primarily qualitative, in recent years researchers have been focusing on how different land uses and mosaics mediate nutrient flow in specific watersheds. For example, Valiella (1992) organized a dedicated issue of the journal "Estuaries" on relationships between watershed and coastal waters (see also Naiman and Risser 1991; Naveh and Lieberman 1994). Still, that knowledge is limited: we know more about the effects of agricultural and pasture land-use on water quality than we do about the effects of suburban and urban land-use, the fastest growing component of land-use in coastal areas.

While population growth, land clearance and development appear to be the driving forces in the deteriorating health of aquatic systems, total population may not be as significant as the pattern and density of land settlement, according to Leonard Shabman of Virginia Polytechnic University. Citing calculations by Ed Risse of Synergy Planning, Inc., he points out that if Fairfax, Virginia, with its low density development, were settled like Reston, Virginia, with its high density development, two-thirds of Fairfax would be open space, agriculture and forest. What are the specific effects of such different types of development on water quality? What are the effects on runoff? On nutrient loading? While much of our understanding on the relationship between land use and water quality is more intuitive than empirical, research in the last several years, for instance, in the Patuxent River watershed in Maryland, has begun to model and quantify the effects of land-use on water quality (Costanza et al. 1990; Costanza 1993, 1994).

The national cultural vision of single family home ownership, of personal mobility and of local government control, Shabman argues, is supported by public policies that in general promote low density development; tax codes, for example, provide support for extensive land ownership and speculation. Public policies that would encourage patterns of compact and contiguous land settlement, however, could accommodate future prospective population growth without developing more forested land (Year 2020 Panel 1988). In other words, with population being equal, different types of settlement patterns lead to different impacts on water quality and living resources.

Ecological modeling for predicting the effects of different types of land-use on water quality will be a major step in trying to plan land-use development that can best protect aquatic systems. But land development is driven by a complex web of market and public policy factors. There is promising new research underway that is analyzing the spatial configuration and evolution of the ecological landscape from an economics perspective. This work is developing a model capable of predicting land use change, for example, from open use such as agriculture or forestry to a developed use. Probability of conversion of use is based on ecological attributes, surrounding land use, distances to transportation networks, work and recreational opportunities, macro-economic growth pressures, zoning and growth management controls (Bockstael et al. 1995; Bockstael pers. comm.). In the long run, interactions between economic models and ecological models could allow for predicting the effects of human induced disturbances, land use management controls or other land-related policies on coastal ecosystem health.

Management Information Needs

Land in the mid-Atlantic region is either forested, or "built," i.e., agricultural, pasture, urban or suburban development. Patterns of land development have largely been driven by a network of natural and cultural forces and rarely, until the last 35 years, by considerations of environmental protection. Such considerations have been accelerating since passage of the Clean Water and Clean Air acts and related federal and state environmental legislation. In Maryland, for example, the Critical Areas Act passed in 1985 (Bradley 1985), restricts development within 1,000 feet of Chesapeake Bay shorelines — the aim is to significantly reduce land-borne contaminants from reaching Bay waters.

Such political and development decisions may play a significant role in preventing further decline of the Bay's water quality and living resources. Nevertheless, these decisions are grounded more on a qualitative understanding of land-based effects on aquatic ecosystems than on a quantitative understanding.

With population projected to increase in the mid-Atlantic region, quantitative management tools could be valuable in forecasting the ecological impact of land-use decisions. Many riparian and upland forests and natural features of mid-Atlantic landscapes prior to European development obviously cannot be restored. What we can do, however, is first improve the quality of our understanding of how these natural landscapes functioned in buffering aquatic ecosystems. Then it may be possible to develop alternative models that mimic their role in terms of trapping nutrients, buffering contaminants, and controlling runoff. At the same time, there is a corresponding need to understand what kinds of social incentives (i.e., economic, behavioral, public policy) will make it possible to implement land development that is beneficial to ecosystem health.

While we have a qualitative understanding of the effects of runoff, we are only beginning to obtain a quantitative understanding of the dynamics of soil, nutrient and contaminant transport from land to water. It is such quantitative information that is now becoming possible with new

What kind of information do management communities in the region need?

