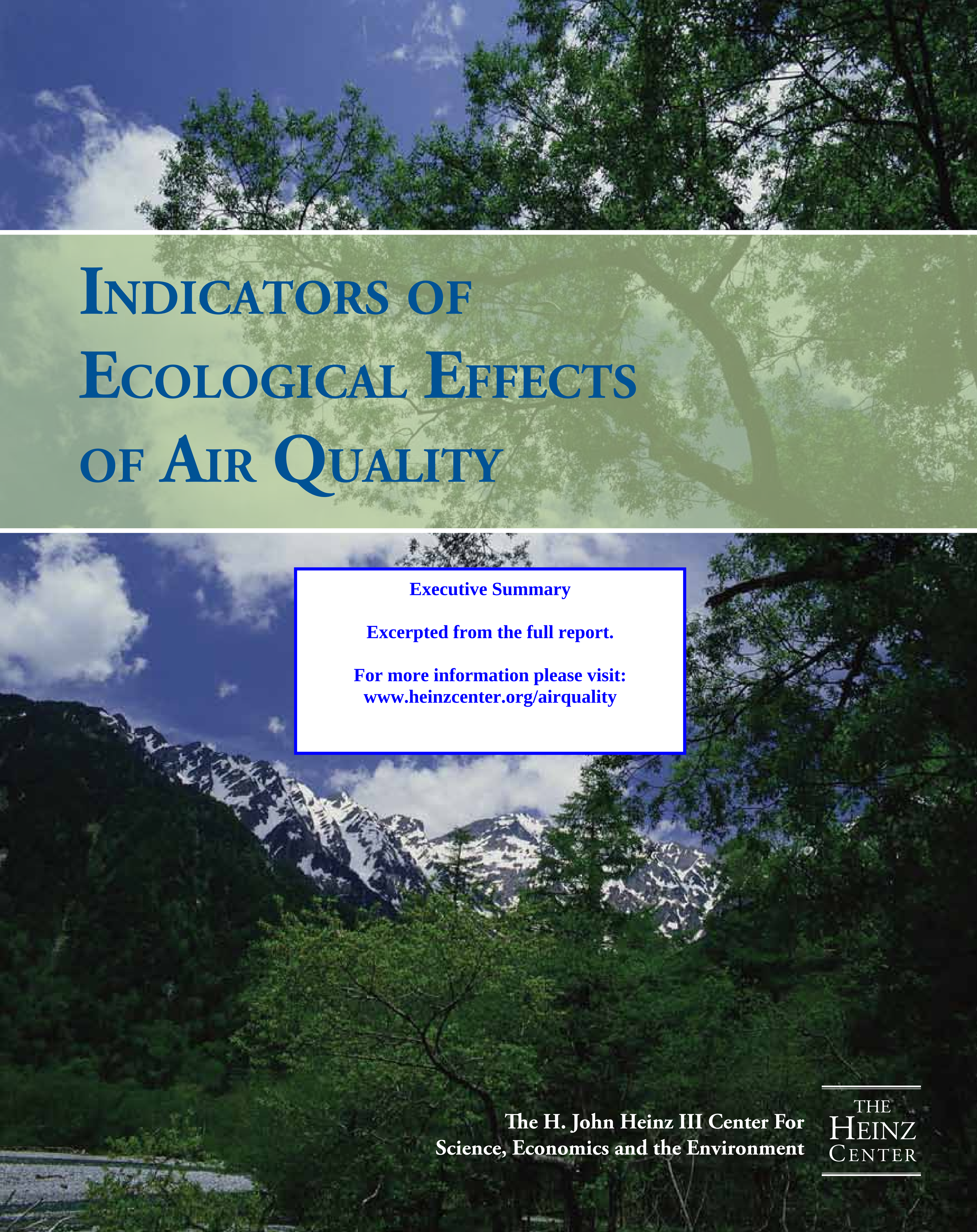

Indicators of Ecological Effects of Air Quality

Executive Summary

Excerpted from the full report.

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The H. John Heinz III Center For Science, Economics and the Environment

The Heinz Center

Executive Summary

Ecological indicators are needed to improve understanding and monitoring of the effects of air pollutants on ecosystems and to scientifically assess the effectiveness of air pollution control strategies. Traditionally, research and monitoring of air quality have focused on human health impacts and have been concentrated in urbanized areas, however pollution impacts on ecosystems are an equally important measure of how well our emission control policies are working.

Decision-makers need tools to help them understand whether and how their decisions are contributing to the achievement of air quality goals. Ecosystem monitoring is one such tool; chosen well, indicators of ecosystem change can help to inform policy development and implementation by documenting whether emission control policies and programs are working as intended and helping to determine if policy change is needed to achieve further ecosystem protection.

With support from the U.S. Environmental Protection Agency (EPA) Clean Air Markets Division, the Heinz Center has developed a suite of indicators to inform environmental data collection and integrated assessment of ecosystem response to changes in air quality. This report focuses on four major ecological effects of air pollution: acidification by nitrogen and sulfur, nitrogen enrichment, ozone damage to plants, and mercury bioaccumulation.

Recommended Indicators

This project identifies well-documented and widespread ecological responses to air pollutants (i.e., ecological conditions that are sensitive to changes in air quality over time) and recommends a small number of ecological indicator metrics that demonstrate the links between ecosystem exposure and response where they are strongly established.

