Climate change and ecosystems of the Mid-Atlantic Region

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ABSTRACT: This paper discusses the current status of forested, wetland, freshwater and coastal ecosystems; the combined impacts of habitat alteration, pollution and non-native invasive species on those systems; how climatic changes could interact with existing stresses; potential management strategies, and crucial research gaps. Changes in climate and climate variability would significantly affect natural ecosystems, and may pose additional threats to the already-stressed ecosystems of the Mid-Atlantic Region (MAR). Fragmentation of the MAR's forests may hinder the migration of some species. Urban development and wetland losses leave the MAR's rivers and streams and near-shore areas vulnerable to damages if the frequency and intensity of storms increase. Inputs of sediments, nutrients and toxic chemicals to streams, lakes and estuaries might increase if precipitation increases. Accelerated sea-level rise could accelerate the loss of coastal wetlands. Estuaries are sensitive to changes in temperature, salinity and nutrient loads, and could be adversely affected by projected climatic changes. Populations of rare, native species could decline, while problems with non-native invasive species, such as kudzu and gypsy moths, might increase. The best strategies to protect ecosystems from climatic changes may be those that reduce other stresses, thus increasing resilience to a variety of stresses. Societal priorities for ecosystem protection need to be articulated, and research is needed into the values of ecosystems, ecosystem functioning, human impacts, long-term ecological monitoring, and management options to provide a basis for selecting effective measures.

KEY WORDS: Ecosystems · Societal values · Climate change · Mid-Atlantic Regional Assessment · Ecological

1. INTRODUCTION

Human activities alter the dynamics within ecosystems, 'interacting systems of biological communities and their non-living surroundings' (US Environmental Protection Agency [EPA] 1999), resulting in changes of societal concern. This paper focuses on ecosystems of the Mid-Atlantic Region (MAR), and addresses 4 questions that guide the National Assessment process[1]: (1) What is the status of resources and what are the current stresses? (2) How might changes in climate and climate variability exacerbate or ameliorate current conditions? (3) What are the potential strategies for coping with risk and taking advantage of new opportunities? and (4) What are the policy-relevant research gaps? Other papers in this Special focus on forestry (McKenney-Easterling et al. 2000), coastal systems (Najjar et al. 2000), agriculture (Abler & Shortle 2000) and human health (Benson et al. 2000). While issues treated in these papers are relevant here, to avoid redundancy, they are not treated in depth in this paper. Cities and farms, important ecosystems in their own right, are discussed primarily in terms of how they affect other ecosystems, such as forests, wetlands, freshwaters, and coastal ecosystems.

Underlying our approach in this paper is the question: What aspects of ecosystems are important to people in the MAR? Unfortunately, our understanding of how people depend upon ecosystems and how people value different aspects of ecosystems is very incomplete. Based on currently available information, we emphasize aspects of ecosystems that we believe are important to residents of the MAR. Previous workshops (Climate Institute 1996a,b, Fisher et al. 1997, U.S. National Assessment 1997) provided useful guidance in identifying issues of concern.

[1]The National Assessment, which is being conducted by the U.S. Global Change Research Program, is mandated by the Global Change Research Act of 1990. For further information, see www.usgcrp.gov

2. WHAT IS THE STATUS OF MID-ATLANTIC ECOSYSTEMS AND WHAT ARE THE CURRENT STRESSES ON THOSE SYSTEMS?

98% of the original stands of the distinctive Atlantic white-cedar Chamaecyparis thyoides swamp forest of the Great Dismal Swamp of Virginia and northern North Carolina has been destroyed (Noss et al. 1995).

Non-forested wetlands or marshes in the region tend to be dominated by emergent plants such as cattails Typha. These marshes often form the transition between uplands and freshwater ecosystems and include several species of sedges and rushes (National Research Council 1995). Losses of lowland evergreen shrub bogs (pocosins) and montane sphagnum bogs have exceeded 85% in some states in the region (Noss et al. 1995).

Drainage (for agricultural and urban purposes) is the major threat to freshwater wetlands. Total losses for all wetland types vary across the region. For Maryland, it is estimated that between 1780 and 1980 73% of the original wetlands were drained (Noss et al. 1995). During the same period, approximately half of the wetlands in Pennsylvania and Virginia were destroyed, but losses were as low as 24% in West Virginia (Noss et al. 1995).

Additional threats to wetland ecosystems include pollution and non-native invasive species. High levels of chemical pollutants can accumulate in wetlands because pollutant-carrying sediments are trapped in wetland vegetation. Non-native invasive species, such as the European plant purple loosestrife Lythrum salicaria, force out more beneficial native marsh plants.

2.3. Freshwater ecosystems

The importance of freshwater ecosystems to residents of the MAR is difficult to put into words, in part because of the deep attachments that many people have to streams, rivers and reservoirs in their communities. Freshwater resources have multiple, sometimes conflicting, values. These include fishing, swimming, boating, water supply, beauty, flood control, navigation and transportation, and hydropower. Freshwater ecosystems support aquatic plants and animals, as well as organisms in wetland and terrestrial ecosystems that depend upon freshwater. Downstream estuaries, such as the Chesapeake Bay, also depend on freshwater inflows.