- Strong evidence and scientific consensus of the successes of scientifically-based regulatory practices, as well as failures.
- Quantitative models that can be used to predict ecological impacts of land use patterns and population density on coastal ecosystems.
- Economic models that can be used to predict land-use and development patterns.
- Integrated ecological and economic models to help explain how, under different regulatory regimes, land-use decisions are made and the impact of those decisions on aquatic ecosystems.

techniques in landscape ecology and economic modeling, with digitized geographical information systems (GIS) and with high speed advanced computer technology. It is becoming possible to model large regions with different landscape patterns and mosaics and to predict the impact of different types of land uses, including soil runoff and nutrient loading, on aquatic ecosystems.

Current trends without improved management of the patterns of land development are likely to lead to continued degradation of coastal ecosystems. For policy makers and legislators at state, county and local levels, advanced modeling capabilities can provide a sound basis for evaluating land development alternatives. More compelling and understandable communication of this knowledge among scientists, policy makers and citizens will be a critical factor in developing rationally-based strategies of land management for protecting coastal waters. Towards reaching these ends, the following needs are critical:

- A synthesis of existing data, comparisons and coupling between land/estuary/coastal systems.

- More extensive interdisciplinary research combining upland, estuarine and coastal research, as well as economic factors driving land-use changes.

- Spatially explicit, hydrologic landscape ecology models that link land-uses with the health of aquatic ecosystems. These models must be linked in their development with policy and economic models that explain and predict land-use patterns.

- Quantitative proof that mosaics, riparian buffers, and concentration of development are effective management practices.

- Demonstrate where management and regulation have worked to improve water quality and living resources, i.e., "good news stories."

- Demonstrate how market forces and government policies that contribute to specific settlement patterns lead to greater environmental degradation.

Research Recommendations: Land-Use Effects on Coastal Ecosystems

The research goals of land-use effects on aquatic ecosystems are to develop predictive capabilities for assessing how different types of landscapes affect the ecological integrity and health of aquatic systems (National Research Council 1995). In the long run, if such predictors can be linked with government policy and economic modeling of behavioral factors that influence land development, then it may be possible for planners to optimize ecosystem health with economic development of land.

> ***Research recommendations on land-use effects on coastal waters***
>
> - Need more synthesis of existing data, possible through focused regional workshops, and compilations of case studies.
> - Need interdisciplinary research, including linkages of upland, estuarine and coastal research, and economic and policy issues.

The ability to achieve these goals will depend on a number of factors, among them, interdisciplinary research (e.g., collaboration by planners, marine scientists, soil scientists, economists, modelers); the synthesis of available data; continued monitoring that will give important time series data; and comparative research among different land-use and aquatic ecosystem interfaces.

Scientists must begin to focus research efforts on linking studies of upland terrestrial and aquatic habitats to their estuarine and coastal waters. In addition, research must be expanded to include quantitative studies on the contribution of urban and suburban development to water quality. Towards these ends, major research needs include the following:

- Develop quantitative models that link landscape, land-use patterns and population density to their effects on coastal environments.
- Document nonpoint source loads and effects on aquatic systems.
- Develop an improved understanding of land markets and resulting land settlement as a response to public policies.

- Develop and evaluate the incentive effects of "radical" public policy reforms on land settlement.
- Study the application of market based land management tools to provide for their extension region-wide.
- Customize watershed specific solutions to problems: modeling based on existing and projected loads; quantify loadings based on land use/land cover type.
- Conduct comparative studies to demonstrate if and how land settlement patterns can be adjusted to ameliorate environmental impacts.

Regional Planning and Cooperation

> **How can a regional perspective be used to protect the mid-Atlantic ecosystems?**
>
> - Regional research databases such as the MARMRP research inventory on internet, to disseminate information.
> - Regional workshops to synthesize existing data, and review case studies.

Coastal ecosystem processes generally function on a regional scale that falls between federal and state or local interests. From a management perspective, the relevant ecosystems of the coastal zone are drainage basins, streams-rivers-lakes, estuaries and coastal waters. Ocean currents, frontal systems, diversity and extent of wildlife, habitats, geologic basins, and terrestrial soils and slopes, often cross state boundaries but are not national in scale. In order to understand and manage coastal ecosystems, it is necessary to study the environmental conditions, processes and functions, land use, and contaminant effects that occur on these regional scales. Management can then be coordinated for the maximum benefit to both local areas and the region.

