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Ecosystem Monitoring and Ecological Indicators

An Annotated Bibliography

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Ecosystem Monitoring and Ecological Indicators: An Annotated Bibliography

Compiled by

Jerry A. Griffith* and Carolyn T. Hunsaker**

*ECO, Inc.
Boston, MA

**Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, TN

Project Officer
M. Craig Barber
Environmental Research Laboratory
U.S. Environmental Protection Agency
Athens, GA

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ATHENS, GA 30605-2720

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ABSTRACT

This annotated bibliography serves as the initial literature base for ecological indicators for regional monitoring within the U.S. Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP). Five hundred and fifty-six citations on issues surrounding indicators of ecosystem condition and ecosystem monitoring were obtained through a combination of computerized searches and manual searches of reference lists of selected literature. One section directs readers to the literature judged to be the most relevant to EMAP at this point in the program's development. Citations are classified into nine categories: indicators of ecosystem condition/ecosystem health, general issues surrounding ecosystem monitoring, ecological endpoints, fauna, flora, techniques, lower hierarchical level indicators, social issues, and EMAP-associated articles.

Key words: Ecological monitoring, Ecological indicators, Ecosystem health, Ecosystem assessment, Environmental quality, Stress-response, Stress ecology, Biological monitoring, State of environment

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1. Introduction and Background

Recent efforts in ecology have focused on examining anthropogenic stresses on a regional scale and assessing ecosystem condition (Graham et al., 1991; Hunsaker et al., 1990; Loehle, 1989; Schaeffer et al., 1988). One program in particular, the U.S. Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP), has defined among its goals to confirm that the nation's environmental protection efforts are truly maintaining or improving environmental quality (Hunsaker and Carpenter, 1990; Messer et al., 1991). The selection of ecological indicators for monitoring and reporting plays a vital role as stated in the program objectives:

- estimate the current status, trends, and changes in indicators of the condition of the nation's ecological resources on a regional basis with known confidence;

- estimate the geographic coverage and extent of the nation's ecological resources with known confidence;

- seek associations between selected indicators of natural and anthropogenic stresses and indicators of the condition of ecological resources; and

- provide annual statistical summaries and periodic assessments of the nation's ecological resources.

EPA has initiated a new, "top down" approach to ecological risk assessment, focusing on larger geographic scales and higher levels of biological organization. Past approaches to risk assessment have traditionally involved single–species toxicity tests and media–specific exposure models and are often done at local scales (Kutz et al., 1992). EMAP's monitoring of the status and trends in the condition of representative ecosystems will serve as the foundation of EPA's Ecological Risk Assessment Program. EMAP will develop and use biological response indicators to assess ecological conditions, and will also measure indicators of contaminant or stress exposure to identify relationships between changes in response indicators and changing stresses on ecosystems over time. Habitat indicators (e.g., salinity, sediment type, vertical vegetation composition, snags, etc.) will be measured to account for natural variations in biological response indicators (Kutz et al., 1992).

The purpose of this document is to provide a general literature base for ecological indicators and ecosystem monitoring. Through the 1970s, the application of the concept of indicators of environmental condition generally was focused upon organisms as specific indicators of air pollution/quality, water pollution/quality, etc. (e.g., Harris, 1976; Thomas, 1972). This type of indicator is still an integral part of ecology and environmental assessment (Freedman, 1989). This document focuses on the literature that addresses general indicators of ecological condition and issues surrounding the EMAP program and ecosystem monitoring; it is not a comprehensive listing of references on every biological indicator used in pollutant accumulation studies or in the context of a particular cellular or physiological response. It is also not a comprehensive bibliography on wetland indicators, forest indicators, agroecosystem indicators, etc.; the eight EMAP Ecological Resource Groups (agricultural ecosystems, arid ecosystems, forests, integrated landscapes, near–coastal waters, the Great Lakes, inland surface waters, and wetlands) are tracking the specific literature on individual indicators and monitoring techniques of interest to their respective resources. For more detailed references on indicators considered for use in specific resource classes, see Hunsaker and Carpenter (1990). Additional sources of information on indicators and monitoring strategies are in an "indicator development strategy" (Olsen, 1992) and in published reports and articles by the individual resource groups (Heck et al., 1991; Hedtke et al., 1992; Holland, 1990; Kepner et al., 1991; Liebowitz et al., 1991; Palmer et al., 1991; Paulsen et al., 1991; Riitters et al., 1992; Whittier and Paulsen, in press).

We review literature on indicators of ecosystem state, generalized ecosystem responses to anthropogenic stresses, rationale of monitoring programs, monitoring program design, functional vs structural monitoring, environmental indices, ecological risk assessment, and extrapolation from effects at lower levels (e.g., toxicity tests, organisms) to higher levels (e.g., communities and/or ecosystems) of ecological organization. This report is divided into three sections: (1) methods for the literature search, (2) results, and (3) a summary of selected literature judged to be among the most relevant to the development of programmatic guidance on ecological indicators and ecosystem monitoring.

2. Methods for Literature Search

Three sources for the literature search were utilized: (1) DIALOG "on-line" services (DIALOG Services, 1991); (2) the bibliographic data bases *Current Contents: Agricultural, Biological, and Environmental* and *Focus On: Global Change*; and (3) actual reference lists/bibliographies from articles, books, and proceedings.

Specific data bases used in the "on-line" searches were BIOSIS, 1969–1981, Enviroline 1970–1992, Pollution Abstracts 1980–1992, Environmental Bibliography (1980–1992), and the NTIS (National Technical Information Service) CD-ROMs, 1985–1992. In desiring a broader treatment of indicators (generally, at higher levels of biological organization than the individual level), the keywords environmental/biological/ecological indicator were chosen and crossed with ecosystem/ecology. Using the former without crossing them with ecosystem or ecology resulted in too many cellular and organism-level indicators. Inclusion of such terms as stress, monitoring, and trends yielded too many unrelated articles while specific queries on "ecosystem health" or ecosystem indicators resulted in few or no appropriate references. Apparently, the terms "ecosystem indicator" and "ecosystem health" have only been infrequently used in the recent past. As more literature is produced in this area, additional keywords suggested for future literature reviews are: environmental assessments, environmental analysis, ecosystem health, stress-response, environmental effects, ecoepidemiology, environmental/ecological indices, state of environment, and ecosystem indicator.

A brief description of the contents of each data base follows:

BIOSIS — 9000 serials, technical reports, and conference proceedings

Enviroline — 5000 journals and proceedings

Pollution Abstracts — 2500 conference papers and serials

Environmental Bibliography — 400 journals (Dialog Services, 1991)

NTIS (National Technical Information Service, Springfield, Virginia) — Covers government sponsored research, development and education. Contains analyses prepared by over 240 government agencies.

A search profile consisting of over 20 keywords/phrases/authors was created and used to search from January 1, 1991, through December 7, 1992, in *Current Contents* (ISI, 1991) and *Focus On: Global Change* (ISI, 1991). The search profile is listed in Appendix A. For these current data bases a broad keyword search was performed because it was easy to manually sort references. Using a broad search allowed as many related articles on indicators and monitoring as possible to be obtained. Descriptions of these literature data bases are:

Current Contents (ISI, 1991): Contains information for 1200 publications per year, including 930 journals;

Focus On: Global Change (ISI, 1991): Is a data base of 14,000 science and social science journals, books, and proceedings.

The reference lists of most of the literature identified in the previous steps were checked for literature of interest. Because the topic was difficult to bound with keywords, it was considered necessary to manually check for some literature to ensure a comprehensive bibliography.

3. Results

The literature search yielded 556 references. As stated previously, the search focused on general indicators of ecosystem condition and not on the myriad of organismal and biological indicators (e.g., contaminant accumulation in lichens, mussels, fish, or other animal and plant tissue). Citations for articles dealing with ecosystem response to stress, analysis of long-term ecological trends, and general ecological/biological monitoring philosophy were included. The majority of the references were identified by manually searching the reference lists of appropriate articles. Less than one-fifth of the articles were identified from the computerized searches.

3.1. Annotation

Whenever possible abstracts are included for a reference. For acquired literature that did not provide an abstract, either an excerpt from the literature, a short description of the contents, or a summary of the issues covered is included. Keywords were entered for articles which supplied such terms (approximately 10% of the total citations). A directory to the literature is provided by classifying citations into one or more of the following nine categories.

Indicators of ecosystem condition/ecological health: This category includes literature dealing specifically with the concept of ecosystem indicators or discussing responses of ecosystems to anthropogenic perturbations, parameters used to monitor or characterize ecosystems, the construction of environmental indices, or information on the implementation of ecosystem indicators such as criteria of a good indicator of ecosystem condition.

Ecosystem monitoring/general issues: Literature included in this category covers issues such as the rationale behind monitoring, general monitoring of ecological condition, structural vs functional monitoring, and specific case studies of ecosystem monitoring.

Endpoints: All articles discussing at length, or in part, ecological or regulatory endpoints are included in this category. Suter (1989) defines endpoints as "valued ecosystem attributes; quantitative or quantifiable expression of environmental values that are accessible to prediction or measurement."

Fauna: Included in this category is literature dealing with the use of animals at a higher level than the individual level or physiological level (i.e., where animals or guilds of animals are being used as indicators of ecosystem condition).

Flora: Literature that deals with individual plants, communities, or forests and vegetation complexes is included in this category.

Techniques: Included in this category is literature discussing monitoring design, statistical analysis of ecological data for trend analysis, issues of extrapolation of effects at lower levels to ecosystem levels, remote sensing applications, etc.

Individual or Lower Level: Literature placed into this category addresses issues at the individual organism or at lower levels of biological organization such as bioassays, physiological indicators, etc.

EMAP-related: Literature placed into this category either provides a background/overview of the EMAP program or addresses some issue or aspect of the program. This category primarily includes literature written by EMAP scientists and administrators but also contains some literature written about EMAP by persons outside the program.

Social: Literature placed into this category covers such issues as sustainability or sustainable development indicators, human response to environmental change, public participation in environmental monitoring programs, prioritizing environmental problems, etc. Such material relates to the selection of environmental values in EMAP's indicator strategy.

4. Summary of Selected Literature

The articles reviewed in this section are judged to be among the most relevant and appropriate to programmatic issues surrounding the development of ecological indicators for a national program such as EMAP.

Other literature reviews on the subject of environmental monitoring and environmental indicators have been performed. In a background report for the Canadian State of the Environment program, Sheehy (1989) provides an annotated bibliography on 45 indicators in six areas: quality of life indicators, environmental indices, environmental quality profiles, biological indicators, chemical indicators, and urban environmental indicators. A review of this literature is synthesized into a discussion on requirements of good indicators, problems and limitations in development and application, and what is needed to improve the art of indicator development. Rajagopal and others (1992) present a review and data base of literature on information integration related to environmental monitoring and assessment. "Indicators" is one subtopic covered within four broad areas: Institutional issues, resource/ecological issues, design issues (mathematical/statistical), and technological issues (computer, GIS, remote sensing, and others). In an extensive review of environmental monitoring for protected areas, Slocombe (1992) discusses indicators in the context of environmental monitoring and the analysis of ecosystem stresses and responses while providing a lengthy reference list with particular depth on Canadian environmental monitoring schemes. An excellent source of information on indicators with particular relevance to EMAP and to regional and national monitoring schemes can be found in the proceedings of a recent international symposium on ecological indicators (McKenzie et al., 1992).

4.1. Monitoring

The National Research Council (1990) has recently recommended conducting comprehensive monitoring of regional and national ecological status and trends and strengthening the role of monitoring in environmental management. The Council determined that monitoring information meets many needs including: (1) providing information needed to evaluate pollution abatement problems, (2) serving as an early warning system allowing for lower–cost solutions to environmental problems, (3) contributing to knowledge of ecosystems and how they are affected by human activity, (4) providing essential data to the construction, adjustment, and verification of quantitative predictive models, which are an important basis for evaluating, developing, and selecting environmental management strategies, and (5) providing environmental managers the scientific rationale for setting environmental quality standards.

The philosophy and objectives upon which a monitoring program is based are critical to the success of the program and are mentioned frequently in the literature (Roberts, 1991; Usher, 1991; Miller, 1978; Hinds, 1984; Hellawell, 1991; Herricks and Schaeffer, 1987). Miller (1978) discusses some of the past deficiencies of EPA's monitoring program (mainly in relation to regulatory monitoring). Bernstein (1992) has attempted to provide a framework for incorporating managerial perspectives with the more technical issues surrounding ecological indicators. The premise of Cullen (1990), that monitoring is necessary because we need to know information about the state of the environment both to help in choosing appropriate management action and in evaluating what our interventions have achieved is reflective of some of EMAP's objectives. Hellawell (1990) presents three categories of reasons for instituting a monitoring program that also echo some of EMAP's objectives: (1) assessing the effectiveness of policy or legislation, (2) regulatory, and (3) detecting incipient change. Schindler (1987) lists characteristics of successful monitoring programs: (1) they must be inexpensive enough to survive budget cuts in funding agencies; (2) they must be simple and verifiable, so they are little affected by changes in personnel; and (3) they must include measurements which are highly sensitive to changes in ecosystems. Good monitoring formats and bad formats (the "collect [data] now, think [of a good question] later" format) are described by Roberts (1991). Usher (1991) proposes a hierarchical set of questions that should be answered when implementing a monitoring system:

Purpose: What is the aim of monitoring?

Method: How can this aim be achieved?

Analysis: How are the data, which will be collected periodically, to be handled?

Interpretation: What might the data mean?

Fulfillment: When will the aim have been achieved?

In his stepwise methodology for a monitoring plan, Hinds (1984) stresses the importance of properly designed monitoring plans and describes some of the difficulties of ecosystem level monitoring as opposed to monitoring of organisms.

What constitutes ecosystem integrity is another question that a national monitoring program must contend with. Kay (1991) provides a framework for assessing ecosystem integrity by determining how an ecological system is moved away from an optimum operating point due to changing environmental conditions. Karr (1987, 1991) discusses biological integrity for water resources and maintains that monitoring and assessment should be guided by: the need to preserve human health; the need to preserve aesthetic, recreational, and other uses of biological systems for direct human benefit; and the need to preserve life support systems that provide both goods and services to human society through maintenance of healthy ecosystems. Steedman and Regier (1990) list the following characteristics of ecosystems with regard to ecological integrity: (1) energetic in that natural ecosystemic processes are strong and not severely constrained; (2) self-organizing, in an emerging, evolving way; (3) self-defending against invasions by exotic organisms; (4) having biotic capabilities in reserve to survive and recover from occasional severe crises; (5) attractive, at least to informed humans; and (6) productive of goods and opportunities valued by humans.

The literature stresses the importance of connecting monitoring and the choice of indicators to human values. Relevance to issues of concern to humans is the most useful criterion in selecting indicators of ecosystem health (Kelly and Harwell, 1990). Schroevers (1981) emphasizes the need for ecologists to help define the notion of quality, not by imparting what is bad or good but by providing the arguments necessary to make judgements. As Green (1984) aptly asserts, "if the ecologist has not established any linkage between the public concern and the criterion variables used in his study, then it may be that nobody else will do it either." To avoid meaningless data collection and wasted finances, a greater emphasis is needed on defining the questions to be answered by a monitoring program. Perry and others (1987) declare that the primary objective of monitoring programs should be "asking the right questions at the right time and then collecting only that data necessary to answer the questions."

4.2. Ecological Indicators and Ecosystem Response to Anthropogenic Disturbances

The selection, use, and development of ecological indicators used to characterize the response of ecosystems to various stresses will be crucial to the success of EMAP's monitoring endeavors. Suggested research on characterizing ecosystem response to anthropogenic perturbations emanates from several sources. These include calls for increased understanding in the areas of long-term monitoring, ecosystem response to disturbance, "leading environmental indicators," or status of the state of the environment (Draggan et al., 1987; Lubchenco et al., 1991; Barrett, 1976, 1978; Hildebrand et al., 1987; Alm, 1991; Environmental Protection Agency, 1988; Holling, 1986, Huntley et al., 1992; National Research Council, 1990).

Ecological monitoring, which serves as the sensory tool for ecological risk management, is critical to the understanding of long–term trends. Of paramount importance in ecological monitoring/assessment programs is the concept of ecological indicators and the specific measurements used for these indicators. An indicator is defined as a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to a stressor, or degree of ecological response to the exposure (Hunsaker and Carpenter, 1990). The concept of ecological indicators has thus evolved from not only including analysis of bioaccumulation of xenobiotic material in organisms or presence/absence of individuals or species but also to indicators of total ecosystem functioning and structure.