The diversity of freshwater mussels in the Southeast, which includes southern portions of the MAR, is unmatched by any other area in the world (Williams & Neves 1995). The number of mussel species historically known to occur ranges from 12 to 80 across the MAR’s states, but the percentages at risk of extinction range from 46 to 71% (Williams & Neves 1995). The number of native freshwater fishes range from 70 to 201 across these states, and the percentages of these fish estimated to be imperiled range from 3 to 12% (Warren & Burr 1994).

Freshwater ecosystems, like terrestrial and wetland ecosystems, are stressed by habitat alteration, pollution and non-native invasive species. Stream habitat alterations include dams, road crossings, channelization, and loss of streambank vegetation. Dams are built to

2.4. Coastal ecosystems

The coastal zone of the MAR harbors a series of distinct ecosystems with enormous recreational, commercial and aesthetic value. The

(Dukes & Mooney 1999, Harvell et al. 1999). In addition, increases in species may not be beneficial if those that respond favorably to climate change are invasive, exotic species already considered pests (Dukes & Mooney 1999).

It may be helpful to consider the ecological processes that determine how changes in climate and climate variability could affect ecosystem structure (e.g. which species are present, and in what abundances) and functioning. Environmental variables projected to change in the MAR include: carbon dioxide concentrations (increases are certain), temperature (increases are highly likely, but the distribution across space and time is uncertain), precipitation (projections are uncertain, increased frequency and intensity of severe storms and overall increases in precipitation are possible), sea level (already rising, highly likely to accelerate) and fires (predictions remain uncertain, Intergovernmental Panel on Climate Change [IPCC] 1996b).

Species may respond to changes in environmental variables by adapting, shifting their range, changing their abundance, or by disappearing altogether. Rapid evolution might help species with short generation times, such as insects and annual plants, to adapt to environmental changes (Rodríguez-Trelles et al. 1998). Evolution may be slower in long-lived species, such as trees (Mátyás 1997). Optimal climates for the MAR's dominant tree species in maple-beech-birch and oak-hickory forest communities are predicted to shift to the north (Iverson & Prasad 1998), while conditions for southern species such as longleaf and loblolly pine will become more favorable in the MAR (IPCC 1996a). Pest species may shift north or increase in abundance if temperatures increase. Shifts in fish species from cool and cold water species to warmer water species are likely (U.S. EPA 1995). Species (or whole coastal wetland ecosystems, in the case of sea-level rise) could fail to shift their range if they cannot disperse fast enough to keep pace with change, if landscape features (such as cities) block their movement, or if new suitable habitats are simply not available (Pitelka and the Plant Migration Workshop Group 1997). A species may fail to colonize a prospective habitat if it cannot adapt to that habitat's soils, to the level of human development, or if it cannot coexist with other species already in residence.

Invasive species share a set of traits that predispose them to successfully invade pre-existing communities (Dukes & Mooney 1999). These traits include a high rate of population growth, which contributes to rapid colonization; ability to move long distances, which

Losses of coastal wetlands are relatively easy to predict. Accelerated sea-level rise is likely and coastal wetlands are unlikely to be able to migrate inland quickly enough, particularly because the MAR's coast is heavily developed (Najjar et al. 2000). Changes in climate and climate variability would affect the Chesapeake and Delaware Bays via changes in temperature, sea level, precipitation, wind and water circulation patterns. Temperature is particularly important because it influences activity, feeding, growth, metabolism and reproduction. (See Najjar et al. 2000 for discussion of some of the consequences of climate change upon coastal ecosystems.) The incidence of 2 oyster diseases, Dermo and MSX, could increase if sea-level rise mimics saltwater intrusions caused in the mid-1980s by unusually warm and dry years that resulted in mass mortalities of oysters. If summer precipitation increased and resulted in increased streamflow, it could have an ameliorating effect by reducing salinities. Fish kills caused by Pfiesteria tend to occur in warm water with high nutrient loads, moderate salinity and poor flushing (U.S. EPA 1998). Harmful algal blooms caused by Aureococcus anopahagefferens are also sensitive to changing climate conditions and are favored by warm, saline, eutrophic waters (Beltrami 1989). Uncertainty in projections of climate and nutrient loading make it difficult to predict the future extent and magnitude of these problems.

4. WHAT ARE THE POTENTIAL STRATEGIES FOR COPING WITH RISK AND TAKING ADVANTAGE OF NEW OPPORTUNITIES?

Maintaining resilience in ecosystems is the primary objective of adaptation strategies to protect wildlife and habitats (IPCC 1996a, Markham & Malcolm 1996). Compared to other sectors, 'adaptation options for ecosystems are limited, and their effectiveness is uncertain' (IPCC 1998).

