

US EPA ARCHIVE DOCUMENT

Regional Vulnerability Assessment for the Mid-Atlantic Region: Forecasts to 2020 and Changes in Relative Condition and Vulnerability

US EPA ARCHIVE DOCUMENT

Regional Vulnerability Assessment for the Mid-Atlantic Region: Forecasts to 2020 and Changes in Relative Condition and Vulnerability

Prepared by

Paul F. Wagner¹, Robert V. O'Neill², Liem T. Tran³, Megan Mehaffey¹,
Timothy Wade¹, and Elizabeth R. Smith¹

¹U.S. Environmental Protection Agency
Office of Research and Development
National Exposure Research Laboratory
Environmental Sciences Division
944 E. Harmon Ave.
Las Vegas, NV 89119

²T N and Associates
704 S. Illinois Ave., Suite C-104
Oak Ridge, TN 37830

³Department of Geography,
The University of Tennessee
1000 Phillip Fulmer Way
Knoxville, TN 37996

Notice: Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy. Mention of trade names and commercial products does not constitute endorsement or recommendation for use.

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

Notice

The information in this document has been funded wholly by the United States Environmental Protection Agency. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document.

Acknowledgements

Many people contributed to this report, through analyses and interpretation, methods development, and other input to the ReVA program. Specifically we would like to acknowledge the following:

Robert Abt, Duke University

Earl Greene, U.S. Geological Survey, Water Resources Division

Laura Jackson, EPA, National Health and Environmental Effects Research Laboratory

Kimberley Johnson, EPA, National Exposure Research Laboratory

Bruce Jones, U.S. Geological Survey

Vasu Kilaru, EPA, National Exposure Research Laboratory

Daniel Kluza, EPA, National Center for Environmental Assessment

Andrew La Motte, U.S. Geological Survey, Water Resources Division

Joshua Lawler, National Research Council

Rick Linthurst, EPA, Office of the Inspector General

Peter McKinnis, Waratah Corporation

Michael O'Connell, Waratah Corporation

Valeria Orozco, Waratah Corporation

Elizabeth Price, King and Associates

Rex Schaberg, North Carolina State University

Roger Tankersley, Tennessee Valley Authority

Dennis Yankee, Tennessee Valley Authority

Lisa Wainger, King and Associates

Executive Summary

The EPA's Regional Vulnerability Assessment (ReVA) Program develops and demonstrates approaches to 1) integrating spatial data and model results, 2) forecasting future scenarios, and 3) applying these methods towards regional priority setting and decision making. This report demonstrates the projection of multiple drivers of ecological change at a broad scale to the year 2020 followed by the application of different integration methods that synthesize results to address a suite of assessment questions to guide proactive decision making.

Identified drivers of change for the Mid-Atlantic region include land use change and population growth, non-indigenous species, pollution, and resource extraction (Smith *et al.* 2001). Making use of available data and models, projections were made for land use/land cover, population and demographics, non-point source pollutants in surface water, nitrogen in groundwater, and spread of non-indigenous species for the year 2020. These were then compared to a similar set of variables available for the current time period to assess changes in condition and vulnerability for the Mid-Atlantic region.

Selecting the appropriate integration method(s) to address specific assessment questions was an important objective of this project and the process followed results of earlier work evaluating a suite of integration methods for their sensitivity to different data issues and how well they addressed different assessment questions (Smith *et al.* 2003). To address questions associated with changes in pattern and condition, three integration methods were used: the Simple Sum, Principal Components, and State Space. Simple Sum and Principal Components have been shown to be complementary in their results as they are sensitive to different properties of the data. Together, they provide a good overview of regional conditions. State Space, used in this example to quantify the distance between each individual watershed and the most vulnerable watershed, is useful for quantifying how much change has occurred in that it highlights both where degradation is small and where major changes might occur.

To address questions related to identifying the most important stressors and resources now and in the future, the matrix method was used. While this method has been used for many years in a qualitative manner, correlation coefficients were used to quantify the relationship between stressors and resources based on the large amount of data available for the Mid-Atlantic region to rank among stressors and resources for both current and future periods.

Vulnerability questions were addressed using the Stressor-Resource Overlay method and the Criticality method. The Stressor-Resource method highlights areas where valued resources coincide with stressors that threaten them and where there are either no resources left or where there are only a few stressors threatening them. The Criticality method is based on the theory that as an ecosystem is moved further from its natural state it moves towards a state of being irreversibly damaged. Application of the Criticality method requires setting the suite of variables to values that are near "natural" which was done in this application using fuzzy numbers to reflect our imperfect knowledge.