Much of the literature on the assessment of ecological condition and stress ecology discusses generalized responses of ecosystems to stress and should prove helpful in deciding which ecological parameters to choose as indicators for quantifying the degree of stress and thus indicating condition. Woodwell (1970) is among the earliest of researchers to generalize ecosystem and community response to pollutants. His hypotheses stem from experiments on the effect of ionizing radiation on an oak-pine community. Odum (1985) categorized 18 generalized responses (trends) of ecosystems to stress into four areas:

Energetics

- community respiration increases;
- production/respiration becomes unbalanced (< or > 1);
- production/biomass and respiration/biomass (maintenance:biomass structure) ratios increase;
- importance of auxiliary energy increases; and
- exported or unused primary production increases.

Nutrient Cycling

- nutrient turnover increases; and
- horizontal transport increases and vertical cycling of nutrients decreases; and
- nutrient loss increases (system becomes more "leaky").

Community Structure

- proportion of r-strategists increases;
- size of organism decreases;
- lifespans of organisms or parts (e.g., leaves) decrease;
- food chains shorten because of reduced energy flow at higher trophic levels and/or greater sensitivity of predators to stress; and
- species diversity decreases and dominance increases; if original diversity is low, the reverse may occur; at the ecosystem level, redundancy of parallel processes theoretically declines.

General System-level Trends

- ecosystems become more open (i.e., input and output environments become more important as internal cycling is reduced);
- autogenic successional trends reverse (succession reverts to earlier stages);
- efficiency of resource use decreases;
- parasitism and other negative interactions increase, and mutualism and other positive interactions decrease; and
- functional properties (such as community metabolism) are more robust (homeostatic or resistant to stressors) than are species composition and other structural properties.

Odum's hypothesis is that a disturbance to which a community is not adapted reverses autogenic development. Schindler (1987, 1990) has compared these 18 generalizations to actual responses to acidification observed in experimental lakes.

The metaphorical employment of the ecosystem-as-organism concept and medical diagnosis analogy as heuristic tools have been frequently used in assessing ecological condition, most recently in a series of articles by Rapport and others. An introduction to the concept of "ecosystem medicine" is provided in Rapport and others (1979), who outline possible questions in stress ecology that could be investigated using analogous medical science methodology such as identifying ecological correlates to human health "vital signs" to serve as diagnostic protocols, observing the presence of early-warning signals of degradation, using epidemiology in studying biological invasions or ecosystem pathology, and observing the presence of sensitive zones in ecosystems (Table 1). They compare the study of stress in ecosystems with the study of stress in organisms using the principles of Selye's General Adaptation Syndrome, a physiology concept which identifies symptoms of stress in mammalian systems. Rapport has termed this kind of analysis "clinical ecology" (1992a). Some of his selected response variables are: nutrient pools in systems; primary productivity; size distribution of dominant biota; species diversity; and system retrogression, or an apparent reversion to an earlier successional stage involving among other characteristics, a shift in species composition to more opportunistic species; a simplification of communities; the opening of niches; the loss of nutrient inventory; etc. These generalized responses to stress form the basis of an "ecosystem distress syndrome" (Rapport et al., 1985). In later papers, Rapport outlines the issues surrounding the diagnosis of ecosystem health. General approaches to assessing ecosystem health are outlined in Rapport (1989) and Rapport and Regier (1980). The diagnosis of ecosystem health and identification of ecosystem critical characteristics are discussed in Rapport (1984) and Rapport and others (1981). A case study of the Baltic Sea provides an example of the application of this concept (Rapport, 1989). Norton (1989) also recognizes useful aspects of the medical analogy as it: (1) acknowledges the dynamism of natural systems, (2) emphasizes relationships among parts of the system and relationship of the functioning parts to the larger whole, and (3) encourages useful rules of thumb in the area of contextual management. However, Norton acknowledges that the medical analogy does not provide an operable definition of ecosystem health; it does not set ecological condition goals to which managers must strive.

The concept of ecosystem health has also been promoted by Schaeffer and others (1988, 1991, 1992). The medical science metaphor is utilized again as the roles of the human/veterinary physician and what is termed "ecological system physician" are compared. A table is presented identifying 54 ecosystem measures in relation to eight critical ecosystem characteristics: (1) habitat for desired diversity and reproduction of organisms; (2) phenotypic and genotypic diversity among the organisms; (3) a robust food chain supporting the desired biota; (4) an adequatenutrient pool for desired organisms; (5) adequate nutrient cycling to perpetuate the ecosystem; (6) adequate energy flux for maintaining the trophic structure; (7) feedback mechanisms for damping undesirable oscillations; and (8) the capacity to temper toxic effects, including the capacity to decompose, transfer, chelate or bind anthropogenic inputs to a degree that they are no longer toxic within the system (Schaeffer et al., 1988). An earlier version of this information is provided in Herricks and Schaeffer (1987). Seven generalized responses of ecosystems to stress are also provided. In Schaeffer (1991), a comparison of classical toxicology with ecotoxicology, comparing animal and ecosystem responses to chemical exposures, is provided. Chapman (1992) also provides a discussion of ecosystem health in a synthesis of material presented at a conference devoted to the subject. Of note in his article is the observation that among the 100 mostly professionals in attendance at that conference, not even a consensus was reached that a definition of ecosystem health was possible. This suggests that an assessment of the meaning of ecological change observed in long-term monitoring of ecosystems may be a difficult and controversial task.

Schaeffer (1992) also evaluates the concept of an ecosystem threshold. Investigation into this area of "ecosystem health" would provide information on the point at which, when crossed, ecosystems begin to break down. An associated question is whether, in fact, thresholds exist, or whether all impacts are effective and cumulative. Herricks and Schaeffer (1987) provide a review of test system (analysis units ranging from simple biochemical assays to experimental manipulation of ecosystems) selection for ecosystem response to chemical exposure and provide a chart identifying for such test systems individual level measures, measures for populations and below, system level factors and abiotic elements. Data characteristics (variability, sensitivity, and reproducibility) of common biomonitoring measures (organization, function, state descriptors and habitat assessment) are provided in Herricks and Schaeffer (1985).

Several scientists provide a counterpoint to the metaphorical usage of the concept of ecosystem health. Suter (1993 in press) argues for caution in using multiparameter indices and the medical analogy.

Table 1. Comparison of ecological health research and human health diagnosis (adapted from Rapport *et al.*, 1979)

Ecological research question area	Analogous human health area
Early warning indicators of ecosystem transformation	Early warning indicators of disease (e.g., the CEA carcinoembryonic antigen as an indicator of early intestinal cancer)
Exotic plant/animal/virus invasion or outbreak of native indigenous pathogens	Epidemiology
The presence of "sensitive zones" in ecosystems	The study of certain parts of the body that are crucial to functioning and well-being of the whole
Do ecosystems develop immunity to to particular classes of combinations of stress?	Immune antibody responses to foreign antigens

Suter considers the "ecosystem health" concept a poor metaphor because unlike organisms, ecosystems are not consistently structured, do not develop in a consistent and predictable manner, and do not have mechanisms like the neural and hormonal systems of organisms to maintain homeostasis. Statements attesting to the usefulness of analogous concepts such as "economic health" are not considered appropriate by Suter because economists, unlike environmental managers, have well-defined goals for an acceptable state of the economy. Suter believes health is simply not an operational property of ecosystems and that a collected set of ecosystem properties combined into an index may have the following faults: ambiguity, the eclipsing of one variable by others, arbitrary weighting of variables, lack of measures possessing real-world units (monetary, for example), and the obscuring of variables which make diagnostic analyses of environmental problems difficult. Amir and Hyman (1992) also do not think that the ecosystem health concept is presently operable, but develop ecosystem stock and flow variables as ecological health indicators in a step toward operability. Kelly and Harwell (1989) believe the ecological/human health analogy is unsatisfying due to the complexity and variability in ecosystems. Calow (1992) believes "health" can be objectively understood when discussing organisms and populations, but does not deem the same concept as applicable to ecosystems.

Finally, in addition to the medical analogy approach is the environmental assessment framework of Loehle (1989) (and Loehle et al., 1990a; Loehle et al., 1990b), which emphasizes the successional characteristics of ecosystems because the majority of ecosystems have been influenced by anthropogenic disturbance. The assessment in this case depends on how closely ecosystems are progressing along the expected successional sequence.

Sheehan (1984) and Miller (1984) diagram the responses of ecological systems to toxic pollutants at varying temporal (days to centuries) and spatial scales: cellular/ physiological, individual, populations, and communities/ecosystems/landscapes (also adapted by de Kruijf, 1991) (Figure 1). Kimmins (1990) also provides a review of lower hierarchical level indicators (physiological and species). Taub (1989) comments on assumptions and generalizations surrounding the implementation of indicators of environmental change and recommends new research on promising indicators of change. Assumptions about indicators that are analyzed include such assertions as "human impacts will have different indicators than natural impacts," "all ecosystems will respond in the same manner to stress," and "a magic index exists that requires no detailed study."

Kelly and Harwell (1989, 1990) provide a thorough overview of the mechanisms involved in ecological disturbance and the issues surrounding evaluation of anthropogenic stress on the environment including exposure, response, recovery, and uncertainties in analysis (resulting from variability in exposure and ecosystems, and extrapolation across types of stress and ecosystems). They present the basics for analyzing ecological disturbances within the framework of ecological risk assessment, and distinguish between four different purposes of indicators: intrinsic importance, early warning indicators, sensitive indicators, and process indicators. Intrinsic importance refers to valuable species, endangered species, or other aspects of direct importance to humans. The primary importance of early warning indicators is their rapid indication of effect. These types of indicators can be used as "red flags" to alert attention to a possible problem. Sensitive indicators focus on actual responses rather than potential ecological effects. In this case, there should be a strong specificity to a type of stress. Process indicators highlight change in ecological functions and processes. These indicators could also serve as early-warning or sensitive indicators. Indicators of ecosystem vulnerability focus on both abiotic and biological aspects and include geochemical character, presence of physical refugia, linearity of food webs leading to a major species, etc. De Kruijf (1989) also discusses these same issues while adding a discussion on extrapolation of effects at lower levels of biological organization to higher levels. Harwell and Harwell (1989) examine the complexity of ecosystem response to chemical exposure by discussing direct biological effects, indirect biological effects, ecosystem level effects, and extrapolation issues. Johnson (1988a, 1988b) analyzes ecosystem response to stress by representing ecological parameters as multidimensional state vectors in a Cartesian space.

The use of animals as indicators of ecosystem properties and responses, specifically to air emissions, is presented in Newman and Schreiber (1984), in which a reference list for specific case studies is also provided. Indicators of biodiversity are provided by Noss (1991) and Williams and Marcot (1991). Other literature provides specific environmental parameters (indicators) used in monitoring wilderness

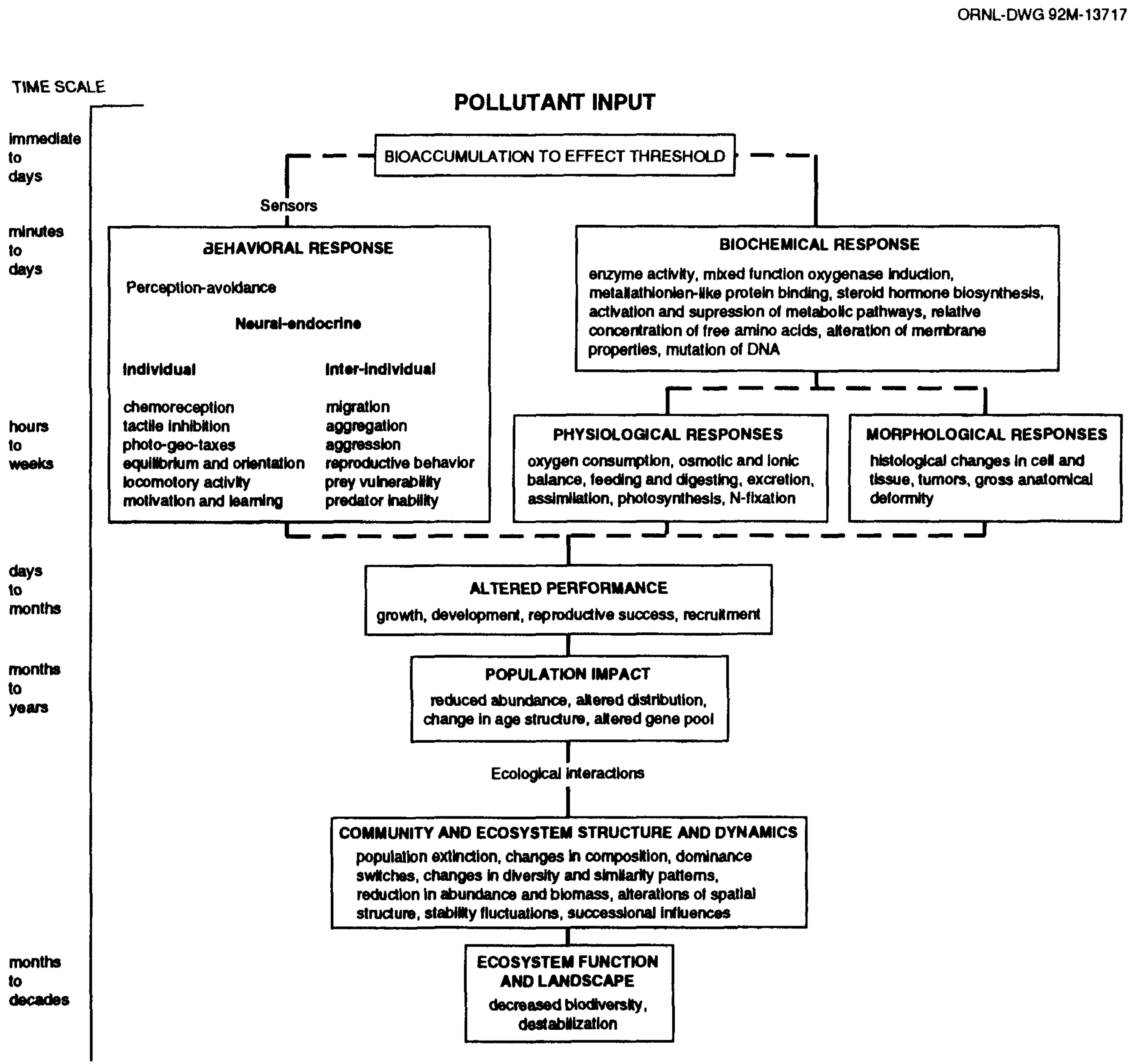

Figure 1. Generalized framework of biological/ecological effects of contaminants at various hierarchical levels. (Sheehan et al., 1984 and adapted from de Kruijf, 1991)

areas (Bruns et al., 1991, 1992), national parks (Hermann and Stottlemyer, 1989), and in The Netherlands (de Haes et al., 1989). Keddy (1992) reports on some of the issues surrounding indicators, including the selection of indicators and monitoring in relation to environmental prediction and decision-making.

4.3. Criteria of Good Indicators

The selection of indicators for characterizing ecosystem condition and their ongoing evaluation will be an integral part of an environmental monitoring program. Indeed, some believe that the choice of measurements (indicators) selected acts as a keystone in framing environmental problems (Alberti and Parker, 1991). A summary of criteria for indicators expressed in the literature is provided in Table 2. Schaeffer and Herricks (1987) provide criteria for "measure" selection, with particular emphasis on biological measures. Schaeffer and others (1988) provide criteria for determining ecosystem health. Rapport (1990) provides the "three Rs" for a good indicator: relevance, robustness, and reliability. Krantzberg (1990) and Day (1990) provide criteria for indicators with reference to the Canadian State of the Environment Program. Liverman (1989) provides criteria for desirable global sustainability indicators. Frost (1992) states that indicators may have two desirable but possibly contradicting properties: (1) sensitivity to a variety of anthropogenic stresses and (2) predictability in unperturbed ecosystems. Since sensitive parameters may show some degree of unpredictable variability, the choice of ecological indicators will involve compromising these two factors. Miller (1984) also describes characteristics of a good indicator. Still other authors synthesize various listings of criteria of good indicators (Cairns and McCormick, 1992; Seidl and Murray, 1991; Sheehy, 1989).

Taub (1989) confronts some of the assumptions and generalizations about the implementation of ecological indicators. Marshall and Ryder (1987) provide criteria for animals as indicators ofecosystem health, specifically referring to the Great Lakes system. Kelly and Harwell (1990) distinguish between two types of indicators: screening indicators (to act as a red flag) and state-specific indicators. Riitters (1990) provides indicator criteria for the assessment of forest health: strategic value, tactical value, and scientific credibility.

5. Conclusion

This bibliography is intended to serve as a comprehensive reference to literature on general topics related to ecological indicators and ecosystem/environmental monitoring. Environmental scientists and managers within EMAP and those persons involved in ecological monitoring and indicators should familiarize themselves with the literature in this document when conducting ecological assessments.

