ENVIRONMENTAL SCIENCE RESEARCH SERIES

indicators of environmental quality

edited by William A. Thomas

INDICATORS OF ENVIRONMENTAL QUALITY

Proceedings of a symposium held during the AAAS meeting in Philadelphia, Pennsylvania, December 26-31, 1971

Edited by

William A. Thomas

Group Leader, Environmental Indices
Environmental Program
Oak Ridge National Laboratory
Oak Ridge, Tennessee

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"Our discussion will be adequate if it has as much clearness as the subject-matter admits of, for precision is not to be sought for alike in all discussions . . . [I]t is the mark of an educated man to look for precision in each class of things just so far as the nature of the subject admits . . . "

ARISTOTLE, 384–322 B.C.
Nicomachean Ethics
Book 1, Chapter 2

PREFACE

Researchers and agencies collect reams of objective data and authors publish volumes of subjective prose in attempts to explain what is meant by environmental quality. Still, we have no universally recognized methods for combining our quantitative measures with our qualitative concepts of environment. Not all of our environmental goals should be reduced to mere numbers, but many of them can be; and without these quantitative terms, we have no way of defining our present position nor of selecting positions we wish to attain on any logically established scale of environmental values. Stated simply, in our zeal to measure our environment we often forget that masses of numbers describing a system are insufficient to understand it or to be used in selecting goals and priorities for expending our economic and human resources.

Attempts at quantitatively describing environmental quality, rather than merely measuring different environmental variables, are relatively recent. This condensing of data into the optimum number of terms with maximum information content is a truly interdisciplinary challenge. When Oak Ridge National Laboratory initiated its Environmental Program in early 1970 under a grant from the National Science Foundation, the usefulness of environmental indicators in assessing the effects of technology was included as one of the initial areas for investigation. James L. Liverman, through his encouragement and firm belief that these indicators are indispensable if we are to resolve our complex environmental problems, deserves much of the credit for the publication of this book.

Unfortunately, the scientific literature is not abstracted or indexed with appropriate keywords that allow rapid dissemination of these new ideas and methodologies. To encourage cooperation among persons with diverse professional interests and to review the state of the art, the American Association for the Advancement of Science sponsored a two-day symposium entitled "Indicators of Environmental Quality" during its annual meeting in Philadelphia from December 26 to 31, 1971. The authors of the first 18 of the 21 chapters of this book prepared their papers for presentation at that symposium. The concluding three chapters were added to broaden even more the book's coverage of environment. Due to time limitations, not to a restricted viewpoint of what constitutes our environment, we had to restrict the symposium's scope primarily to the physical, chemical, and biological aspects. The social consequences of our actions are recognized throughout the volume, and one author directly addresses the social aspects of environment.

The symposium emphasized the need for public participation in decisions concerning environmental quality, and all speakers agreed that indicators

facilitate the required communication among public officials, scientists, and the public. A total of 86 members of the audience submitted written questions for consideration during the panel discussions that followed each half-day session. All of the speakers had the opportunity of responding to the applicable questions before submitting the final revisions of their manuscripts. Speakers alone do not make a symposium successful, and the active participation of the audience contributed greatly to the success of this one. Special acknowledgement is due the individual authors who cooperated in many ways; their promptness in meeting the necessary deadlines ensures a timely volume.

Designing and testing indicators of environmental quality are not mere academic exercises – scientists have a responsibility to make "environment" comprehensible to all segments of society that justifiably demand a greater participatory role in determining the habitability of our planet. It is in the spirit of interdisciplinary action toward providing objective measures of environmental quality that this volume is published.

W.A.T

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INDICATORS OF ENVIRONMENTAL QUALITY: AN OVERVIEW*

William A. Thomas

Leader, Environmental Indices Group
Environmental Program, Oak Ridge National Laboratory†
Oak Ridge, Tennessee 37830

A concerted effort to enhance habitability of our planet is unlikely to succeed unless we know "where we are" and "where we want to go." To answer these questions, we first must consider exactly what we include in the term "environment." If we restrict our consideration to overly simplified definitions, such as the amount of a specified pollutant in air, we have very little difficulty in measuring environment. However, as we broaden our definition to include all the physical components, or all the physical and biological, or all the physical, biological, and cultural ones, environment becomes exponentially more difficult to describe. Nonetheless, I believe we must take the holistic approach at the outset and define environment as that complex of interacting physical and cultural factors which routinely influences the lives of individuals and communities. This indeed is a broad definition, but we should not forget when we study the individual components that the entirety functions as a system of interacting components.