Acidification by nitrogen and sulfur deposition:

Base Saturation. This indicator would report change in the base saturation of forest soils: the relative abundance of basic cations (such as calcium, magnesium, and potassium) compared to total exchangeable cations (i.e., base cations plus acid cations such as hydrogen and aluminum). This metric has been found to be correlated to biological availability of nutrient cations.

Acid Neutralizing Capacity. This indicator will report the percentage of freshwater systems with low, medium, and high ANC, for both chronic and episodic acidification. ANC is well correlated with pH, an important chemical variable for aquatic biota, but also reflects ecological susceptibility to changing pH.

Nitrogen enrichment:

Streamwater Nitrogen. This indicator will report change in nitrate levels in forested streams nationwide. This metric is intended to capture nitrate leaching and export resulting from nitrogen saturation in forest systems.

Organic Soil Carbon to Nitrogen Ratio. This indicator would report the ratio of organic carbon to nitrogen in the surface horizon of forested soil systems. This metric is relevant to the decomposition rate of organic materials and relates to the forests' overall vulnerability to nitrogen enrichment and leaching loss.

Ozone damage to plants:

Foliar Injury in Forests. This indicator will report an index value for ozone-induced foliar injury detected in sensitive forest plant species, stratified by two important controlling variables: ozone exposure and plant available moisture.

Change in Growth/Yield in Cropped Systems. This indicator will report the mean national annual yield of several crops that are known to be sensitive to ozone stratified by ozone exposure.

Mercury bioaccumulation:

Change in Methylmercury in Prey Fish and Piscivorous Fish and Birds. These indicators would report annual summary statistics (e.g., annual average) for methylmercury levels in biota that have been documented to bioaccumulate mercury, stratified by watershed categories of mercury sensitivity and mercury deposition. (National-scale mercury data are not yet available and watershed categories are under development.)

Research Needs

A number of other metrics of ecological response to air pollution were evaluated, however further scientific investigation is needed to support indicator development for these metrics. In the future, as research continues, it may be possible to develop additional indicators to complement the indicator metrics recommended above.

Nitrogen enrichment:

Foliar N Concentrations and Nitrogen to Nutrient Ratios. Foliar chemistry changes and nitrogen to nutrient ratios may be useful indicators of nitrogen-induced changes in terrestrial ecosystems, particularly in N-limited forests, but more research is needed to clarify issues such as sampling methods and the interaction of multiple effects.

Changes in Community Structure. Bioindicators such as lichens and diatoms are useful integrators of changing ecological conditions, and changes in nitrogen-sensitive species can signal the onset of broader pollution-induced changes in community composition, but knowledge of these relationships is still geographically limited.

Nitrogen Enrichment in Coastal Systems. Nitrogen loading to coastal systems has been shown to produce harmful effects such as algal blooms and oxygen depletion, however the relative contribution of atmospheric nitrogen deposition is not yet fully understood. In order to propose a nationally-relevant indicator metric for this ecological effect, further progress in synthesizing and/or scaling up existing watershed-level research may be needed.

Ozone damage to plants:

Changes in Species Composition. Ozone-induced changes in community composition have been detected for lichens and other organisms at the research-scale, however broad-scale or long-term decline in ozone-sensitive species is difficult to detect due to confounding factors (e.g., moisture availability). Future research holds promise for indicator development.

Remotely Sensed Changes in Plant Physiology. Emerging research in the use of remote sensing data represents an opportunity to detect patterns of ozone effects on plant chlorophyll levels and water use efficiency by factoring out effects of climate and/or ambient CO_2 concentrations. As this work matures, the scientific basis and data systems may support national-scale indicator reporting.

Mercury bioaccumulation:

Change in the Relative Abundance of Methylmercury in Streams and Coastal Systems. This metric would reflect the overall bioavailability of mercury for methylation, however, comprehensive national-scale monitoring systems are not yet in place for mercury in water and sediments. Therefore, at this time indicator development is constrained (although there is a consortium actively designing a comprehensive national mercury monitoring network).

Change in Total Mercury in Invertivores. Mercury bioaccumulation pathways have begun to be detected in terrestrial systems and, as research develops further, mercury levels in insect-eating organisms (e.g., spiders, songbirds, and bats) may represent a useful indicator of the transfer of atmospheric mercury to higher tropic level biota.

Conclusion

Scientists have learned much about the ability to track pollution effects in ecosystems, and how to tease apart the causes behind those changes. For many air pollution impacts, existing research provides a solid foundation for understanding how ecosystems are being affected. For others, research is still emerging or limited to geographic regions.

The intention of this project is to provide federal and state agencies and other natural resource managers and policy makers with quantitative tools for assessing ecosystem responses to changes in air quality. In moving towards a set of ecological indicators of air quality supported by a comprehensive system for which data will be collected and reported on a regular basis, it is important to continue to draw others into the decision-making process. Indicators are an evolving tool, a starting point to be refined and revised as necessary. With information in hand, policymakers can make informed decisions about proposed changes to legislation and associated activities. In the realm of the impacts of air quality on ecosystems, this project aims to assist in the development of a monitoring system that is comprehensive, cost-effective, and flexible enough to be adaptable to future changes.