The use of such terms as ecosystem health and ecosystem indicator appear to be relatively new and not yet common in the scientific and environmental literature. The development of ecological indicators at the ecosystem level and on a regional scale is a science in its infancy, and accurate indicators of ecological condition are still being determined (Herricks et al., 1989). Nonetheless, literature is rapidly being produced in the subject area and more articles directly addressing the issue will undoubtedly appear in the coming decade. For future searches where more detailed or mechanism-specific indicators are desired, the approach suggested by American Management Systems (1987) may prove fruitful. For obtaining a more thorough search of the term "endpoint," they suggested searching a desired stressor (e.g., acid rain), in which case an abundance of literature exists, most likely including effects on ecosystem processes and structure.

Regardless of the actual choices, an adequate monitoring system designed to assess ecological condition on a regional scale will consist of a multivariate suite of indicators integrating biological, chemical, and physical measures and integrating hierarchical levels (Cairns, 1990a; Izrael and Munn, 1986; Karr, 1987; Kelly and Harwell, 1990; Loehle, 1989; Munn, 1988; Riitters, 1992; Schaeffer et al., 1988; Spellerberg, 1991) rather than placing inordinate emphasis on any one or two indicators.

Table 2. Criteria/characteristics of ecological indicators.

Kelly and Harwell (1990)	Schaeffer et al. (1988)	Liverman et. al. (1990)	Herricks and Schaeffer (1985)	Suter (1989, 1990)	Bruns et al. (1992)
"Criteria for selecting indicators"	"Basis for an initial assessment of ecosystem health"	"Criteria for desirable global sustainability indicators"	"Criteria for biomonitoring data selection"	"Characteristics of good measurement endpoints"	"Criteria for evaluation of environmental monitoring parameters for a wilderness ecosystem"
Signal-to-noise-ratio -Sensitivity to stress -Intrinsic stochasticity	Should not depend on presence/absence or condition of a single species	Sensitivity to change in time	Must be biological or have proven relationships to biological-ecological effect in the system	Corresponds to or is predictive of an assessment endpoint	Have an ecosystem conceptual basis Data variability
Rapid Response -Early exposure -Quick dynamics -Stress-specific sensitivity	Should not depend on a census or even inventory of large numbers of species	Sensitivity to change across space or within groups Predictive ability	Must be amenable to application at other trophic levels, reflect effects at other levels of the biological-ecological hierarchy, or provide an experimentally verified connection to other organisms or trophic levels	Is readily measured Is appropriate to the scale of the site	Uncertainty Usability Cost-effectiveness
Reliability of Response -Specificity to stress	Should reflect our knowledge of normal succession or expected sequential changes which occur naturally in ecosystems	Availability of reference or threshold values		Is appropriate to the exposure pathway	
Ease/Economy of Monitoring -Field sampling -Laboratory expertise -Preexisting data base and history -Early test for process	Does not have to be measured as a single number Should assure that measures have a defined range	Ability to measure reversibility or controllability Appropriate data transformation Integrative ability	Must be sensitive to the environmental conditions being monitored -Sensitive to small magnitude changes -Have a range of response that will allow differentiation of effect from consequences	Has appropriate temporal dynamics Has low natural variability Is broadly applicable Is standard Has existing data series	
Relevance to Endpoint -Intrinsic -String of ecological connections	Should be single-valued (monotonic) and vary in a systematic and discernible manner	Relative ease of collection and use			
Feedback to Regulation or Management -Adaptive management potential -Hierarchical suites of indicators	Should be responsive to change in data values but should not show abrupt changes even when values change by several decades Should have known statistical properties if relevant		Response range of the measure must be suitable for intended application		
Relevance to Recovery Processes -Short-term and long-term processes -Refugia, colonizing capacity -Adaptation to new physical constraints	Must be related and hierarchically appropriate for use in ecosystems Should be dimensionless Should be insensitive to the number of observations, given some minimum number of observations		Must be reproducible and precise within defined and acceptable limits Variability of the measure must be low		

Table 2. Continued

Frost (1992)	Kreisel (1984)	Lubchenco et al. (1991)	Marshall et al. (1987)	Landres (1988)
"The choice of ecological indicators"	Characteristics of environmental indicators used in an environmental quality profile of a metropolitan area	"Ideally indicators would be chosen on basis of:"	Criteria of an ideal indicator organism to represent ecosystem health in the Great Lakes	"Ecological criteria for selecting vertebrate indicator organisms"
Must balance: -Sensitivity and -Predictability	Valid -Actually measure what they are supposed to measure	Speed of their response	Baseline historical records on abundance available	Sensitivity -Should be sensitive to contaminants or attributes of concern
		Sensitivity to specific stressor		
	Objective -Should be same if measured by different people	Ability to optimize sensitivity and variability	Be an integrator of the community in which it plays a key ecological role	Variability of response -Should be low
	Sensitive		Have a wide distribution	Specialist vs. generalist -Should demonstrate relationship to habitats of interest and not just be chosen solely on whether they are a specialist or generalist
	Specific -Reflect changes only in the situation concerned		Have extensively quantified and well-developed niche envelope	
			Have habitat requirements that are comprehensively understood and documented	
			Exhibit at least a moderate degree of phenotypic diversity	Size/population turnover and species turnover -Both small and large species may be necessary for assessments over both short and long time scales
			Be susceptible to, or reflect in various ways, most interventions of cultural origins	
			Have a high human value and a ready recognition by humans	Residency status -Should be permanent residents
				Area requirement -Area per se is a tenuous criterion unless research confirms that a species with a large home range can serve as an indicator of habitat quality or of an entire community in that particular in that particular location

Table 2. Continued

Rapport (1990c)	Day (1990)	Krantzberg (1990)	Miller (1984)	de Haes et al. (1990)	Riitters (1990)
"Criteria of well-chosen environmental indicators"	"Criteria to be used for evaluating indicators of marine and Great Lakes Environmental Quality"	"Characteristics of indicators used for Canadian State of the Environment Report"	"Desirable properties of parameters for assessing change in ecosystems"	"Criteria for selecting 'environmental quality' criteria in The Netherlands"	"Criteria to evaluate forest health indicators"
Relevance -Socially desirable	Can be applied nationally or over broad biophysical regions	Must reflect SOE (State of Environment)	Indicative of overall condition of the ecosystem	Relevance to environmental policy	Strategic value -Be part of broader plan for assessing changes in forest health
Reliability	Scientifically defensible	Must be understood by policymakers	Comparable for a variety of ecosystems	Sensitivity	
Robustness	Adequate historical record and projected availability of ongoing/future data	Should be used by scientists to compile the SOE report, but should still be interpretable by decision makers	Easily and reliably measured	Detectability	Tactical value -Provide useful information for different types of health assessment
	Reliability and consistency of types of measurements used to assess indicators			Appeal -To laypersons, policymakers, etc.	
	Simplicity -Of measurement and interpretation	Should include a range of indicators as many indicators will not be universal			Scientific value -Should be chosen from biological models that lend realism and that are interpretable
	Data generally should be quantitative				

5.1 Suggested Future Directions

The review of this literature on ecosystem monitoring and indicators of ecological condition has revealed a great variety of information on general responses of ecosystems and foundations for a good monitoring program. Ecologists need to work towards defining what is "good" ecological condition and to determine how useful or misleading the "ecosystem health" analogy is. Although scientists and environmental managers promoting the ecosystem health concept do not regard ecosystems as organisms, there still exists the notion among some that this abstraction connotes an ecosystem/human medicine analogy which may prove misleading when communicating environmental information to the public.

6. Guide to Literature by Category

Indicators of Ecosystem Condition/Ecosystem Health - 2, 4-6, 8, 9, 11, 12, 14, 17, 32-35, 37, 39-41, 44, 47, 53, 59-61, 63, 71, 78, 79, 81, 84-87, 89, 92, 96-98, 103, 105-107, 110-112, 114, 117, 119, 120, 123, 125, 126, 128-130, 133, 138, 140, 145, 149-153, 157, 161, 164, 165, 169, 171-173, 175, 176, 178, 183-188, 190, 192, 198, 203-206, 210-214, 216-219, 222, 224-227, 230, 235, 236, 239, 240, 243, 244-247, 249-251, 253-255, 257, 259-261, 264, 265, 268-271, 273-276, 278-280, 282, 283, 286, 288, 291-293, 299, 301, 310-312, 316, 319, 320, 324, 325, 329, 333, 335, 342, 344, 353-356, 359, 360, 362, 365, 371, 376, 378, 379, 382, 385, 387, 388, 390, 394, 395, 398, 400-402, 404-406, 409, 410, 413, 414-429, 431, 432, 436, 441-443, 453, 454, 457, 458, 460, 462, 463, 465, 472, 475-478, 481, 483, 484, 486, 487, 489, 490, 491, 496, 499, 501, 503, 505, 506, 508, 509, 512, 520, 528, 531, 533, 536, 538, 545, 547, 551, 556

Ecosystem Monitoring - general issues - 1, 3, 7, 13, 15-18, 24-30, 33, 34, 37, 42-46, 49-51, 54, 57-60, 62, 64-70, 75, 77, 80, 88-91, 93, 94, 99, 101, 104, 106, 108, 113, 114, 118, 119, 121, 123, 124, 132, 134, 138-144, 146, 152, 159-163, 165-167, 172, 177, 184, 189, 191, 192, 194, 196-199, 201, 202, 207, 208, 215, 229, 231, 238, 241, 246, 249-251, 253, 258, 260-264, 269, 270, 272, 282, 285, 287-293, 297, 300-304, 309, 318, 320, 321, 324-327, 330-332, 334, 336, 337, 339, 343, 345-349, 358, 364, 368, 370, 372, 375, 378-381, 384, 389, 391-393, 396, 397, 402, 403, 413, 433, 435, 438, 440, 444-447, 451, 452, 453, 455, 462, 466, 471, 472, 474, 486, 490, 491, 502, 503, 511, 522, 523, 534, 535, 540, 546, 548, 553

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Fauna - 28, 39-41, 52, 63, 100, 103, 106, 107, 128, 143, 145, 152, 157, 161, 178, 218, 224, 245, 266, 269, 270, 273, 277-279, 283, 306, 316, 339, 340, 342, 347, 353-356, 387, 436, 437, 474, 491, 501, 507, 508, 521, 547

Flora - 1, 11, 29, 36, 38, 42, 60, 62, 117, 125, 138, 143, 162, 165, 178, 218, 223, 225, 236, 261, 282, 312, 318, 320, 331, 337, 365, 411, 413, 442, 443, 451, 479, 480, 482, 487-489, 491, 500, 512, 514, 540, 550

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Individual or lower-level - 6, 10, 12, 29, 35, 38, 80, 112, 120, 122, 138, 143, 162, 169, 178, 186, 190, 204, 218, 224, 262, 267, 280, 283, 285, 286, 289, 311, 312, 316, 318, 320, 339, 348, 394, 408, 441, 459, 462, 473, 482, 514, 524, 554

EMAP-related - 20, 48, 53, 99, 193, 217-219, 242, 275, 276, 281, 291, 307, 320, 323-326, 361-363, 376, 388, 392, 393, 445, 543, 545

Social Issues - 25, 91, 96, 105, 114, 121, 125, 129, 131, 136, 174, 181, 210, 211, 222, 292, 301, 317, 319, 338, 344, 345, 352, 359, 360, 369, 382, 383, 412, 413, 417, 429, 444, 447, 458, 472, 492, 499, 522, 539

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Note: All other references cited in the introductory text appear in the annotated bibliography in Appendix B.

Appendix A. Search profile keywords used with *current contents* and *focus on:global change*

(Ecosystem* or Ecol* or Environment*) and Indicator*
(Biol* Indicat*) or Bioindicator* or Biomarker* or (Biol* and Marker*)
Landscape Ecology
Ecos* or Ecol*
Indicat*
Index or Indices
Landscape*
Wildlife or Forest* or Wetland*
Lake* or Desert* or Coast*
Response*
Endpoint* or Predict*
(Expos* or Effect*) and (Man or Anthropo* or Climat* or Manag* or Pollut* or Disturb* or Impact)
Remote or Agroecosystem* or Arid
Stress* or Monitor*

Note: An * denotes a wild card, meaning that any suffix added to a word at the * will be searched.

Appendix B. Annotated Bibliography

1.**Addison, P.** 1989. Monitoring the health of a forest: A Canadian approach. Environ. Monitor. Assess. 12:39-48.

In Canada, acid rain is the generic term encompassing all forms of air pollution including wet and dry deposition, gaseous pollutant concentrations, and airborne particulates. It was because these pollutants, alone or in combination, may directly or indirectly affect the health of Canada's forests, that in 1984, the Canadian Forestry Service initiated a national forest monitoring program (Acid Rain National Early Warning System or ARNEWS).

Research studies on pollutant effects of the past 15-20 years have demonstrated that it is not possible to define specific symptoms of acid rain or mixtures of pollutants on native tree species or specific responses of the forest ecosystem. Consequently, ARNEWS monitored incipient acid rain effects by determining the forest's state of health rather than by concentrating on specific pollutant responses.

The detection system entails experienced insect and disease survey forest rangers assessing both specific plots and the forest as a whole for extraordinary forest damage. The techniques used include mensurational and symptomatological measurements as well as evaluation of stands for damage from natural and anthropogenic causes. Critical also to the system was the capability of the Canadian Forestry Service to support the detection system with research staff who could carry out studies to explain any abnormalities in forest condition detected during the annual surveys. The ultimate outcome of the monitoring system, if unexplained forest damage is detected, is a research project on possible causes.

2.**Alberti, M. and J.D. Parker.** 1991. Indices of environmental quality: The search for credible measures. EIA Rev. 11:95-101.

Monitoring environmental change is much more difficult than most people think. Environmental changes are difficult to interpret without a clear understanding of how environmental systems work. There are sharp disagreements among scientists and policymakers concerning the best measures and methods for measuring changes in environmental quality. In this "Viewpoint" article, the authors argue that the measures and methods used to monitor the status of the environment play an important role in framing environmental problems and in shaping the way we think about possible solutions. They suggest that the success of environmental monitoring activities and their impact on policy-making depend above all on the ability to handle disagreement among experts.

3.**Aldhous, P.** 1992. UK sets 'early warning system'. Nature 355:383.

This brief news item is quoted here: London: Nine UK government agencies, led by the Natural Environment Research Council, are setting up a new 'early warning system' designed to detect environmental change. Starting with eight stations, the Environmental Change Network (ECN) aims to monitor a range of British terrestrial ecosystems, recording a suite of data from simple meteorological measurements to samples of soil invertebrates. The network is expected to help to define future UK governmental environmental policy, but more stations may have to be added to distinguish between local environmental fluctuations and national trends. Relatively few countries have set up similar monitoring networks. The new British effort joins similar monitoring schemes in China, Sweden, and the United States.

4. **Alimov, A., V. Bul'on, B. Gutel'makher, and M. Ivanova.** 1979. Use of biological and ecological indicators for determining the degree of pollution of natural waters. (English translation of Vodnye Resursy). Water Resour. 6(5):737-747.

Pollution and eutrophication of water bodies are occurring as a result of anthropogenic influences. They are characterized by a marked influence of the biomass of phytoplankton and, accordingly, of primary production and by an increase of the content of blue-green algae in plankton, causing excessive water bloom. In this case, the transparency of the water decreases, an increasing amount of organics enters the hypolimnion of lakes, and an oxygen deficit is created in the bottom layers in the stagnation period. Pollution of water bodies by organic matter (unlike eutrophication) does not necessarily lead to an increase of phytoplankton biomass and primary production; in a number of cases, a suppression of the development of phytoplankton algae or their complete disappearance may even be observed. The use of methods of biological indication of water quality and ecologo-functional methods for assessing changes in aquatic ecosystems subjected to anthropogenic influences is demonstrated in this work.

5.**Alm, A.** 1991. Leading environmental indicators. Environ. Sci. Technol. 25(5):839.

This editorial discusses the need for development of environmental indicators to predict environmental trends. It discusses indicators as predictive tools and discusses human health warnings also.

6.**American Management Systems, Inc.** 1987. Review of the literature on ecological endpoints. Report to the Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency. EPA Contract No. 68-01-7002. American Management Systems, Arlington, VA.

The Office of Policy, Planning, and Evaluation (OPPE) asked American Management Systems, Inc. to conduct a literature review and to summarize ecological endpoints that are measured by researchers and used by analysts in ecological risk assessment. The goal of the review was to support the Office of Research and Development in establishing ecological risk assessment guidelines and in arranging a series of workshops on ecological endpoint selection and measurement. The review was also designed to aid the Office of Toxic Substances in preparing for U.S. leadership at a meeting of the Organization for Economic Cooperation and Development on test methods used to predict ecological effects. This document contains a review of the literature and an annotated bibliography.

7.**Amir, S.** 1983. Ecosystems productivity and persistence: On the need for two complementary views in evaluating ecosystem functioning. ERC-047 Cornell University (Ecosystems Research Center), Ithaca, NY. 103 pp.

8.**Amir, S.** 1989. On the use of ecological prices and system-wide indicators derived therefrom to quantify man's impact on the ecosystem. Ecol. Econ. 1:203-231.