A major difficulty in describing environment is that all of its components cannot be measured directly. The challenging field of social indicators[2,3,9,10] provides ample evidence of the problems involved in assigning values to the social or cultural aspects of environment such as education, public order, and recreational opportunities. However, we can measure certain variables that indicate the presence or condition of phenomena that cannot be measured directly. These indicators reflect the state of any aspect or component of the environment. The method of selecting the indicator varies with the characteristics of the component, but they all share one requirement. The indicator must respond to changes in the component it is scaling in such a manner that it accurately reflects the magnitude of those changes. Objective aspects such as meteorological conditions seldom require an indicator because they can be measured directly, but indicators usually are necessary to assign quantitative values to subjective aspects such as public health.

Several indicators may be integrated into one index for the more complex components if data are available. An index is a composite value for an

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environmental component for which we have more than one indicator; this distinction in terms is not accepted universally, but it is helpful in understanding the hierarchical nature of our environment. Ideally, these indices also can be aggregated by regions to establish geographical hierarchies. For example, we lack a universal measure for water quality even though we do measure the principal contaminants and thus have a series of indicators that can be combined into a single water quality index. Assignment of quantitative weighting factors to the values of the individual indicators poses complex questions due to incomplete scientific conclusions on the relative detrimental effects of some contaminants. Even the identification of suitable criteria for measurement is difficult for some pollutants; the undesirable effects of noise and odors, for example, are not easily characterized.

Because measures of the more subjective components of environmental quality, such as urban sprawl, uniqueness of open spaces, and scenic landscapes, cannot be devised as objectively as other measures might be, indices for them may incorporate value judgments by necessity. Obviously, the preferences even of prudent men often differ; therefore, use of personal judgments is minimized wherever possible.

Living organisms provide convenient full-time monitors of all pollutants, including their synergistic effects. Thus biological indicators, like the miners' canary, measure the actual responses of organisms or populations to environmental quality rather than predict a biological response from physical measurements. The physiological and ecological diversity of species allows a wide choice of indicator species for various environmental factors and situations. At the other end of the biological spectrum, biochemical reactions might possibly be used in tests for more specific classes of contaminants. Because ability to support life is a prime characteristic of any environment, the general vigor of natural populations provides a readily accessible gage of habitability which will be used more frequently as our ability to interpret population fluctuations increases. Systematic use of a series of biological indicators permits a more detailed description of quality.

We need to facilitate communication among the segments of society now concerned with environmental quality by providing adequate information in a compact format. The major goal in development of indicators is a translation by a scientifically defensible method of the many components of environment into an optimum number of terms with maximum information content. To do this, we accept some reduction in precision, but in return we gain the ability to communicate. We can classify the potential users of this information into five not-mutually-exclusive categories.

1. *Citizenry*. The majority of citizens realize that the quality of their environment is threatened, but the complexity of the environment precludes their understanding it. Indicators can enhance public sensitivity to environmental issues and encourage accountability of elected officials.

2. *Local and Regional Planners and Government Officials.* Alternatives for many decisions which affect our environment seldom are explored; again, complexity of the system discourages the attempt. Causally related indicators can provide predictions of consequences that may be expected from alternative courses of action. Objective allocation of public funds at all levels of government can be encouraged by the use of indicators to establish priorities for funding and to measure the effects of budgetary decisions.
3. *Judiciary, Legislature, and Regulatory Agencies.* These groups often attack environmental problems by establishment and enforcement of standards. A rational series of indicators is the precursor of a rational series of standards. The National Environmental Policy Act of 1969 requires the President to submit an annual report to Congress in which he shall convey the "status and condition of the major natural, manmade, or altered environmental classes of the nation" and the "current and foreseeable trends in the quality ... of such environments." Prose alone soon will be inadequate, and the Council on Environmental Quality now includes environmental indicators and indices in these reports.[4] Regulatory mechanisms for maintenance and enhancement of our natural and manmade resources often lack clear guidelines that allow intelligent appraisal of the effectiveness of our stewardship policies. Similarly, our courts will benefit from a system of objective indicators that quantitatively describe the impairment of resource quality by pollutants. Indices can link scientific knowledge with legal standards for environmental quality.
4. *Scientists and Engineers.* Research priorities for private and public resources can be set and defended with indicators in circumstances where perspective alone might fail. Indices provide a convenient format for summarizing and handling data and for presenting research results and proposals for action to responsible authorities, who also would find them useful in making their decisions.
5. *Special Interest Groups.* Many groups – including labor and industrial organizations, lobbies, public interest firms, conservation societies, and others – advocate positions on what constitutes desirable environmental quality and thus need quantitative terms to support those positions. By standardizing the use of data, indices can make the efforts of these groups more efficient to the benefit of all concerned.