Assessment results are necessarily the sum of the full set of analyses as each integration method provides different information and insights into the pattern of condition and vulnerability and how it may change for this region. Current patterns generally showed that the best conditions were in the Mid-Atlantic Highlands and the worst were in the urban areas of Baltimore, Washington, Pittsburgh and Raleigh. For future conditions, the Principal Components Analysis (PCA) showed less degradation of the urban areas as it adjusts for covariance among the stressor variables, which may underestimate the possibility of synergistic effects. The Simple Sum may thus be a more conservative predictor of environmental condition and better predictor of the probability of where cumulative effects can be expected. The State Space method indicated the least change in watersheds in the highlands and the most in watersheds in

suburban areas around urban centers with intermediate changes projected for the coastal plain and piedmont. The State Space method maintains full dimensionality but minimizes the effect of covarying stressors so the pattern can be interpreted as the minimum change expected.

The matrix method identified land conversion by humans, nitrogen and phosphorus loading to streams, forest fragmentation, and soil erosion as the most damaging stressors to present environmental conditions. The most damaging stressors identified for the year 2020 were predicted to be the same with the exception of fragmentation, which was replaced by road density. The most vulnerable resources both now and in the future were small intact forest patches and forest cover in general.

The overlay analysis identified several watersheds in the highlands and several in the piedmont and coastal plains as vulnerable currently. Vulnerability to irreversible change as identified by the Criticality method was shown to be associated with more intense human activity particularly around Baltimore, Washington, north of Pittsburgh and east of Raleigh. Another 20 vulnerable watersheds were concentrated around urban centers. An additional five watersheds in eastern suburban areas entered this category of vulnerable to irreversible change with the 2020 projections.

Table of Contents

| | |
|---|-------------|
| Notice | iii |
| Acknowledgements | v |
| Executive Summary | vii |
| List of Tables | xi |
| List of Figures | xiii |
| Introduction | 1 |
| Background | 1 |
| Purpose of this Report | 1 |
| Study Area, Temporal Extent, and Reporting Units | 2 |
| Projecting the Drivers of Change in the Mid-Atlantic Region | 3 |
| Data and Variables | 5 |
| Landscape Metrics | 5 |
| Native and Nonnative Species | 5 |
| Water | 6 |
| Demographics | 7 |
| Methods | 9 |
| Future Scenario Analysis | 9 |
| 2020 Land Cover Change Projection | 9 |
| Projection of Migratory Bird Flights | 9 |
| Projection of Non-Indigenous Species | 10 |
| Projection of Nitrogen and Phosphorus in Surface Water | 11 |
| Projection of Nitrate in Groundwater | 11 |
| Combining Various Projections in Future Scenario Analysis | 12 |
| Integration Methods Used in Scenario Analysis | 12 |
| Simple Sum | 12 |
| Principal Components Analysis | 12 |
| State Space Analysis | 13 |
| Matrix Method | 13 |
| Criticality Analysis | 14 |
| Stressor-Resource Overlay | 14 |
| Results | 15 |
| Pattern and Condition | 15 |
| About the Analysis | 15 |
| Maps | 16 |
| Stressors and Resources | 19 |
| Tables | 20 |
| Stressors | 20 |
| Resources | 21 |
| Vulnerability | 21 |
| About the Analysis | 22 |

| | |
|---|----|
| Maps | 24 |
| Stressor-Resource Overlay | 24 |
| Criticality | 24 |
| Discussion | 29 |
| Current Conditions and the Future Scenario: Analysis of the Mid-Atlantic Region | 29 |
| Other Uses of ReVA Assessments | 31 |
| Environmental Conservation | 31 |
| Ecological Restoration | 31 |
| Appendix | 33 |
| References | 35 |

List of Tables

| | | |
|---|---|----|
| 1 | List of variables (Stressors and Resources) used in scenario analysis..... | 6 |
| 2 | The most important stressors from matrix analysis | 20 |
| 3 | The most important resources from matrix analysis..... | 21 |
| 4 | Definition of “natural state” of the 24 indicators used in the analysis..... | 23 |
| 5 | Stressor and resource change in two of the top 20 watersheds most vulnerable to irreversible change | 27 |

List of Figures

| | | |
|---|---|----|
| 1 | Study area | 2 |
| 2 | National Land Cover Data (NLCD) land-cover map of the Mid-Atlantic region (1992) | 3 |
| 3 | Map of predicted land cover for the Mid-Atlantic region in 2020..... | 10 |
| 4 | Map of current and future environmental condition in the Mid-Atlantic integrated using the Simple Sum method..... | 16 |
| 5 | Map of current, future, and comparative environmental stress in the Mid-Atlantic integrated using the PCA Sum method..... | 17 |
| 6 | Map of current environmental condition in the Mid-Atlantic using PCA and Simple Sum methods | 18 |
| 7 | State Space analysis | 19 |
| 8 | Stressor-Resource Overlay showing the most vulnerable watersheds | 25 |
| 9 | Watersheds currently most vulnerable to irreversible change, most vulnerable to irreversible change by 2020, and comparison map | 26 |