Ecological prices and other system-wide, quantitative descriptors of ecosystem functioning are derived from the assumption that ecosystems allocate available resources efficiently among their components. However, ecological prices are not efficiency prices only, and their use does not assume that the ecosystem is completely controlled by humans. The same prices balance flows of different biomasses in a multicomponent system. As such, they play the role of exchange prices in a decentralized ecosystem. Properly defined with the help of ecological prices, the resulting ecosystem productivity is no less a significant indicator of ecosystem functioning than is the national product for assessing the functioning of an economy. Considerations of the values taken simultaneously by our proposed indicators and by their economic analogs are of much help in judging the desirability of projects with relatively mild environmental repercussions. These values are obtained from am integrated model of a system in which ecological and economic activities are intertwined. However, for the indicators to have an analytical meaning, the methodology should be applied to trace only those dynamic paths during which the system possesses unique, state-dependent, intensive properties. In other cases, a more comprehensive methodology is scale-dependent and probabilistic in nature. While delineating relations between the structure of the system and its behavior, this method implies that efficiency and viability are two complementary rather than two commensurate attributes of a single entity. An outside observer may be guided by subjective values in attempting to weigh these features, but no inherent property of the system exists that supports these values unequivocally. Nevertheless, this paper proposes an approximation to overcome this difficulty and to estimate a quantitative limit to the rate of substitution between productivity and viability. Such a limit is also an intensive property of the simulated system, and the estimation of its value is shown to be crucial for studying the vulnerability of real ecosystems to severe human-made disturbances.

9.**Amir, S., and J. Hyman.** 1992. Measures of ecosystem health and integrity. Pages 661-668. In: A. Gasith, A. Adin, Y. Steinberger, and J. Garty, eds. Environmental Quality and Ecosystem Stability. Vol. 5/B. ISEEQS Publications, Jerusalem.

The health and integrity of an ecosystem is a multifaceted concept. It can become operational and of use in setting environmental policies once it is backed up by a theory that explicates the basic mechanisms of ecosystem functioning in response to stress. Despite the fact that ecosystem health remains a theoretical construct, the theory proposes a set of observed variables, basically the biotic stock and flows of the ecosystem, empowered by a computable model, that give rise to operational and diagnostic measures of ecosystem health. The proposed measures are shown to correlate well with several other qualitative and quantitative measures of ecosystem health.

Key Words: Ecosystem, Health, Redundancy, Stability, Turnover time

10.**Anderson, J.** 1971. Assessment of the effects of pollutants on physiology and behaviour. Proc. R. Soc. London Ser. B 177:307-320.

Many pollutants, even when present in the water in concentrations well below lethal levels, may cause marked changes in the physiology and behavior of fish. The work reported deals mainly with salmonids. The responses to insecticides are particularly interesting. Of fundamental interest is the suggestion that DDT seems to act by interfering with the normal thermal acclimation mechanism(s), probably within the central nervous system. The results are not without practical significance. Some responses, including those induced by heavy metal ions from mining wastes, may cause long-term ecological changes of consequence.

11.**Anderson, J.E.** 1991. A conceptual framework for evaluating and quantifying naturalness. Conserv. Biol. 5:347-352.

Naturalness is a scientific concept that can be evaluated and quantified. Intactness or integrity of ecosystems can be defined and assessed in similar ways. Three indices of naturalness are proposed: (1) the degree to which the system would change if humans were removed; (2) the amount of cultural energy required to maintain the functioning of the system as it currently exists; and (3) the complement of native species currently in an area compared with the suite of species in the area prior to settlement. These indices are complementary and provide a conceptual framework for evaluating naturalness. The latter two can be quantified.

12.**Arndt, U.** 1992. Key reactions in forest disease used as effects criteria for biomonitoring. Pages 829-840. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Ft. Lauderdale, FL, 16-19 October, 1990. Elsevier, Essex, England.

For 20 years biomonitoring has been a well-established procedure in support of practical environmental protection in Central Europe. It is used routinely around emittents or regionwide and statewide, delivering important data on effects and accumulation of pollutants in plants and animals. These data are used in the broadest sense to keep and optimize our surroundings. Much less experience exists with synecological bioindicators that give information about the behavior of ecosystems under pollution stress. However, intensive research on forest disease within the last 10 years shows the necessity for and provides the opportunity to develop a system for monitoring the current situation of our forests. Using some of the known "key reactions" at different biological levels as effects criteria, a proposal of synecological character is made for a biomonitoring at permanent plots in the forests of Southern Germany.

13.**Arndt, U.** 1992. Bioindication and the European perspective. Pages 1485-1490. In: D. McKenzie, D.E Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

14.**Arshad, M.A., and G.M. Coen.** 1992. Characterization of soil quality: Physical and chemical criteria. Am. J. Altern. Agric. 7(1-2):25-31.

The impact of soil degradation on human welfare and the global environment presents a major challenge. A significant decline in soil quality has occurred worldwide through adverse changes in its physical, chemical, and biological attributes and contamination by inorganic and organic chemicals. There is a need to develop criteria to evaluate soil quality so that the progress of any corrective action required by the international community can be monitored. There currently are no generally accepted criteria to evaluate changes in soil quality. This lack impedes the design and evaluation of meaningful soil management programs. This paper examines the principle physical and chemical attributes that can serve as indicators of a change in soil quality under particular agroclimatic conditions. Proposed indicators include soil depth to a root restricting layer, available water–holding capacity, bulk density/penetration resistance, hydraulic conductivity, aggregate stability, organic matter, nutrient availability/retention capacity, pH, and where appropriate, electrical conductivity and exchangeable sodium. The authors also discuss the justification for selecting these key attributes, their measurement, critical limits for monitoring changes in soil productivity, and future research needs in soil quality.

Key Words: Soil quality evaluation, Soil degradation

15.**Auerbach, S.I.** 1981. Ecosystem response to stress: A review of concepts and approaches. Pages 29-41. In: G. Barrett and R. Rosenberg, eds. Stress Effects on Natural Ecosystems. John Wiley & Sons, New York.

Effective ecological policy designs require a clear understanding of the resilience and stability properties of ecological systems and of the institutional and societal systems with which they are linked. Any pervasive understanding requires that the underlying scientific paradigms be well understood. The stress concept underlies a more complete understanding of the impacts of anthropogenic perturbations, the assessment of which is necessary for the development of policies for environmental or ecosystem management.

16.**Auerbach, S.I.** 1989. Monitoring the environment in the 21st century. Pages 165-171. In: R. Noble, J. Martin, and K. Jensen, eds. Air Pollution Effects on Vegetation. U.S. Forest Service, Northeastern Forest Experiment Station, Broomall, PA.

In this article, research directions regarding monitoring are proposed and issues surrounding environmental monitoring, such as the need to determine trends in ecosystems or in the environmental parameters that influence these systems are discussed. Other issues discussed are long-term monitoring and the problem of keeping monitoring systems dynamic rather than becoming mere collections of data used for checking compliance.

17.**Ausmus, B.** 1984. An argument for ecosystem level monitoring. Environ. Monitor. Assess. 4:275-343.

One objective of environmental monitoring programs is to document qualitative and quantitative environmental changes in response to external stresses, including chemical contamination. Chemical contaminant, biological, and ecological measurements have been used as environmental monitors. Contaminant monitoring allows estimation of exposure; biological and ecological monitoring allows estimation of uptake and effects.

Measurements of ecosystem homeostasis such as nutrient cycling processes have been shown to be good ecosystem level monitors. The rate of dissolved nutrient loss from ecosystems has been conclusively shown to increase as a function of chemical contamination until a new equilibrium is reached, the pollutant input has become negligible, or until nutrient pools have become depleted. Consequently, nutrient pools in environmental strata and in biota are altered and eventually depleted by chemical stress.

The use of nutrient cycling to determine sensitive responses to and long-term changes for chemical contamination is an essential monitoring strategy for environmental management and compliance purposes. Measurement of export (rapid response) and pools (long-term consequences) is within the capability of current technology, is cost-effective, and allows rapid implementation of remedial measures of environmental controls.

[illegible]. **Babich, H., D. Davis, and J. Trauberman.** 1981. Environmental quality criteria: Some considerations. Environ. Manage. 5(3):191-205.

The physicochemical characteristics of the recipient environment into which chemical contaminants are deposited may influence their chemical speciation, mobility, bioavailability, and toxicity. In formulating water quality criteria, the U.S. Environmental Protection Agency (EPA), in an innovative regulatory approach, considered the modifying effect of abiotic environmental factors on pollutant toxicity. Scientific knowledge of the interactions and correlations between pollutant toxicity and abiotic factors remains limited. Recognition of the influence of the physicochemical characteristics of the recipient environment on pollutant toxicity has implications for the eventual formulation of regional, rather than uniform and national, criteria. In addition, in developing water quality criteria that incorporate the effects of pollutants on "aquatic life," EPA focused primarily on toxicity to aquatic animals and plants (including unicellular algae). The effects of pollutants on microbe-mediated ecological processes that are necessary for maintaining the state and quality of the ecosphere (such as biogeochemical cyclings, litter decomposition, and mineralization) were not included in the formulation of the water quality criteria. To facilitate the recognition and quantification of adverse effects of pollutants on these ecological processes, the development of a computation, termed the "ecological dosage 50%" (EcD_{50}) is recommended. Such a formulation could also be applied to setting environmental quality criteria for terrestrial ecosystems.

Key Words: Pollutant toxicity, Water quality criteria, Microbe-mediated ecological processes, Ecological dosage 50%, Cadmium, Phenol, Physicochemical environmental factors

19.**Bailey, R.** 1991. Design of ecological networks for global monitoring. Environ. Conserv. 18(2):173-175.

Worldwide monitoring of agricultural and other natural resource ecosystems is needed to assess the effects of possible climate changes and/or air pollution on our global resource base. Generally, there are two choices for monitoring particular geographic areas. The first is a detailed examination of all ecosystems in that area that could throw any light on those effects. This, however, is rarely possible except in a small area. Thus, we are left with the alternative, for most areas a sampling strategy in which sites would be selected for examination. Monitoring of all sites is neither possible nor desirable for large areas, and so a means of choice has to be devised and implemented. The question then becomes: Where should the necessary monitoring sites be located?.

20.**Balogh, M.E., and R.S. Lunetta.** 1991. Evaluation of remote sensing for the Environmental Monitoring and Assessment Program's landscape characterization. In: GIS/LIS '90 - Technical Papers. Geographic Information Systems/Land Information Systems Annual Conference, Anaheim, Ca.

21.**Barnthouse, L.W.** 1992. The role of models in ecological risk assessment: A 1990s approach. Environ. Toxicol. Chem. 11(12):1751-1760.

Previously published reviews of mathematical models available for ecological risk assessment have emphasized population and ecosystem modeling approaches originally developed 20 years ago or more. Discussions of applications have focused on quantifying ecological effects of toxic chemicals and pesticides. This review emphasizes: (a) modeling approaches developed within the last decade; (b) applications to a broad array of environmental problems on local, regional, and global scales; and (c) the relevance of different types of models to different components of the risk assessment products.

Key Words: Time varying concentrations, Individual based model, Of the art, Physiological ecology, *Lepomis macrochirus*, Aquatic organisms, Simulation model, Sublethal copper, Regional scale, Life history

22.**Barbour, M., J. Plafkin, B. Bradley, C. Graves, and R. Wisseman.** 1992. Evaluation of EPA's rapid bioassessment benthic metrics: Metric redundancy and variability among reference stream sites. Environ. Toxicol. Chem. 11:436-449.

The data analysis scheme used in the U.S. Environmental Protection Agency's (EPA's) rapid bioassessment protocols (RBPs) integrates several community, population, and functional parameters (or metrics) into a single assessment of biological condition. A reference database of macroinvertebrate data obtained from 10 ecoregions in Oregon, Colorado, and Kentucky was used to evaluate the appropriateness and variability of the benthic metrics and the similarities of results among ecoregions. Several statistical procedures, including principle component analysis, correlation coefficient, analysis of variance, and stepwise discriminant analysis, were used to test the efficacy of 17 community metrics. A general separation between the mountain ecoregions and the valley/plains ecoregions was determined to exist for the metrics. Two of the original eight metrics described in the EPA's RBPs for benthic macroinvertebrates were found to be highly variable and unreliable as measures of biological conditions in some ecoregions. Eleven metrics were determined as being valuable in discriminating between montane and valley/plains groupings of ecoregions.

Key Words: Bioassessment, Metrics, Ecoregions, Macroinvertebrates, Streams

23.**Barrett, G.W.** 1974. The trophic dynamic aspects of equitability as an indicator of ecosystem stress effects. (abstract only). First International Congress of Systematic and Evolutionary Biology Abstracts, University of Colorado, Boulder, CO.

It is suggested that the equitability concept of Lloyd and Ghelardi provides an approach for the evaluation of stress effects on total ecosystems when both the stressor and the stress effects are viewed in a trophic dynamic manner. The equitability index is a measure of fit of observed relative abundance of species to those as predicted by MacArthur's broken-stick model for contiguous, non-overlapping niches. It appears that equitability values on a long-term basis more nearly approach one for higher-trophic-level groups compared with lower trophic level groups when both groups are presented with identical stressors (e.g., fire, pesticides, grazing, etc.). The duration of this response pattern appears to be the result of the trophic level at which the stress is directed; the lower the "target" trophic level, the longer the duration of stress effects on secondary consumers. This response may be the result of long-term energy resource limitation at higher trophic levels.

24.**Barrett, G.W.** 1978. Stress effects on natural ecosystems. Ohio J. Sci. 78:160-162.

This article briefly addresses the need for both structural and functional approaches to the study of stress, and the research of ecosystem-level stress.

25.**Barrett, G.W.** 1985. A problem-solving approach to resource management. Bioscience 35(7):423-427.

To assess stress in a given system, resource management must take into account socioeconomic as well as biological and physical factors. The 19-step algorithm presented here should help applied ecologists tackle management problems holistically, objectively, and systematically.

26.**Barrett, G., and R. Rosenberg, eds.** 1981. Stress Effects on Natural Ecosystems. John Wiley & Sons, New York. 305 pp.

This book provides a compendium of information regarding stress ecology. Chapters include discussions on: an integrative approach to stress, a working definition and critique/review of stress, a review of concepts and approaches to ecosystem response to stress, the effects of stress on succession, and a future approach to stress in ecosystems.

27.**Barrett, G., G. Van Dyne, and E. Odum.** 1976. Stress ecology. Bioscience 26:192-194.

Numerous studies have already addressed the evaluation of foreign stress effects on total ecosystems. Among the perturbations considered are pesticides, fire, and radiation. Various stress effects on the structure and function of ecosystems have been summarized by Odum and by Woodwell. More recently, in the U.S. International Biological Program (IBP) a series of ecosystem-level natural stress experiments was conducted in grasslands, deserts, tundra, and coniferous and deciduous forests.

These large-scale studies are being followed by numerous small-scale ecosystem-level investigations dealing with stress ecology. However, no attempt has been made to provide a set of guidelines for testing perturbations and for evaluating stress response in the future. The objective of this article is to offer the following set of guidelines for testing and evaluating perturbations on total ecosystems.

28.**Bayly, I., and P. Lake.** 1979. The use of organisms to assess pollution of freshwater: A literature survey and review. Publication No. 258. Ministry for Conservation, Victoria, Australia.

29.**Bazzaz, F.A.** 1990. The response of natural ecosystems to the rising global CO_2 levels. Annu. Rev. Ecol. Syst. 21:167-196.

The large body of literature on the response of crops and intensively managed forests to elevated CO_2 is not treated in this review because this information has been thoroughly reviewed recently elsewhere. Instead, this review concentrates on the response of natural vegetation to elevated CO_2 and on some of the predicted climate changes that may result. The review addresses the response of individuals to CO_2 at the physiological level and the consequences of that response at population, community, and ecosystem levels. It must, however, be emphasized that (1) most of the findings on the physiological and allocational response to CO_2 were first discovered in agricultural crops, and (2) much of the initial work on plants from natural ecosystems tests that variation among species in these responses.

30.**Beck, M.** 1991. Forecasting environmental change. J. Forecast. 10(1-2):3-19.

A context and introduction are provided for nine contributed articles on Forecasting Environmental Change. Since the first quantitative studies of the "predicament of mankind" at the end of the 1960s, large-scale forecasting models have attracted substantial criticism on the grounds of failing both to inform the policy process and to embrace the notion of surprise-rich futures. Almost all attempts to develop models of environmental systems, on whatever scale, have been dogged by the skeptic's question: Is the model capable of predicting conditions substantially different from those observed in the past? The question, strictly speaking, is not answerable. The paper defines, therefore, three approaches to the development of models—the mechanical, metric, and linguistic paradigms—and constructs a reorientation of the customary problem of prediction in order to explore the concept of reachable and radically different futures. Such reorientation depends crucially on a juxtaposition on the linguistic and mechanical descriptions of a system's behavior. The nine papers in this special issue are then summarized in the context of reconsidering how we formalize our thinking about the behavior of systems, and what might be meant by the systematic analysis of reachable futures.