No user group is likely to limit its use of environmental information to indicators and indices alone; in fact, data might not assist at all in resolving some problems. Certainly, all appropriate data will be examined when specific issues arise, but indices and indicators do serve as a convenient shorthand system that users can understand, appreciate, and utilize in attaining their objectives. Ample evidence and recommendations exist to indicate a genuine need for these indicators.[1,4-8] These indicators and indices are susceptible to misuse just as all information systems are, but I think they actually promote open discussion and retard the misleading uses of environmental information that may occur when only selected raw data are available to a limited number of individuals. One of

the constituents of a successful indicator system must be the means of explaining its proper use and limitations to its users.

The available indicators today are useful in depicting trends through time and in comparing environmental quality among geographical areas. It obviously would be much more helpful to learn in advance what the expected environmental conditions will be than to be informed after the fact. This current limitation on the use of indicators results from the present data collection methods and is not an inherent fault of the indicator concept. We need to increase the predictive capability of indicators to permit prophylactic action when necessary. Sufficient data might not be available now to do this, but by coordination of development of techniques with expansion in the data collection system, many inefficiencies can be avoided. Rather than design indices to use the available data, as we now do, we should collect data that will be used most advantageously in the indices. In this manner we can learn from the indices themselves which data should be added or deleted from the system.

In addition, we should scale all our indicators to a common denominator, such as human health, so that we can discuss as many environmental variables as possible with a standard reference point. We then would know which problems should be given increased attention. Not all aspects of environment are compatible with a common denominator approach, and synergistic effects will remain troublesome, but the result nonetheless would be an improvement over our present efforts.

Development and communication of environmental indicators represents a truly interdisciplinary challenge that requires the merging of talents from many diverse disciplines and viewpoints. Perhaps Edna St. Vincent Millay best described our purpose when she wrote in her Sonnet Number CXL:

> Upon this gifted age, in its dark hour
> Rains from the sky a meteoric shower
> Of facts ––; they lie unquestioned, uncombined,
> Wisdom enough to leech us of our ill
> Is daily spun, but there exists no *loom*
> To weave it into fabric. (Italics added)

We should recognize the difficulties that must be overcome to produce this "loom" and should not hope for instant panaceas; but when we succeed, the beneficial consequences will be far ranging – objectivity will replace subjective rhetoric in assessment of shifts in environmental quality. Indeed, we will be able not only to define our goals but also to measure how well we progress toward them.

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WHY ENVIRONMENTAL QUALITY INDICES?

Thomas L. Kimball

Executive Vice-President
National Wildlife Federation
1412 Sixteenth Street, NW
Washington, D.C. 20036

Science and technology in general, and professionalism in particular, are under attack in our great nation. The average American citizen is confused and confounded by purported scientific rationales that mix philosophy, politics, and opportunism with the analysis of factual research data. That confusion turns to disgust, and then rejection, when the public listens to professionals trained in our best institutions of higher learning and with similar long-term experience who come forth with diametrically opposed conclusions and recommendations from an analysis of environmental research data. Unfortunately, there appears to be a growing conviction among the American populace that it is extremely difficult if not impossible to get the unvarnished truth from the scientific community. As a consequence, professionalism is being downgraded in direct proportion to the inability of the public to guess which scientist has the right answer. Nowhere is there a better example of this phenomenon and dilemma than in an analysis of the current environmental–ecological revolution. In February, 1969, the National Wildlife Federation commissioned the Gallup Organization to survey public opinion on environmental degradation.[1] Gallup found that the majority of Americans were either somewhat or deeply concerned about the deteriorating quality of living brought about by the fouling of our own nests. Both fortunately and unfortunately, many and varied segments of our modern complex society have also become aware of this burgeoning public interest. It has brought forth new pollution abatement laws replete with political tub thumping, a new dimension to more intense and centralized government regulation, an alarmed industrial complex – insecure in its continued ability to pollute at the expense of the environment, the Madison Avenue hucksterings of endless products reportedly harmless to the plant and animal ecosystems, and a citizenry that is incapable of separating advertising fantasy-land from the truth. Extremist "eco-freaks" and a rash of instant ecologists whose dire predictions have failed to materialize have created a king-size environmental credibility gap that threatens to destroy any significant progress toward the real solution of our critical environmental problems.