In the United States, most of the basic research and management of coastal areas are carried out by federal, state and local agencies, including assessments and monitoring. Federal funding for marine research is based on research priorities as seen on a national level and may not be site specific. On the other hand, state and locally funded research is often very site specific and may be initiated to respond to short term needs, management of local natural resources, or increased benefit to local users of marine areas.

A regional perspective can be very beneficial, in that more data is available on a regional basis that can be synthesized in response to particular issues. For example, one overwhelming recommendation from this workshop was to have more regional workshops on specific land use issues, to bring together experts from different fields and different localities. There is a need for a compilation of management practices that have or haven't worked in relation to land use effects on coastal waters on a regional scale, in terms of the ecosystem scales present. Regional research databases need to be available to managers within the entire region, so that related research, (including upland, estuarine, and coastal areas), and success stories can be utilized to their maximum benefit.

The Regional Marine Research Program was initiated to address these types of issues. Each regional RMR Program is directed by a Board of experts (in different disciplines) from throughout each of nine regions around the country. One charge to the Mid-Atlantic Regional Marine Research Program was to develop ways to facilitate the exchange of information between and among marine research institutions and management agencies within the Mid-Atlantic region. To meet this goal and demonstrate what can be done using existing technology, the MARMRP embarked on a series of activities related to information transfer. One of these was the workshop on land use effects on coastal ecosystems in the Mid-Atlantic, and this report. The MARMRP has also commissioned a report on "Data management in the Mid-Atlantic Region,"which is now available, and finally, hypertext versions of the Mid-Atlantic Research Plan and Research Inventory are available on diskettes, and also available via internet.

The hypertext versions of the Mid-Atlantic Research Plan and Research Inventory are examples of what can be done with text and databases to make them easily searchable as reference tools on the computer. The database inventory of research projects and programs in the Mid-Atlantic region, is easily updated in this format, and is a powerful way of keeping the management and research community informed of recent and on-going research. These and other electronic versions of the Research Plan are available from the Sea Grant Mid-Atlantic gopher and World Wide Web home pages via internet (see Resources, p. 29).

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Resources

Mid-Atlantic Regional Marine Research Program: Hypertext versions of the Mid-Atlantic Research Plan and Research Inventory, available via Mid-Atlantic World Wide Web and gopher server. Addresses are <http://www.mdsg.umd.edu> and <gopher.mdsg.umd.edu>.

Coastal Change Analysis Program (C-CAP), National Oceanic and Atmospheric Administration. Contact: Dr. Ford Cross, National Marine Fisheries Service, Beaufort Laboratory, Beaufort, NC 28516-9722.

National Estuary Programs:

- ***Delaware Estuary Program;*** contact: Robert Tudor, Delaware Estuary Program, US. EPA Region III, 841 Chestnut Building, 3ES41, Philadelphia, PA. 19107-4431.

- ***Delaware Inland Bays Program;*** contact: Dr. Kent Price, College of Marine Studies, University of Delaware, Lewes, Delaware 19958; or c/o Dept. of Natural Resources & Environmental Control, P.O. Box 1401, 89 Kings Highway, Dover, DE 19903.

- ***Albemarle-Pamlico Estuarine Study Program;*** contact: Guy Stefanski, APES, 111 Hillsborough Street, Raleigh, NC 27603; or APES, NC DEHNR, P.O. Box 27687, Raleigh, NC 27611.

Chesapeake Bay Program, contact: Dr. Kent Mountford, US EPA Chesapeake Bay Program Office, 410 Severn Avenue, Suite 109, Annapolis, MD 21403.

Mid-Atlantic Sea Grant Programs, see new Mid-Atlantic World Wide Web and gopher servers: <www.mdsg.umd.edu> and <gopher.mdsg.umd.edu>.

- ***Delaware Sea Grant***: Delaware Sea Grant Program, College of Marine Studies, University of Delaware, Newark, DE 19711.

- ***Maryland Sea Grant:*** Maryland Sea Grant Program, 0112 Skinner Hall, University of Maryland, College Park, MD 20742.

- ***North Carolina Sea Grant***: North Carolina Sea Grant Program, North Carolina State University, 105 1911 Building, Box 8605, Raleigh, NC 27695-8605.
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