Key Words: Environmental systems, Environmental change, Reachable futures

31.**Belward, A.** 1991. Remote sensing for vegetation monitoring on regional and global scales. Pages 169-187. In: Remote Sensing and Geographical Information Systems for Resource Management in Developing Countries. ECSC, EED, EAEC, The Netherlands.

Information is needed to assess the impact of human activities, to predict future conditions, and to arrive at a more complete understanding of the processes supporting the earth system. But what information should be obtained? Being responsive to both climate and human activity, the vegetation canopy is in itself a good indicator of ecosystem condition. Vegetation is dynamic in responding and adapting to prevailing environmental conditions; these dynamics are manifested in changes in the distribution of vegetation types and in changes in plant growth and development. In either case, monitoring such change calls for repeated observation and measurement.

The study of vegetation dynamics on regional and global scales is concerned with the community, biome, and ecosystem levels of organization rather than with individual plants or, even, populations. Repeated observation and measurement on these scales is not possible with conventional in situ measurements. However, satellite sensor remote sensing does provide a mechanism for global observation on a regular and repeatable basis. Vegetation monitoring on regional/global scales is an integral part of natural resource surveys such as tropical deforestation assessment, agricultural production forecasting, bush fire monitoring, and environmental degradation monitoring. These are the themes of subsequent chapters of this book; this chapter introduces some of the fundamental considerations to using remote sensing for this type of work.

32.**Bernard, D.** 1990. Workgroup issue paper: Community or ecosystem level indicators. Environ. Monitor. Assess. 15:281-282.

This presentation was designed to serve two purposes: (1) to summarize practical experience in selecting indicators at the community or ecosystem level for use in environmental monitoring programs and (2) to provide questions that would serve as focal points for working group discussions.

Accordingly, the introduction is built around the following three questions: (1) Is there anything that can be measured at the ecosystem level that cannot be measured at the community (or lower) levels?; (2) What types of indicators are appropriate for use in monitoring programs that are designed to detect problems involving cumulative effects? and; (3) What role will monitoring of indicators play in helping us determine whether efforts to restore damaged ecosystems have been successful?

An attempt is made to highlight issues associated with these questions rather than to answer them.

33.**Bernes, C., B. Giege, K. Johannsson, and J. Larsson.** 1986. Design of an integrated monitoring programme in Sweden. Environ. Monitor. Assess. 6:113-126.

A National Swedish Monitoring Program, the PMK, has been designed for regular and permanent recording of environmental conditions and long-term changes in background regions, and for keeping track of the flux of pollutants in and between various media. Many of the projects involved deal with integrated monitoring of terrestrial and limnic ecosystems. This work is carried out in or near some 20 small watersheds, usually selected in national parks or nature reserves. The environmental factors monitored in these areas include concentrations of chemical substances in precipitation, soil, groundwater, surface water, and organisms, as well as biological parameters (e.g., population size and reproductive capacity of certain species) that may indicate effects of environmental disturbances. The data from this program can be used as a reference to environmental data acquired near pollution sources, and as a basis for measures against, for example, acid rain, heavy-metal pollution, and use of pesticides. The biological parameters may also reveal effects of yet unknown pollutants or other disturbances.

34.**Bernstein, B.B.** 1992. A framework for trend detection: Coupling ecological and managerial perspectives. Pages 1101-1114. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Ft. Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Ecological indicators of environmental trends must fulfill two distinct, yet related, functions. They must be ecologically realistic and at the same time managerially useful. Each function alone presents difficult challenges, and together, they create an often conflicting set of constraints. This situation is made difficult because scientific and managerial views of the world reflect different perspectives, assumptions, and values.

From an ecological perspective, the development of effective trend measures is complicated by the many different underlying processes that contribute to ecological change. There are, for example, many kinds of successional sequences, cycles, and chaotic or random events. In addition, events and trends at larger space and time scales can mask, enhance, or interact with more-localized processes. Finally, complex, site-specific interactions and indirect effects often confound the interpretation of trends.

From a managerial perspective, the need for definitive information often conflicts with the complex realities of ecological systems. Management attention frequently focuses on time and space scales that do not match those on which ecological processes are occurring. Further, there are cultural differences between the two perspectives in standards of proof and in use and understanding of concepts such as causality and probability.

Illustrated with examples of effective as well as ineffective indicators, this paper explores these issues in detail. It builds on this discussion and on the examples to suggest a framework for evaluating and developing useful indicators. It also stresses the point of view that indicators are necessarily context-dependent; they cannot be interpreted independent of their ecological and managerial context. In many cases, a suite of indicators, rather than a single one, will be best suited to fulfilling the complex needs of trend detection.

35.**Best, E., and J. Haeck, eds.** 1983. Ecological indicators for the assessment of the quality of air, water, soil, and ecosystems. Environ. Monitor. Assess. 3(3-4):205-406.

36.**Binkley, D., T.D. Droessler, J. Miller.** 1992. Pollution impacts at the stand and ecosystem levels. Pages 235-257. In: R.K. Olsen, D. Binkley, and M. Bohn, eds. Response of Western Forests to Air Pollution. (Series: Ecological Studies: Analysis and Synthesis 97). Springer-Verlag, New York.

37.**Bird, P., and D.J. Rapport.** 1986. State of the environment report for Canada. Environment Canada, Ottawa.

38.**Boer, J.** 1983. Ecological indicator organisms for environmental protection policy. Symposium on Ecological Indicators for the Assessment of the Quality of Air, Water, Soil, and Ecosystems. Environ. Monitor. Assess. 3(3-4):399-403.

39.**Bohac, J., and R. Fuchs.** 1991. The structure of animal communities as bioindicators of landscape deterioration. Pages 165-178. In:D.W. Jeffrey and B. Madden, eds. Bioindicators and Environmental Management. Academic Press, London.

Biodiagnostic evaluation methods were developed from 1986-1990. Biodiagnostic investigations are made on a range of life forms and at various scales. They are performed both at population and community levels. The data on plants and animals must be obtained at the appropriate scale of investigation (e.g., local, regional, and fluvial). Biomonitoring at regional and fluvial scales mainly uses populations of small mammals and communities of birds. These groups, because of their size and migratory habits, are optimal bioindicators of the complex of factors that degrade the landscape and lead to air pollution.

Biomonitoring at the local scale mainly uses populations and communities of invertebrates. These groups have small body sizes and a lower tendency for migration and, therefore, are suitable for indicating local environmental factors such as unsuitable application of fertilizers and pesticides, unsuitable methods of landscape management, and overdrainage and the consequent desiccation of the landscape. Biomonitoring at the local scale is often the sole method used to investigate the biotic conditions in reserves and national parks. The investigation of key organisms and their communities in portions of the landscape is important for the research at regional scales. The mosaic of well-preserved landscape units increases the stability of the landscape.

Key Words: Ecological classification, Square mapping, Environmental factors, Invertebrates, Birds, Czechoslovakia

40.**Bolger, P.** 1990. Rapporteur's report of work group: Indicators and assessment of the state of fisheries. Environ. Monitor. Assess. 15:295-296.

This article identifies the most important indicators that should be examined, and the indicator thresholds which could be used to alert managers to achieve sustainable management of the fisheries resource.

41.**Bongers, T.** 1990. The maturity index: An ecological measure of environmental disturbance based on nematode species composition. Oecologia 83:14-19.

Nematode assemblages constitute a potential instrument for assessing the quality of submersed, temporarily submersed, and terrestrial soils and for the development of an ecological typology and biomonitoring system. Interpretation of physical or pollution-induced disturbances has hitherto been based mainly on changes in diversity, dominance patterns, or percentage of dorylaimids (Adenophorea). The maturity index, based on nematode fauna, is proposed as a gauge of the condition of the soil ecosystem. Values on a colonizer/persister scale are given for nematodes that occur in The Netherlands. The possibilities for the use of this index are demonstrated by a respective interpretation of some literature data. The use of nematodes in environmental studies is discussed.

Key Words: Nematodes, Maturity, Ecology, Colonization, Biomonitoring

42.**Bormann, F.** 1985. Air pollution and forests: An ecosystem perspective. Bioscience 35(7):434-441.

Widespread forested areas may be undergoing early stages of ecosystem decline. Although this is difficult to detect because of uncertainty about pollution input and the natural variation common to any ecosystem, the potential danger is too grave to delay regulatory action while waiting for conclusive research that may never become available.

43.**Bourdeau, P., and M. Treshow.** 1978. Ecosystem response to pollution. Pages 313-330. In: G. Butler, ed. Principles of Ecotoxicology. SCOPE 12. John Wiley & Sons, Chichester, England.

Although the book as a whole covers ecotoxicology and response to pollution at lower hierarchical levels, this chapter covers response of the system as a whole to pollution. The chapter is divided into the following sections and subsections: Introduction; Methods of Studying Ecosystem Response; Assessment of Levels of Pollution—(i) quantitative, (ii) qualitative; Assessment of Effects on Ecosystems—(i) eutrophication, (ii) acid rain in lakes, (iii) oil spills in the environment, (iv) detergents in sewage, (v) ecosystems with algal and protozoan communities, (vi) rivers and lakes, (vii) estuarine ecosystems, (viii) coral reefs, (ix) mangrove ecosystems, (x) terrestrial ecosystems; Conclusions and Predictions—(i) diversity, stability, maturity of ecosystems, (ii) effects of pollution on ecosystem characteristics.

44.**Boyle, T., ed.** 1987. New Approaches to Monitoring Aquatic Ecosystems. ASTM 940. American Society for Testing and Materials, Philadelphia.

This volume represents recent state-of-the-art research in the field of environmental monitoring. The purpose of this collection of papers is to provide a range of examples of areas in which new methods and approaches of environmental monitoring are being employed. This volume is intended for scientists who will design monitoring programs as part of their research and for environmental managers who initiate the questions for monitoring and who would be the ultimate users of the results. The papers in this volume elaborate specific concerns, questions, and program criteria that characterize the development of monitoring programs and provide specific examples as paradigms for future monitoring programs. Contributions to this book address preplanning monitoring programs, decision making in relation to monitoring, and case studies.

45.**Boyle, T., J. Sebaugh, and E. Robinson-Wilson.** 1984. A hierarchical approach to the measurement of changes in community structure induced by environmental stress. J. Test. Eval. 12(4):241-245.

A new index of dissimilarity to measure changes in community structure caused by environmental stress is proposed. A new statistical algorithm was also devised to test the similarity or dissimilarity between two communities. This procedure tests the mean dissimilarity between the same communities. These new indices of community structure are cast in a proposed hierarchical scheme for testing different degrees of changes in stressed communities. Several examples illustrate that the proposed procedures give a more interpretable comprehensive analysis than does a limited set of indices.

Key Words: Statistical tests, Environmental tests, Biological surveys, Community dissimilarity, Statistical test of dissimilarity, Hierarchical community measurement scheme, Stressed communities

46.**Breckenridge, R.P.** 1990. The role of quality assurance in conducting terrestrial ecosystem monitoring. Pages 73-81. In: D.R. Hart, ed. Proceedings of the Third Annual Ecological Quality Assurance Workshop. Environment Canada, Canada Centre for Inland Waters.

47.**Bretherton, F.** 1989. Taking the pulse of the planet. EPA J. May/June:40-41.

This article briefly addresses and argues for the premise that we must monitor the "vital signs" of the planet. Very general global measurements are suggested. The issues surrounding the measurements and models are also discussed.

48.**Bretthauer, E.W.** 1991. The need for EMAP. Lake Line September:4-5.

Why do we need a national program to address ecological status and trends? The author welcomes the opportunity to provide a perspective on new directions for the Environmental Protection Agency and on the role that an ecological status and trends program will play. No doubt the membership of the North American Lake Managers Society will want to debate the specifics of the lake component of this program, and a view of the larger perspective will be useful in doing so.

49.**Breymeyer, A.** 1981. Monitoring of the functioning of ecosystems. Environ. Monitor. Assess. 1:175-183.

The theoretical basis, content, and possible applications of the program "Monitoring of Ecosystems" are considered. A functional definition of ecosystem is proposed, and some features of ecosystems are defined on this basis. The program "Monitoring of Ecosystems" is visualized as a large-scale program of simple measurements of the rates of the main ecosystem processes. The expected results can be utilized in two ways: (1) a comparative knowledge of ecosystem functioning provides the fundamentals of geography of ecosystems, and (2) the constant, repeatable evaluation of a given ecosystem function provides a basis for its rational management.

50.**Breymeyer, A.** 1990. Measuring function and disfunction in ecosystems. Pages 116-140. In: W. Grodzinski, E.B. Cowling, and A. Breymeyer, eds. Ecological Risks: Perspectives from Poland and the United States. National Academy Press, Washington, DC.

Topics covered in this workshop contribution are: Ecosystems: definition and function; Natural influences on ecosystems; Anthropogenic influences on ecosystems; Status of forest ecosystems in Poland and; Evolution of ecosystems.

51.**Bro-Rasmussen, F., and H. Lokke.** 1984. Ecoepidemiology— A casuistic discipline describing ecological disturbances and damages in relation to their specific causes: Exemplified by chlorinated phenols and chlorophenoxy acids. Regul. Toxicol. Pharmacol. 4:391-399.

Ecoepidemiology is a recently created concept that is analogous to human epidemiology. It is the study of ecotoxicological effects at the levels of ecosystems, biological communities, and populations in relation to causative environmental exposures, mostly by chemicals. Ecoepidemiology is described by presenting an example of unintentional dissipation and possible discharges of chlorophenols and phenoxy acids into the terrestrial environment. A specific case of a marine area is given, the Koge Bay immediately to the south of Copenhagen, Denmark. The examples are illustrative of the complex situation that characterizes most ecoepidemiological cases. Difficulties with which the ecoepidemiologist are confronted are not only the identification of possible causative and confounding chemicals and the description of ecoepidemiological effects per se, but also the assessment of critical pathways of multimedia pollutants. Biomonitoring, computer-based handling of data from natural localities, and determination of a variety of anthropogenic impact factors are necessary elements of ecoepidemiological studies.

52.**Brock, R., T. Crisman, W. Courtenay, and V. Nilakantan.** 1991. The ecological effects of exotic species in North American Lakes. Pages 95-104. In: Hydrology of Natural and Manmade Lakes. Series:

IAHS Publications 206. International Association of Hydrological Sciences, Wallingford, United Kingdom.

Effective lake management requires a clear understanding of the complex interrelationships between abiotic and biotic forces. As humans have continually sought to biomanipulate lacustrine ecosystems for perceived gain, exotic species have reached dominance in many North American lakes. Because natural ecosystems require many years to develop, a sudden addition of an exotic species usually results in dire consequences. Exotic fish, zooplankton, mollusks, and aquatic macrophytes drastically change any lake ecosystem in which they become firmly established.

53.**Bromberg, S.** 1990. Identifying ecological indicators: An environmental monitoring and assessment program. J. Air Waste Manage. Assoc. 40(7):976-978.

The U.S. Environmental Protection Agency is initiating the Environmental Monitoring and Assessment Program (EMAP) to monitor the status and trends of the nation's near-coastal waters, forests, freshwater wetlands, surface waters, agroecosystems, and arid lands. This program is intended to evaluate the effectiveness of Agency policies for protecting ecological resources within these systems. Monitoring data collected for all ecosystems will be integrated for national status and trends assessments.

54.**Bromenshenk, J., and E. Preston.** 1986. Public participation in environmental monitoring: A means of attaining network capability. Environ. Monitor. Assess. 6:35-47.

In the Puget Sound region of the United States a task force of community volunteers using bees monitored environmental pollution. This paper discusses advantages and limitations of public involvement in the assessment of regional environmental problems, particularly with respect to biological monitoring. This approach not only yielded extensive information about pollution levels but also was very cost-effective.

55.**Brown, D.E., C.H. Lowe, and C.P. Pase.** 1979. A digitized classification system for the biotic communities of North America. With community (series) and association examples for the southwest. J. AZ-NV Acad. Sci. 14(Supplement 1, May):1-16.

In previous publications on the North American Southwest System the authors have addressed primarily the North American Southwest region. Responses to both this classification system and the classification have been favorable in both interest and use. In this report the classification nomenclature at digit levels 1-4 is expanded to represent the North American continent.

The Southwest System is evolutionary in basis and hierarchical in structure. It is a natural biological system rather than primarily a geography-based one in the sense of Dice 1943; Bailey 1978 and others. The resulting classifications are, therefore, natural hierarchies.

This classification system is tentatively being considered for use in prototype ecological resource assessments by the EMAP Integration and Assessment Group.

56.**Bruns, D. 1991.** Editorial: Ecological monitoring for global change. Environ. Monitor. Assess. 17(1):1.