Government leadership has been a great disappointment. Whenever government finds itself in the middle of two aggressive constituencies with conflicting

viewpoints, its reflexes are predictable. Instead of concentrating on an aggressive action program based upon the best scientific evidence available, government usually embraces one of two cop-outs: (1) a proposal for government reorganization is drafted or (2) a commission is appointed for further study. Both of these inept measures usually take years to complete, and neither effort has ever made any great contribution to the solution of a problem. Then there is a Congressional propensity to place in the same federal executive agency the mandate to both promote and regulate a specific important natural resource. The best examples are: the Atomic Energy Commission, which possesses the authority both to promote and to regulate the peaceful uses of atomic energy, and the Federal Power Commission, with authority to promote and regulate the energy needs of our nation. The Commerce Department is industry's spokesman in governmental affairs. Agriculture promotes and regulates the farmer and the commodities he produces. The entire executive branch of our federal government (and also to a lesser degree in state government only because of size) is rapidly losing the confidence of increasingly larger segments of our society because of its apparent willingness to react to principal special interest lobbies while unable or unwilling to respond to majority public opinion or to take the responsive actions essential to resolving critical issues.

The seniority system in our Congress perpetuates rules which essentially place in the hands of an individually powerful committee chairman the authority to prevent the entire Congress from considering, debating, and voting on critically needed legislation.

By now everyone should be convinced why we need Environmental Quality Indices. The lay citizen is interested in preserving and perpetuating a quality life in a natural environment in addition to keeping our nation strong, healthy, and secure from our enemies, both foreign and domestic, by preventing the misuse and waste of our great wealth of resources. The effort is now entering a crucial stage. The conservation, environmental, and ecological forces have been and are anxious to continue the battles which shape our national priorities. The man on the street must be armed with the facts and figures he considers accurate and has confidence in if we expect him to enter the fray with any significant firepower. The NWF's Environmental Quality (EQ) Index[2,3,4] is an effort designed to provide the concerned citizen with a comprehensive review of published information on factors affecting environmental quality presented in rather simple language and graphics readily understood by the masses.

While we are very proud of the innovative work done within the ranks of the National Wildlife Federation staff, we are not so foolish or short-sighted as to think that our EQ Index – now in its third year – represents the ultimate product or even the best analysis of available data. However, we do feel that it gives the average citizen a much better grasp of the environmental situation as it exists today and as it might look tomorrow and next year and in the foreseeable future.

The NWF EQ Index is the end product of an exhaustive, scholarly exercise that attempts to reduce reams of information – much of it disjointed at best and

some possibly erroneous at worst – into a simple, orderly, graphical representation of environmental conditions. We are persuaded that our EQ Index enables the average reader to quickly grasp the overall environmental situation and to "zero in" on the key issues. Armed with the information contained in a comprehensive Environmental Quality Index, and the trends that it discloses, a citizen is in a position to go through the accepted democratic processes of examining the pros and cons of the issue, listening to the comments and advice of others, and eventually reflecting his views in the various forums and forces that shape our national policy.

For those of you who might not be familiar with the EQ Index prepared by the National Wildlife Federation, I will spend a few minutes outlining its major points and describing the processes by which some of the judgments are made and by which some of the costs are determined.

The National Wildlife Federation's third annual Environmental Quality Index was published in October. When first published in the fall in 1969, the EQ Index evaluated six natural resources: air, water, soil, forests, wildlife, and minerals. In 1970, a seventh item – living space – was added to the list.

The various categories of the environment were subjectively rated from best to worst and then were scored on a numerical scale of 0 to 100, as listed in Table 1. A "0" would equal death or disaster; "100" would be ideal conditions with environmental equilibrium. For example, soil is, in our relative judgment, in the best condition of any single resource, but soil conditions are still far less than ideal. In 1970, it was given an Index value of 80. This year, because of continuing losses, the rating slipped to 78. Air is the natural resource that is in the worst shape. It actually poses a danger to human health in many cities. The 1970 Index was placed at 35. Continuing pollution reduced this to 34 in 1971.

Table 1. Environmental categories and ratings

Category	1971 Score
Soil	78
Timber	76
Living space	58
Wildlife	53
Minerals	48
Water	40
Air	34

Next, the seven elements were assigned a relative importance value expressed as a percentage. Some elements such as air, water, living space, and soil for food are essential to life and must necessarily be assigned a higher value. Table 2 shows our evaluation of relative importance.