There is general agreement that humans already have overwhelming impacts on natural ecosystems (Vitousek et al. 1997) and that this interferes with the functioning of ecosystems in ways that are detrimental to our well being. A panel of 11 scientists (Daily et al. 1997) was 'certain' that 'ecosystem services are essential to civilization,' that 'human activities are already impairing the flow of ecosystem services on a large scale,' and that 'if current trends continue, humanity will dramatically alter virtually all of the earth's remaining natural ecosystems within a few decades.' The primary threats are: land-use changes that cause loss of biodiversity; disruption of carbon, nitrogen and other biogeochemical cycles; human-caused nonnative species invasions; releases of toxic substances; possible rapid climate change; and depletion of stratospheric ozone. This panel was 'confident that … the functioning of many ecosystems could be restored if appropriate actions were taken in time' (Daily et al. 1997).

Attempts to take timely action to minimize climate-related risks are hampered by: (1) the perception by some decision-makers that the impacts of climate change are distant and speculative and therefore do not warrant action, (2) the difficulty in making site-specific predictions of future climate at a scale relevant to ecological processes (Root & Schneider 1993), and (3) the global nature of climate change requiring large-scale efforts integrating local, regional, and national activities. It is increasingly unlikely that greenhouse gas emissions will be reduced quickly enough to fully prevent significant warming. Likewise, measures directed at specific effects of climate change are unlikely to be applied widely enough to protect the range of ecosystem services upon which society depends. Fortunately, reducing the impacts of nonclimate stresses on ecosystems would also buffer ecosystems from negative effects of climate change. The range of potential strategies (Table 2) is broad enough to involve every resident of the MAR. Activities that conserve biological diversity, reduce fragmentation and degradation of habitat, and increase functional connectivity among habitat fragments will increase the ability of ecosystems to resist anthropogenic environmental stresses, including climate change (

The purpose of assessing the potential impacts of climate change upon ecosystems is to provide information to decision-makers and stakeholders about the consequences of possible actions. Research should be guided to meet these information needs. Crucial research gaps include:

- **Ecosystem valuation.** We need to improve our understanding of how society depends upon ecosystems and how people value different aspects of ecosystems. This information should be used in developing research priorities and in choosing among alternatives for increasing ecosystem resiliency.
- **Ecosystem functioning.** We still lack basic information about how ecosystems function, limiting our ability to predict and understand how changes in one part of an ecosystem affect other parts. Such changes include how current stresses, such as habitat loss and alteration, pollution, and non-native species are affecting ecosystems, and how these stresses could interact with climate change. The limits of our understanding are highlighted by the current difficulties in attempting to predict the ecological impacts of climate change.
- **Monitoring.** Indicators of the status of ecosystems, and the magnitude and distribution of stresses upon ecosystems, should be included in long-term ecological monitoring plans. Early warning signs of potential losses of valued ecosystem functions should be identified and included as indicators.
- **Management options.** Understanding the effectiveness of various management strategies is crucial to targeting limited resources for ecological protection.

An example drawn from experiences with the Chesapeake Bay illustrates the value of these areas of research. Concern about declines in fish, crabs and waterfowl stimulated research into ecosystem function and human impacts, revealing the links between land-use practices, nutrient runoff, overgrowth of algae, loss of submerged aquatic vegetation and depressed levels of dissolved oxygen in bottom waters, and the animal declines. Ecological monitoring was essential to the discovery of these relationships, and to measuring the effectiveness of ongoing efforts to control inputs of nutrients to the Bay. Such experience can serve as a model to design an integrated research strategy for the other major types of MAR ecosystems likely to be sensitive to climate change.

Acknowledgements. We thank Joel Scheraga, Michael Slimak, Ann Fisher, Janet Gamble, Bill van der Schalie, Susan Norton, L. LaReesa Wolfenbarger, Terry Keating and 3 anonymous reviewers for comments on earlier versions of this manuscript. J.P.M. gratefully acknowledges the support of the American Association for the Advancement of Science and the US EPA's National Center for Environmental Assessment during the preparation of this manuscript. Note: The views expressed are the authors' own and do not represent official EPA policy.

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Table 2. Strategies to increase resilience of ecosystems to climate change and other stressors

Stressor	**Strategy/human response**	**Examples**
Physical habitat alteration	Conservation	Establish protected areas Protect natural features of managed landscapes Minimize water consumption (to protect aquatic habitats)
	Restoration	Examples to date include: Long-leaf pine ecosystems Everglades hydrology Tall-grass prairie Manage species directly
Pollution (resulting in eutrophication, acid deposition, increased UV-B radiation, other problems)	Regulation of emissions	Control SO_2, NO_X, and VOC [volatile organic compounds] emissions from power plants and motor vehicles Regulate emissions of CFCs (e.g. Montreal Protocol) Reduce point source water pollution
	Regulation of land use and non-point sources	Protect riparian buffers Change urban and agricultural practices
Non-native invasive species	Prevention of introduction and establishment	Monitor areas around ports of entry and eliminate new populations
	Management of established populations	Release biological controls Eradicate invasive species
Global climate change	Reduction of greenhouse gas emissions	Reduce emissions from power plants and motor vehicles Conserve energy
	Reduction of climate impacts via reduction of other stressors	Increase ecosystem resiliency to climate impacts via habitat protection, reduced pollution, control of invasive species
	Direct reduction of climate change impacts	Schedule dam releases to protect stream temperatures Transplant species Establish migration corridors