This editorial provides introductory remarks on the symposium on environmental monitoring held at the 74th Annual Meeting of the Ecological Society of America.

57.**Bruns, D., G. Baker, J. Clayton, S. Greene, M. Harmon, M. Minshall, T. O'Rourke, B. Smith, C. Staley, G. White, and G. Wiersma.** 1988. Integrated environmental monitoring at remote ecosystems: First annual report. Informal report, EGG-CEMA-8713. EG&G Idaho, Inc., Idaho Falls, ID.

58.**Bruns, D., and G.B. Wiersma.** 1988. Research plan for integrated ecosystem and pollutant monitoring at remote wilderness study sites. Informal Report, EGG-EES-7951. EG&G Idaho, Inc., Idaho Falls, ID.

59.**Bruns, D., G.B. Wiersma, and G. Minshall.** 1992. Evaluation of community and ecosystem monitoring parameters at a high-elevation, Rocky Mountain site. Environ. Toxicol. Chem. 11:459-472.

A multimedia systems approach was used to field test wilderness monitoring guidelines (U.S. Forest Service) at a high elevation site in western Wyoming. Five evaluation criteria having a primary emphasis on an ecosystem conceptual framework were applied to selected ecological parameters (aquatic and terrestrial) that the authors ranked on a relative scoring basis. The ecosystem conceptual criterion was based on the general attributes of the subalpine system, the nature of the potential environmental problem (acidic deposition), and the ecological resources at risk. The other criteria were data availability, uncertainty, usability of methods, and cost-effectiveness. Data on sulfate deposition and buffering capacity of soils and surface waters relative to an elevational gradient supported the notion of greater risk to ecological resources in the subalpine environment. Within this ecosystem perspective, litter decay and taxonomic richness of lotic macroinvertebrates had the highest rating, followed by lotic functional feeding groups and lignin-to-nitrogen ratios. A biotic index for stream macroinvertebrates received the lowest rating on an ecosystem conceptual basis and also scored low on the uncertainty and cost-effectiveness criteria; however, suggestions were made for future improvement. Most parameters were similar in regard to variability and usability, except for functional groups, which exhibited greater data variability.

Key Words: Ecosystem monitoring, Terrestrial, Aquatic, Subalpine

60.**Bruns, D., G.B. Wiersma, and E. Rykiel.** 1991. Ecosystem monitoring at global baseline sites. Environ. Monitor. Assess. 17(1):3-31.

Integrated ecosystem and pollutant monitoring is being conducted at prototype global baseline sites in remote areas of the Noatak National Preserve, Alaska; the Wind River Mountains, Wyoming; and Torres del Paine National Park, Chile. A systems approach has been used in the design of these projects. This approach includes (1) evaluation of source-receptor relationships, (2) multimedia (i.e. air, water, soil, and biota) monitoring of key contaminant pathways within the environment, (3) the use of selected ecosystem parameters to detect anthropogenic influence, and (4) the application of a systems conceptual framework as a heuristic tool.

Initial short-term studies of air-quality (e.g., SO_2 and NO_2) plus trace metal concentrations in mosses generally indicate pristine conditions at all three sites as expected, although trace metals in mosses were higher at the Wyoming site. Selected ecosystem parameters for both terrestrial (e.g., litter decomposition) and aquatic (e.g., shredders, a macroinvertebrate functional feeding group) habitats at the Wyoming site reflected baseline conditions when compared with other studies. Plans are being made to use U.S. Department of Energy research parks for global change monitoring. This will involve cross-site analyses of existing ecological data bases and the design of a future monitoring network based on a systems approach as outlined in this paper.

61.**Brydges, T.** 1990. Rapporteur's report of work group: Indicators and assessment on the state of forest. Environ. Monitor. Assess. 15:301-302.

This articles briefly addresses three questions: (1) How do we separate "normal" from human-induced change in forests?; (2) How can we predict long-term changes based on backward-looking science? and; (3) How do we decide on the acceptability of changes?

62.**Burkman, W.G., and G.D. Hertel.** 1992. Forest health monitoring. J. For. 90(9):25-26.

This article provides a brief description of the Forest Health Monitoring Program and EMAP. Subtopics include: Program establishment; Establishing permanent plots; Information integration and; Program support.

63.**Cairns, J., Jr.** 1974. Indicator species vs the concept of community structure as an index of pollution. Water Resour.Bull. 10:338-347.

This article compares the advantages and disadvantages of using indicator species vs assemblages of organisms as indexes of pollution.

64.**Cairns, J., Jr.** 1979. Biological monitoring — concept and scope. Pages 3-20. In: J. Cairns Jr., G. Patil, and W. Waters, eds. Environmental Biomonitoring, Assessment, Prediction and Management—Certain Case Studies and Related Quantitative Issues. International Co-operative Publishing House, Fairland, MD.

Biological monitoring is the regular, systematic use of organisms to determine environmental quality. Chemical-physical monitoring determines the concentration or level (e.g., temperature) of the various components. However, currently no reliable way exists, other than biological monitoring, to determine the integrated, collective impact of these chemical-physical parameters on living material. Consequently, space flights with human crews include both types of monitoring.

This paper is divided into three sections: (1) a rationale for using biological monitoring, (2) a discussion of how it might be used, and (3) some of the problems that must be resolved before biological monitoring is widely accepted.

Key Words: Monitoring, Toxic chemicals, Hazard evaluation, Bioassays

65.**Cairns, J., Jr.** 1981. Biological monitoring. Part VI — future needs. Water Res. 15:941-952.

Biological assessment of water pollution has depended historically on the direct observation of effects in natural systems. This is unsatisfactory for two reasons: (1) best management practices require prevention rather than documentation of damage and (2) direct observation of an event in one system does not necessarily permit one to make claims about events in other systems. The documentation of damage is a necessary part of biological monitoring. Methods for determining whether biological integrity has been impaired are still being developed, although a wide variety of methods for different types of ecosystems is currently available for practical use. As a consequence, the most important of the future needs in biological assessment of pollution are: (1) development of a predictive capability and (2) developing the means of validating the accuracy of the predictions, which will in turn enable corrections to be made when the predictions are in error.

66.**Cairns, J., Jr.** 1990a. The genesis of biomonitoring in aquatic ecosystems. Environ. Prof. 12:169-176.

The field of biological monitoring had its genesis first in the protection of humans and, subsequently, the organisms living in natural systems against deleterious effects clearly evident to the general public. Ideally, biological monitoring should focus on maintaining established quality control conditions to ensure the health and well being of natural systems. Some professionals disagree with the focus on large systems, maintaining that regulatory agencies and industry are primarily interested only in small fragments of these larger systems.

Biological monitoring of isolated ecosystem fragments is a consequence of the genesis of the field. For example, focusing on single species toxicity tests as a primary determinant of ecosystem health and failure to validate or confirm the predictive models based on single-species laboratory tests are a result of the origins of the field rather than good scientific practices. The purpose of this paper is to raise questions about whether currently-used methodology is accepted because of its origins or because of its scientific suitability.

67.**Cairns, J., Jr.** 1990b. Global climate/ecosystem monitoring: Inland aquatics. Spec. Sci. Tech. 13(1):71-80.

There has been much discussion of global climate change as a result of increased atmospheric carbon dioxide (the greenhouse effect). Small changes of only a few degrees in average annual temperature may have a dramatic effect on the length of the growing season of wheat and other crops on which civilization depends. The effects on ecosystems will probably be equally dramatic. The physical measurements will be straightforward, although distinguishing a trend from normal variability will not be. However, because the relationship between changes in climate and biological/ecosystem effects is not linear, a global biomonitoring system is essential to document these as soon as they occur. Unfortunately, this matter has not been given the attention it deserves by ecologists or governments.

68.**Cairns, J., Jr.** 1991. Environmental auditing for global effects. Environ. Audit. 2(4):187-195.

Even though this is an era of unprecedented global change, information feedback loops have not been established that will explain the nature of the environmental changes taking place. The continuance of this rapid change is ensured because no determination has been made nationally or internationally of the condition of environmental quality necessary for sustainable, long-term use of the planet. Ideally, an audit takes place in order to ensure that previously established quality control conditions are being met. These quality control conditions need not be cast in concrete since they are not in any other quality control situation, but they are established and, when changed, are changed on the basis of evidence indicating the merit of such changes. These changes are not always in one direction (that is, toward more rigid standards). Standards may be relaxed when evidence demonstrates that either no deleterious effects will occur or that these effects are minimal. Because of the very rapidity of the changes occurring (e.g., reduction in biodiversity), global monitoring cannot be preceded by a long trial period of local and regional monitoring. Some humans simply do not believe that the thin envelope around the planet in which life occurs is seriously threatened. Others fear that the end is near. Both groups are handicapped by the lack of robust monitoring information that will provide trend analyses and other information to determine: (1) whether conditions are deteriorating rapidly, (2) where the earth's worst trouble spots are, and (3) what management decisions are likely to alter this deteriorating situation since chemical, physical, and biological monitoring, if properly coupled, will indicate cause/effect relationships. This manuscript focuses on an overall strategy for environmental auditing for global change and provides illustrative attributes that might be used effectively at different levels of biological organization.

Key Words: Global auditing, Global monitoring, Environmental quality control, Global change, Ecological information systems, Landscape monitoring, Early warning systems

69.**Cairns, J., Jr., A.J. Buikema, D. Cherry, E. Herricks, and W. Van der Schalie, eds.** 1982. Biological Monitoring in Water Pollution. Pergamon Press, New York.

70.**Cairns, J., Jr., and P.V. McCormick.** 1991. The use of community- and ecosystem-level end points in environmental hazard assessment: A scientific and regulatory evaluation. Environ. Audit. 2(4):239-248.

Even with a strong scientific basis for the use of toxicity tests at higher levels of biological organization (e.g., communities) for predicting environmental risk, a strong resistance to the use of such endpoints remains among regulators. The use of community- and ecosystem-level end points has been criticized for a lack of consensus regarding which endpoints should be measured. Furthermore, it has been argued that the decisiveness and accuracy of predictions at these higher levels of biological organization are no greater than those resulting from single species tests and are more costly to generate. A rapidly increasing body of evidence refutes many of these assertions. This paper synthesizes recent evidence on the applicability of microcosm tests using microbial communities for predicting effects of chemicals on natural communities and ecosystems. These tests have been effective in providing explicit predictions of hazardous concentrations of many chemicals and in identifying instances where standard single species protocols either underestimate or overestimate the degree of risk. The cost of many microcosm tests is comparable to single species tests. In addition to the usefulness of microcosm tests as exploratory tools in ecotoxicological research, recent evidence supports their incorporation into regulatory procedures in some limited way. Although more substantive investigation is essential before such tests can be accepted as integral parts of the regulatory process, further effort in this direction is warranted.

Key Words: Communities, Ecosystems, Ecotoxicology, End points, Hazard assessment, Microorganisms, Single species tests

71.**Cairns, J., Jr., and P.V. McCormick.** 1992. Developing an ecosystem–based capability for ecological risk assessments. Environ Prof. 14:186-196.

Ecological risk assessment is a scientific process for estimating, with a known degree of certainty, anthropogenic effects on the integrity of natural ecosystems and the services they provide. An inordinate focus has been placed on bottom–up risk assessment strategies, which emphasize laboratory based testing. Laboratory protocols alone are incapable of estimating uncertainties associated with attempts to extrapolate data among levels of environmental complexity, biological organization, and a multitude of potential impact scenarios. Top–down approaches to risk assessment, which utilize ecological indicators present in natural ecosystems, can address these problems and ensure that previously stated environmental objectives are met. Monitoring programs designed to protect ecosystem integrity should include: (1)compliance indicators—for assessing the degree to which previously stated environmental conditions are maintained; (2)diagnostic indicators—for determining the cause of deviations outside the limits of acceptable conditions; and (3)early warning indicators—for signalling impending deleterious changes in environmental conditions before unacceptable conditions actually occur. While scientific, economic, and political constraints preclude development of an ideal monitoring system at this time, implementation of less comprehensive programs currently is feasible.

72.**Cairns, J., Jr., P.V. McCormick, and B.R. Niederlehner.** 1992. Estimating ecotoxicological risk and impact using indigenous aquatic microbial communities. Hydrobiologia 237(3):131-145.

Emphasis has increased on accuracy in predicting the effect that anthropogenic stress has on natural ecosystems. Although toxicity tests low in environmental realism, such as standardized single species procedures, have been useful in providing a certain degree of protection of human health and the environment, the accuracy of such tests for predicting the effects of anthropogenic activities on complex ecosystems is questionable. The use of indigenous communities of microorganisms to assess the hazard of toxicants in aquatic ecosystems has many advantages. Theoretical and practical aspects of microbial community tests are discussed, particularly in related to widely cited problems in the use of multispecies test systems for predicting hazard. Further standardization of testing protocols using microbial colonization dynamics is advocated on the basis of previous studies, which have shown these parameters to be useful is assessing risk and impact of hazardous substances in aquatic ecosystems.

Key Words: Hazard assessment, Microorganisms, Communities, Ecosystems, Single species testing, Multispecies testing, Extrapolation

73.**Cairns, J., Jr., and B. Niederlehner.** 1989. Adaptation and resistance of ecosystems to stress: A major knowledge gap in understanding anthropogenic perturbations. Specul. Sci. Technol. 12(1):23-30.

The capacity of ecosystems to adapt to anthropogenic stress is currently poorly understood. Unfortunately, there are few places in the world where human activities do not have a major influence on natural systems. The capacity of natural systems to generalize an adaptation from one stress to new stresses is virtually unknown. Mechanisms of adaptation at the community level and the influence of the type of stress (whether common in evolutionary history, such as organic enrichment, or unprecedented, such as synthetic pesticides) are only partially understood, and their reversibility is not ensured once the stress is removed. An improvement is needed in our ability to predict the effects of anthropogenic stress on natural systems. Multiple stresses are ubiquitous in systems but are ignored in predictive models because of a lack of data. An information base may confirm hypothetical ranking of the vulnerability of ecosystems based on their history of stress and contribute to the general understanding of stress ecology.

74.**Cairns, J., Jr., B. Niederlehner, and E.P. Smith.** 1992. The emergence of functional attributes as endpoints in ecotoxicology. Pages 111-128. In: G.A. Burton, ed. Sediment Toxicity Assessment. Lewis Publishers, Inc., Boca Raton, FL.

75.**Cairns, J., Jr., G. Patil, and W. Waters, eds.** 1979. Environmental Biomonitoring, Assessment, Prediction and Management — Certain Case Studies and Related Quantitative issues. International Co-operative Publishing House, Fairland, MD.

This volume, while focused largely on environmental biomonitoring, assessment, prediction, and management, includes some applications to the management of certain populations and ecosystems for uses beneficial to man. These have added dimensions of complexity and have certain requirements for monitoring assessment and prediction. The volume is organized into four sections: biomonitoring — concepts and methods, environmental assessment and prediction, environmental management, and other management studies and quantitative issues.

76.**Cairns, J., Jr., and J.R. Pratt.** 1986. Ecological consequence assessment: Effects of bioengineered organisms. Water Resour. Bull. 22(2):171-182.

The introduction of genetically altered microorganisms into natural ecosystems presents fundamentally new problems in risk assessment and ecological effect evaluation. Novel microorganisms, produced by any of several new methods, have the ability to survive and reproduce in the environment. Because most of these organisms are bacteria, they have the potential to interfere with natural processes, displace natural populations, infect new hosts, move between ecosystems, and cause far-reaching ecological disturbances. This paper reviews currently available methods in ecological research that might be used in evaluating the ecological effects of releasing genetically altered microorganisms. Both structural and functional evaluations are critically reviewed. Microcosm, mesocosm, and field tests should provide valuable predictions concerning the potential ecological impact of genetically altered organisms. Ecosystem assessments will also be useful in post-release studies such as those currently used to evaluate toxic impacts. The current problem does not require the development of new testing methods but rather the creation of adequate predictive models (both conceptual and systems-based) to predict the potential for adverse effect of genetically altered organisms.

Besides discussing genetically altered organisms, this article provides, in general terms, information on structural versus functional assessments, methods in ecological assessment, ecosystem functional analysis, ecosystem assessment, gaps in ecological data, and ecological end points.

Key Words: Genetic engineering, Ecosystem assessment, Environmental impact, Community structure, Ecosystem function

77.**Cairns, J., Jr., and J.R. Pratt.** 1986. On the relation between structural and functional analyses of ecosystems: Editorial. Environ. Toxicol. Chem. 5:785-786.

There are two approaches to ecosystem research and the measurement of environmental impact, and these are clearly at odds. One studies ecosystem structure as the sum of interacting species, many of which usually differ from site to site even in healthy ecosystems. The other approach studies ecosystem function by tracing the flow of matter and energy through the processing compartments. What course should be charted — structure or function? What should be measured? Three possible relationships between structural and functional parameters are discussed.

78.**Cairns, J., Jr., and J.R. Pratt.** 1987. Ecotoxicological effect indices: A rapidly evolving system. Water Sci. Tech. 19(11):1-12.

Ecotoxicology has evolved from a modest number of single-species acute-toxicity tests to an integrated system of hazard evaluation for predicting adverse effects of chemicals and complex mixtures on environmental health. The process of screening and regulating chemicals and industrial discharges has improved water quality but has generally not been validated in receiving ecosystems. This deficiency results from the regulation of individual chemicals that rarely occur alone in the environment and from the size of the problem. Many receiving ecosystems have literally hundreds of discharges of complex effluents. Typical single species laboratory tests fail to account for the complexity of ecosystems and the strong interactions that may occur among the component species. Evidence is accumulating that complex test systems such as microcosms and mesocosms can fill this void. Microcosms and mesocosms can be constructed, experiments can be conducted cost-effectively, and several endpoints can be measured in complex systems by the standard dose-response paradigm. For example, the current regulation of chlorine discharges is based on three chronic exposures to chlorinated sewage effluent. In a microcosm test, the authors determined adverse biological effects at nearly an order of magnitude less chlorine (1 µg/l) for the loss of microbial species. To be effective as hazard evaluation tools, microcosms and mesocosms must include ecologically meaningful processes and must be useful in making decisions regarding environmental safety and harm. This can only be done with adequate statistical design and intensive sampling. Nevertheless, laboratory ecosystems can be useful in making direct measurements of effects on a large number of interacting species and can be tied to a site-specific problem in a particular ecosystem or can be standardized by using regional-type ecosystems as references. By using complex natural communities, the ability to validate test system predictions increases because the test system complexity mimics that found in the real world.

Despite hopes that a few sensitive species might be used to make decisions quickly on environmental effects, ecological health will only be maintained when scientists and regulators come to grips with the problem of protecting ecologically important processes as well as sensitive species. This will mean developing increasingly realistic tests in which environmentally realistic concentrations of chemicals can be tested without resorting to the use of safety factors or extrapolation from limited data bases. Developing such tests does not mean skyrocketing costs for screening chemicals and effluents. It does suggest, however, that regulators and toxicologists will need to deal with new information and learn new skills rather than relying on historically pleasing but ecologically deficient testing programs.

Key Words: Ecotoxicology, Toxicity testing, Multispecies testing, Hazard evaluation

79.**Cairns, J., Jr., and J.R. Pratt.** 1990. Biotic impoverishment: Effects of anthropogenic stress. Pages 495-505. In: G.M. Woodwell, ed. The Earth in Transition: Patterns and Processes of Biotic Impoverishment. Cambridge University Press, Cambridge, England.

The author recognizes two types of impoverishment: losses of diversity in a landscape as human effects spread and the in situ transitions that accumulate under chronic disturbance, usually, but not always, reducing the diversity of a community and making it more vulnerable both to invasion and other disruption. The insights are refreshing, if complex and disturbing. They confirm the very patterns now familiar: chronic disturbance in aquatic systems favors the hardy cosmopolitan species that reproduce rapidly and usually do not form the basis of complex food webs. The patterns are systematic, predictable, and increasingly common. One of the greatest dangers is that the disturbances will become so close to universal that sources of species for reintroduction will be lost, despite the general hardiness of the protists used.

80.**Cairns, J.J., and W. Van der Schalie.** 1982. Biological monitoring. Part 1 — early warning systems. Water Res. 14:1179-1186.

One aspect of biological monitoring is the use of aquatic organisms to provide an early warning of the presence of toxic materials in water. Possible applications of this concept are: (1) in an industrial setting to help prevent hazardous waste spills or (2) in a water treatment plant to check on potable water supplies. These tasks have been traditionally carried out exclusively by chemical-physical techniques applied either continuously or at frequent intervals. The inadequacy of these methods by themselves in predicting toxicity is discussed by the author. This article describes the operational requirements that must be met by a biological toxicity early-warning system and some of the organisms and techniques which have been or may be employed in such systems. An early warning toxicity monitoring system will be considered to have the following characteristics:

1. The organisms are held either in a laboratory situation or in the field under controlled conditions and are exposed on an intermittent- or continuous-flow basis to the water or wastewater being tested.
2. A physiological or behavioral parameter of the organism is monitored by a recording device capable of responding to abnormal conditions indicated by the organism.
3. The function of the monitor is primarily for detection of short-term changes in toxicity vs chronic or cumulative effects.

81.**Calow, P.** 1992. Can ecosystems be healthy? Critical consideration of concepts. J. Aquat. Ecosys. Health 1:1-5.

Health, it is argued, implies that a system has an optimum state that can be defended. For organisms and populations this can be understood objectively and generally in terms of neo-Darwinian principles. Similar reasoning cannot be applied to ecosystems. The possible advantages and difficulties of applying this concept of health to ecosystems are critically considered.

Key Words: Analogy, Control, Fitness, Optimization, Teleology

82.**Carpenter, S.** 1990. Large-scale perturbations — opportunities for innovation. Ecology 71(6):2038-2043.
Several approaches are discussed for statistical analysis of large-scale (and possibly unreplicated) ecological experiments. These include intervention analyses and comparisons of alternative models using Bayes' formula. Such techniques are unfamiliar to many ecologists and are not typically included in graduate curricula in ecology. This article argues for increased training in these areas and for collaborations between statisticians and ecologists to develop innovative approaches to the analysis of large-scale perturbations.

83.**Carpenter, S., and P. Matson.** 1990. Editorial: Statistical analysis of ecological response to large-scale perturbations. Ecology 71(6):2037.

This editorial outlines the issues surrounding statistical approaches for interpreting response to large-scale perturbations and cites as a critical challenge the understanding and management of Earth's resources in the face of environmental change.

84.**Chaphekar, S.** 1991. Bio-indicators. J. Environ. Biol. 12(SI):U163-U164.

85.**Chaphekar, S.** 1991. An overview on bio-indicators. J. Environ. Biol. 12(SI):163-168.

86.**Chapman, P.** 1991. Environmental quality criteria: What type should we be developing? Environ. Sci. Technol. 25(8):1353-1359.

The development of environmental quality criteria is a major global industry; it occupies the time and pays for the salaries of professionals in a variety of fields. Scientists provide the framework for or argue against their promulgation; administrators try to make criteria work or seek loopholes; politicians favor them (or say they do); environmentalists alternately promote and denounce them; and members of the general public hope the criteria will protect the environment but not adversely affect their own jobs or lifestyles.

Is all this activity achieving its objective of improving environmental quality? Are we sure what the objective is? The author believes that the answer to both these questions is a clear "no." The purpose of this article is to explain this position, to suggest possible remedies, and to urge their immediate implementation. Subtopics of this article are: Criteria vs guidelines; Endpoints; Ecosystem health; Reality vs perception; A line between good or bad; Prediction vs reaction; What do we want to protect and; Numbers do not ensure quality.

87.**Chapman, P.** 1992. Ecosystem health synthesis: Can we get there from here? J. Aquat. Ecosyst. Health 1:69-79.

This paper provides a synthesis of the presentations made by participants at the International Symposium on Aquatic Ecosystem Health (July 23-26, 1990, Waterloo, Ontario, Canada). A working definition of the ecosystem concept and a framework for defining ecosystem health are proposed, based on both "hard" and "soft" science. Assessment of ecosystem health can be approached either from the bottom up (reductionist approach) or from the top down (holistic approach). The Symposium clearly followed the former approach; present approaches to science and management are also generally reductionist. It is argued that realistic solutions require primarily holistic approaches; such are often claimed but rarely attained. Reductionist approaches are useful for diagnosis and prediction (i.e. warning of potential problems), provided that they are based on appropriate statistical, biological, and societal levels of significance.

Key Words: Ecosystem health, Environmental quality, Environmental assessment, Indicators

88.**Chapman, P., R. Dexter, and L. Goldstein.** 1987. Development of monitoring programmes to assess the long-term health of aquatic ecosystems: A model from Puget Sound, USA. Mar. Pollut. Bull. 18(1):521-527.

Monitoring consists of repetitive data collection for the purpose of determining trends in certain parameters. The term has been used (and misused) in an environmental context; often the final recommendations of short-term environmental studies suggest that monitoring should be done. The purpose of the present paper is to describe a holistic approach to environmental monitoring developed for Puget Sound, which the authors believe to be broadly applicable to all nearshore marine environments in development, purpose, and application. As such, this paper provides specific information complementary to previous recent discussions on data acquisition and general program design for marine pollution monitoring.

89.**Chapman, P., E.A. Power, and G.A. Burton, Jr.** 1992. Integrative assessment in aquatic ecosystems. Pages 313-340. In: G.A. Burton, Jr., ed. Sediment Toxicity Assessment. Lewis Publishers, Inc., Boca Raton, FL.

Integrative assessments are defined as investigations involving attempts to integrate measures of environmental quality to make an overall assessment of the status of the system. The measures can include two or more of the following components: sediment toxicity tests, sediment chemical analyses, tissue chemical analyses, pathological studies, and community structure studies. The purpose of such investigations is to determine environmental quality; such may be defined in terms of relative and/or current status, but particularly related to ecosystem health. Specifically, integrative assessments involve more than one generic measure of environmental quality.

This book chapter is not a comprehensive review of all possible integrative assessments. Rather, this chapter describes the conceptual basis for integrative assessments and provides selected specific, recent examples of an integrative concept and an application of that concept.

90.**Clarke, R.** 1986. The Handbook of Ecological Monitoring. A GEMS/UNEP publication. Clarendon Press, Oxford, England.

This book contains the following sections and subsections:

1. Habitat Monitoring Theory: what is ecological monitoring, the uses of ecological monitoring, the history of ecological monitoring, ecological monitoring in practice, the costs of ecological monitoring, developing an ecological monitoring program, and towards a global system;
2. Ground Monitoring: climate measurements, soil mapping and interpretation, landform classification, soil erosion and sediment yields, vegetation monitoring, large mammal herbivores, nutrition and population dynamics, and social and economic surveys;
3. Aerial Monitoring: the use of light aircraft, operational procedures for aerial surveys and monitoring, selection of data variables, survey planning, piloting and navigation, the front-seat observer records, the rear-seat observations, 35-mm vertical sample photography, the aerial survey data base, and the control of bias;

4. Remote Sensing: Principles of remote sensing, photographic sensors and application, imaging with nonphotographic sensors, multispectral scanners, active microwave systems, space systems useful for ecological monitoring, meteorological satellites, and manned satellites;
5. GRID — A Tool for Environmental Management: national, regional, and global environmental data; utility of existing environmental data; toward a global data base for the environment; and the future of environmental data management.

91.**Cocklin, C., S. Parker, and J. Hay.** 1992. Notes on cumulative environmental change I: Concepts and issues. J. Environ. Manage. 35:31-49.

Environmental impact assessment, as it has been practiced generally, is limited in several ways. Two characteristics are cause for particular concern. The first is that it is a reactive process, rather than representing a proactive approach to environmental management. The second is that the project–based approach often means that the combined effects of two or more developments are often overlooked. Concepts developed under the heading of cumulative environmental change present some clues to the appropriate reform of impact assessment, particularly with respect to these two failings. An analysis of the concept is presented here and the authors discuss also some general issues that arise in respect to the assessment of cumulative environmental change. The latter include boundary issues, ecological response characteristics, monitoring, socio–economic effects and issues in evaluation. A consideration of the institutional context for the management of cumulative change leads us to propose a regional approach, as opposed to project based assessments. Links between cumulative effects assessment, state–of–the–environment reporting and planning of sustainability are explored.

Key Words: Cumulative environmental change, Cumulative effects assessment, Environmental impact assessment, Environmental planning, Environmental monitoring

92.**Colborn, T.E., A. Davidson, S.N. Green, R.A. Hodge, C.I.Jackson, and R.A. Liroff.** 1990. Great Lakes, Great Legacy? Conservation Foundation/Institute for Research on Public Policy, Washington, DC and Ottawa, ON.

Within this book, the following indicators are presented to assess the status of the Great Lakes: air quality, surface water quality, contaminated sediments, groundwater, body burdens of toxics, population status, habitat, fisheries, forests, wetlands, soil erosion, agricultural productivity, shorelines, human health, and economic conditions.

93.**Connell, J., and W. Sousa.** 1983. On the evidence needed to judge ecological stability or persistence. Am. Nat. 121:789-824.

"The balance of nature has been a background assumption in natural history since antiquity." This continues to be true today; some modern field ecologists, assuming that natural ecosystems are stable, have applied ideas of mathematical stability theory to the actual communities they are studying. The authors believe that, before one applies such theory to a natural population or community, one should first decide whether or not it is stable. Their aim is to describe the sorts of evidence needed to obtain from natural populations or communities to decide whether they are stable or persistent, as defined in this article. One aspect that is stressed in particular is whether any given real community exists in multiple stable states in different places at the same time or in the same place at different times.

94.**Conservation Foundation.** 1987. State of the Environment: A View Towards the Nineties. Conservation Foundation, Washington, DC.

95.**Cormack, R., and J. Ord.** 1979. Spatial and Temporal Analysis in Ecology. Statistical Ecology Series. International Co-operative Publishing House, Burtonsville, MD.

This book contains sections on time-series and spatial patterns in ecology and statistical methods for spatial point patterns in ecology.

96.**Costanza, R., B. Haskell, and B. Norton, eds.** 1992. Ecosystem Health: New Goals for Environmental Management. Island Press, Covelo, California.

The introduction to this book covers what ecosystem health is and why we need to worry about it. The book is divided into two sections: Philosophy and ethics, and Science and policy. Topics such as the following are covered: Problems of scale and context, Ecosystem health and ecological theories, and The operational definition of ecological health.

97.**Costanza, R.** 1992. Ecological economic issues and considerations in indicator development, selection, and use: Toward an operational definition of system health. Pages 1491-1502. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

98.**Couillard, D., and Y. Lefebvre.** 1985. Analysis of water quality indices. J. Environ. Manage. 21: 161-179.

To facilitate communication on water quality among professionals of this resource, several summarizing tools, or water quality indices, were developed. Because of the general features of these indices are little known, this article instructs the reader regarding the main components of the indices and the intrinsic characteristics of the operational process. Also included is a list of 20 indices described by category, goals, methodology, applicability, and notes.

Key Words: Index, Water quality index, Water pollution, Water quality, Environmental impact, Environmental evaluation, Environmental management, Pollution control

99.**Courtemanch, D.L.** 1991. EMAP: Considerations for its design and use. Lake Line 11(4):14-17.

This article provides a background to EMAP and asks the question "Will EMAP in its present form be adequate to address its needs and how will EMAP interface with other status and trends work?" The author does not believe some concerns have yet been adequately resolved by the U.S. Environmental Protection Agency. Until these issues are resolved, the author believes that the design and implementation of this new status and trends program can only be tentative and that, specifically, additional considerations must be made before support of the lakes pilot program is justified. The author focuses on the Northeast Lakes Pilot Project of the surface water component.

100.**Cousins, S.** 1991. Species diversity measurement — choosing the right index. Trends Ecol. Evol. 6(6):190-192.

Species are, by definition, different from each other. This fact favors ranking rather than additive indices. In addition, new methods show how the degree of difference between species can be included in an index. The functional aspect of species diversity is strengthened by incorporating other differences between species (such as body size, or whether predator or parasite) as a component of diversity. The choice of index and measurement of diversity are influenced by these developments.

101.**Cowell, E.** 1978. Ecological monitoring as a tool in industry. Ocean Manage. 4:273-285.

102.**Cowling, E.B.** 1992. Challenges at the interface between ecological and environmental monitoring: Imperatives for research and public policy. Pages 1461-1482. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Ft. Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Human activities of many sorts are changing the chemical, physical, biological, and social environment of every nation of the world. Some of these changes are beneficial for human health and welfare and for the stability of ecosystems on which the quality of human life depends. However, many others are having either short-term or long-term adverse effects on human health or on the purity of our air and water, the quality of our lakes and streams, the cleanliness of our oceans, the productivity of our wetlands and estuaries, the health and productivity of our forests and croplands, the quality of scenic vistas in our national parks, the quiet and solitude of our wilderness, the safety of our food supplies, and our personal sense of well-being.

The monitoring of changes in human health and in the health, productivity, genetic composition, and stability of ecosystems requires a long-term commitment and awareness of the natural dynamics of human populations and of both the structure and function of ecosystems. The monitoring of changes in the quality of the environment also requires a long-term commitment and substantial understanding of the chemical, physical, and biological processes that take place in the air, surface waters, groundwaters, soils, and the geological substrata of the earth.

Research is the key to the improved understanding of human health, the structure and functions of ecosystems, and both natural and anthropogenic changes in environmental quality. Continuing investments in research by governmental, industrial, and public-interest organizations will be necessary if future monitoring systems are to become more rationally based, cost-effective, and trustworthy indicators of future changes in environmental quality. This research should include efforts to develop more effective monitoring systems and to discover better ways to implement and sustain existing monitoring programs. It should also involve studies on the use of monitoring data in environmental decision making.

Some suggestions for research on ecological and environmental monitoring and its importance in public decision making are presented using lessons learned from the National Atmospheric Deposition Program (NADP), the National Acid Precipitation Assessment Program (NAPAP), and the Environmental Monitoring and Assessment Program (EMAP).

103.**Crawford, T.J.** 1991. The calculation of index numbers from wildlife monitoring. Pages 225-248 In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

Economic health is sometimes described by using various indices; recently, there has been interest in assessing the state of the environment through such indices. This chapter describes the construction of indices from wildlife monitoring data and some of the problems peculiar to these types of biological data that are not shared by economic data.

104.**Crawley, M.** 1990. The responses of terrestrial ecosystems to global climate change. Pages 141-164. In: G. Macdonald and L. Sertorio, eds. Global Climate and Ecosystem Change. [Series: NATO Advanced Science Institute Series, Series B, Physics 240 (1990)]. Plenum Publishing Corporation, New York.

105.**Crenna, C.D.** 1991. Working towards an environmental information statement: Summary paper. Environmental Information for the Twenty-First Century: International Forum held in Montreal, Quebec. NTIS No. MIC-91-06693/HDM (Available through National Technical Information Service, Springfield, VA). Environment Canada, Ottawa. 28 pp.

In 1989, the Group of Seven (G7) summit leaders agreed on the importance of environmental information and requested that the Organization for Economic Co-operation and Development examine how selected environmental indicators could be developed to improve the integration of environmental and economic decision making and measure progress towards sustainable development. At the 1990 G7 Summit, the Prime Minister of Canada proposed that environmental information be improved on a worldwide basis and announced that Canada would organize the International Forum on Environmental Information for the Twenty-first Century. This summary paper identifies the key issues from the four theme papers and suggests a framework that could be used to guide discussion in the workshops and lead to the development and adoption by the forum of a statement of common conclusions and recommendations for the future.

106.**Crispin, S.** 1991. Using Natural Heritage data to monitor Great Lakes ecosystem health. Endang. Spec. Update 8(5-6):1-4.

The Natural Heritage Data Centers have collected data on hundreds of rare species and natural communities in the Great Lakes Basin. These data can be utilized to identify a set of population- and community-level biological indicators of the change in ecosystem health related to water quality. The Nature Conservancy has developed broad categories for identifying the potential of rare species and natural community elements as indicators of water quality and ecosystem health: fish-eating animals feeding from Great Lakes waters; animals living or feeding from wetlands in the Great Lakes Basin; upland communities dependent on major Great lakes ecosystem processes not related to water quality and; species not directly related to aquatic ecosystems of the Basin. The data system already serves on a state-by-state basis for the environmental review process, endangered species protection, and natural area management.

107.**Croonquist, M., and R, Brooks.** 1991. Use of avian and mammalian guilds as indicators of cumulative impacts in riparian wetland areas. Environ. Manage. 15(5):701-714.

A new method of assessing cumulative impacts of human activities on bird and mammal communities of riparian-wetland areas was developed by using response guilds to reflect how species theoretically respond to habitat disturbance on a landscape level. Using documented information for each species, all bird and mammal species of Pennsylvania were assigned values for each response guild to reflect their sensitivity to disturbances; high guild scores corresponded to low tolerance toward habitat disturbance. The authors hypothesized that, given limited time and resources, determining how wildlife communities change in response to environmental impacts can be done more efficiently with a response-guild approach than a single-species approach. To test the model, censuses of birds and mammals were conducted along wetland and riparian areas of a protected and a disturbed watershed in central Pennsylvania. The percentage of bird species with high response-guild scores (i.e., species that had specific habitat requirements and/or were neotropical migrants) remained relatively stable through the protected watershed. As intensity of habitat alteration increased through the disturbed watershed, percentage of bird species with high response-guild scores decreased. Only 2 to 3% of the neotropical migrants that had specific habitat requirements were breeding residents in disturbed habitats compared to 17%-20% in reference areas. Species in the edge and exotic guild classifications (low guild scores) were found in greater percentages in the disturbed watershed. Composition of mammalian guilds showed no consistent pattern associated with habitat disturbance. Avian response guilds reflected habitat disturbance more predictively than did mammalian response guilds.

Key Words: Guilds, Wetlands, Cumulative impacts, Birds, Mammals, Environmental assessment, Riparian-watershed restoration

108.**Cullen, P.** 1990. Biomonitoring and environmental management. Environ. Monitor. Assess. 14:107-114.
The advantages of biological monitoring of the environment have been long recognized. Direct measurements of biota of importance rather than chemical surrogates, integration of monitoring over time and measurement of subtle changes brought about by minor or intermittent pollution have all been propounded as advantages.

There appear to be a variety of barriers to the wider adoption of biomonitoring approaches: the perception that biomonitoring takes longer and is more expensive than chemical monitoring, the idea that chemical measurements are an adequate surrogate for direct measurement of biological change, and the belief that interpretation of biological data is complex and uncertain compared with chemical data. These widely held myths are addressed and some broad principles to guide the development of biomonitoring programs are developed.

109.**Dale, V., R. Franklin, W. Post, and R. Gardner.** 1991. Sampling ecological information: Choice of sample size. Ecol. Modell. 57:1-10.

It is necessary to identify factors that significantly affect sample statistics obtained from ecological measurements. The authors used a computer simulation to examine the effects of sample size on the mean and variance for four frequency distributions of the attribute of interest. The kurtosis of the underlying distribution affects fluctuations in the sample mean as the number of samples increases.

For large sample sizes, the sample mean of the log normal distribution is less than the population mean because of the skewness of that distribution. The standard error-to-mean ratio, kurtosis, and skewness can be used as guides to suggest the appropriate number of samples to adequately characterize the true distribution.

110.**Danks, H.V.** 1992. Arctic insects as indicators of environmental change. Arctic 45(2):159-166.

The great diversity of terrestrial arthropods in the Arctic suggests that these organisms are especially useful in monitoring environmental change there, where warming as a result of climatic change is expected to be especially pronounced and where current conditions are limiting for many organisms. Based on existing information about Arctic faunas and how they differ from temperate faunas, this paper suggests several elements, including ratios and other quantitative indices, that can be used for long-term evaluations of change. These elements include composition indices, range limits, marker species, interspecific ratios, relationship shifts, phenological and physiological indicators, and key sites. Using such elements in a planned way would exploit the diversity of Arctic insects and emphasize their importance in arctic systems.

Key Words: Polar Bear pass, Bathurst Island, Life history, Northwest Territories, Vegetation

111.**Davey, G.** 1980. The use of biological parameters for the assessment of water quality — A literature review. Publication 99. Environmental Protection Agency (Australia), Melbourne, Australia.

112.**Day, K.** 1990. Rapporteur's report of work group: Indicators at the species and biochemical level. Environ. Monitor. Assess. 15:277-279.

This article summarizes ideas from a conference workgroup that began with two main objectives: (1) to develop criteria for indicators (generic) and (2) to propose a list of species level indicators. The workgroup distinguished predictive from descriptive factors including effect from cause, effect from effect and cause from effect. It also looked at the nature of stress, the importance of species, environments — managed or unmanaged, and locations. The group felt that it had achieved the first objective, but did not get very far with the second objective, the list of "key" species.

113.**Debinski, D., and P. Brussard.** 1992. Biodiversity assessment and monitoring procedure in Glacier National Park. Pages 393-409. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

One way in which the status of an ecosystem may be assessed is to document changes in its biodiversity over time. Because biodiversity can be defined at the level of species, habitats, or genes, temporal changes can be assessed at three very different levels. These changes may indicate responses to natural disturbances, human-induced changes, or long-term environmental trends.

Thus, the immediate goals of this project were to (1) choose appropriate "indicator taxa" or "indicator groups" that could be inventoried and monitored and serve as indices of the state of the overall biological diversity in Glacier, (2) establish an appropriate sampling regime and methodology, and (3) evaluate various analytical techniques for dealing with the data base. The ultimate goal is to be able to track patterns of changing distribution and abundance in several indicator taxa well into the future.

114.**de Haes, H., M. Nip, and F. Klijn.** 1991. Towards sustainability: Indicators of environmental quality. Pages 89-105. In: O. Kuik and H. Verbruggen, eds. In Search of Indicators of Sustainable Development. Kluwer Academic Publishers, Dordrecht, The Netherlands.

This chapter presents a method for assessing environmental quality. Subsections include: Ecosystem approach and environmental quality assessment; The choice of areas; Multifunctional area and environmental quality requirements; Determining an environmental quality objective; The selection of quality parameters; Quantification and; An example assessment for the Dutch Lowland Peat area.

115.**de Kruijf, H.** 1991. Extrapolation through hierarchical levels. Compar. Biochem. Physiol. 100C(1/2):291-299.

The translation of results from low hierarchical levels to higher levels meets with difficulties with respect to temporal, spatial, and organizational scales. In addition, the translation of stress effects through hierarchical levels has not yet been possible, thus hampering ecological risk assessment. Three approaches to link the various levels are described: the energetics, endpoint and minimal structure. A concept to integrate these approaches to enable extrapolation of stress effects across hierarchical levels is described.

116.**Dennis, B., and G. Patil.** 1979. The sensitivity of ecological diversity indices to the presence of pollutants in aquatic communities. Pages 379-413. In: J. Cairns, G. Patil, and W. Waters, eds. Environmental Biomonitoring, Assessment, Prediction, and Management — Certain Case Studies and Related Quantitative Issues. International Co-operative Publishing House, Fairland, MD.

The authors examine the sensitivity of species diversity indices of aquatic communities to changes in water temperature and nutrient concentration. They adopt the "average rarity" definition of diversity proposed by Patil and Taillie. Their diversity index family (delta beta) is found to be a weighted average of species richness and evenness, and beta is shown to be a measure of the weight that is attached to evenness. Weak relationships between diversity and temperature or nutrient concentration are detected through regression analysis of a variety of data sets from many different locales. However, the direction and magnitude of such relationships differs between locales, and little of the variability in community diversity is accounted for by temperature and nutrients in these data. They conclude that diversity indices might be useful for signaling that unknown ecological changes are taking place at given sites but that these indices are not substitutes for detailed biological investigation.

117.**Depietri, D.E.** 1992. The search for ecological indicators — Is it possible to biomonitor forest system degradation caused by cattle ranching activities in Argentina. Vegetatio 101(2):109-121.

Cattle ranching is a typical disturbance factor in the North Patagonian forests. The selection of modal areas having similar natural environmental conditions enabled the analysis of the response of the system to exploitation. Different structural parameters in the vegetal community were studied and secondary data on fire frequency and livestock censuses were compiled. An area gradient showing different degrees of degradation was defined, which was presumed to show the stages an area goes through when under livestock farming. Three ecological indicators were defined: key species, as indicators of the occurrence of a degradation process; vegetal cover, as an indicator of the stage a degradation process is going through; and vegetal biovolume, as an indicator of when the degradation process has become critical. These indicators must be used together in order to obtain a good diagnosis of the state of the area under exploitation.

118.**Diaz. R.J.** 1992. Ecosystem assessment using estuarine and marine benthic community structure. Pages 67-85. In: G.A. Burton, Jr., ed. Sediment Toxicity Assessment. Lewis Publishers, Inc., Boca Raton, Fla.

This chapter is an introduction to the use of benthic community structure as a means of assessing ecosystem response to contaminated sediments is estuarine and marine ecosystems. Since contaminants that enter estuarine and marine ecosystems eventually bind to sediment particles and are deposited on the bottom, emphasis on benthic organisms as a primary means of assessing ecosystem response is warranted. Of particular importance are the macrobenthic invertebrates because of their basic longevity, sedentary life styles, proximity to sediments, influence on sedimentary processes, and trophic importance.

119.**Dixit, S.S., J.P. Smol, J.C. Kingston, and D.F. Charles.** 1992. Diatoms: Powerful indicators of environmental change. Environ. Sci. Technol. 26(1):23-33.

Diatoms are being used increasingly to assess short- and long-term environmental change because they are informative, versatile, flexible, and powerful ecological indicators. Diatoms respond rapidly to

changes in many ecological characteristics. Assemblages are usually diverse and therefore contain considerable ecological information. For this reason and because it is easy to obtain large numbers of individuals, robust statistical and multivariate procedures can be used to analyze assemblage data.

The article begins by describing the kinds of questions regarding ecosystem condition assessment that are increasingly being asked. The article is an overview of how diatoms can be used in monitoring environmental change.

120.**Dixon, D., P. Hodson, J. Klaverkamp, K. Lloyd, and J. Roberts.** 1985. The role of biochemical indicators in the assessment of ecosystem health—their development and validation. Associate Committee on Scientific Criteria for Environmental Quality, Publication No. NRCC 24371. National Research Council of Canada, Ottawa.

121.**Doberski, D., and I. Brodie.** 1991. Long-term ecological monitoring in schools and colleges. J. Biol. Ed. 25(2):123-128.

122.**Doving, K.B.** 1991. Assessment of animal behaviour as a method to indicate environmental toxicity. Comp. Biochem. Physiol. 100C(1/2):247-252.

This review focuses on the effects of toxic agents on fish behavior in particular. Special attention will be devoted to the role of chemosensory systems because (1) these systems are directly exposed to the environment; (2) they mediate a large part of the behavioral repertoire; (3) they are developed early in life, and in some fishes the olfactory organ is developed before the mouth opens; and (4) the receptor cells in these organs show a remarkably rapid and unspecific uptake both of stimulants and toxicants. The author evaluates the methods and the results of the various methods used in behavioral toxicology with respect to advantages and disadvantages and considers the feasibility of the methods.

123.**Draggan, S., J. Cohrssen, and R. Morrison.** 1990. Environmental Monitoring, Assessment and Management — The Agenda for Long-term Research and Development. Praeger, New York. 176 pp.

This book originates from an expert panel meeting on monitoring, assessment, and environmental management. It covers issues surrounding long-term environmental research and recommends research needs relating to such areas as environmental change, the dynamics of stressed ecosystems, ecological markers, biological indicators of ecological health, and ecosystem level studies.

124.**Dubey, P.** 1991. Biomonitoring the environment — Theory, practice and problems. J. Environ. Biol. 12(SI):233-241.

125.**Dumar, K.** 1989. Indicators for measuring changes in income, food availability and consumption, and the natural resource base. AID Program Design and Evaluation Methodology-12, AID-PN-AAX-223. NTIS No. PB90-261975/HDM. Center for Development Information and Evaluation, Agency for International Development, Washington, DC. 42 pp.

This report documents the findings of a workshop held in 1988 to identify a set of simple, practical indicators for monitoring the impact of the Agency for International Development's (AID's) agricultural and rural assistance program. Three groups of indicators are discussed: (1) indicators to measure income change (e.g., macro-level indicators such as Gross National Product, Gross Domestic Product and microlevel indicators such as household income and expenditures, and indicators of intrahousehold income distribution); (2) indicators to measure changes in food consumption (e.g., per capita calorie intake, food expenditures, and market availability and prices) and anthropomorphic indicators such as weight at birth; and (3) natural resource indicators (e.g., including indicators of topsoil erosion, crop yield, actual land use vs soil suitability, surface and groundwater pollution, and the status of rangelands, forests, and wetlands). Good indicators should provide valid measures and be reliable, sensitive to change, replicable, and based on easily accessible data; they should also be measurable quickly and cost-effectively.

126.Ecological Society of America. 1981. Symposium: Indicators of ecosystem responses to fossil fuel residuals. Annual meeting of the Ecological Society of America, 16-20 August 1980, Indiana University, Bloomington. Abstracts of presented papers. Bull. Ecol. Soc. Am. 62:90-91 and 107-108.

127.Ecology Committee. 1980. Goals and criteria for design of a biological monitoring system. Environmental Protection Agency, Science Advisory Board, Washington, DC. 53 pp.

128.Edwards, C. J., R.A. Ryder, and T.R. Marshall. 1990. Using lake trout as a surrogate of ecosystem health for oligotrophic waters of the Great Lakes. J. Great Lakes Res. 16(4):591-608.

The Great Lakes Water Quality Agreement (1978) between Canada and the United States provided for the accommodation of ecosystem objectives for the Great Lakes Basin ecosystem. Accordingly, the two parties to the agreement, under the aegis of the International Joint Commission, acted in concert to define ecosystem objectives for the Great Lakes, and to provide a vehicle for practical application of these objectives. For the oligotrophic portions of the Great Lakes, the lake trout was selected as an exemplary organism for the detection of well-being or "health" of the system. The suitability of lake trout derived from the fact that it occupied a sensitive, integrative node at the top trophic level of the system. There, in its role as a terminal predator, the lake trout acted as a major controlling factor over the remainder of the cold-water community. The lake trout, as the organism of choice, best satisfied a comprehensive set of qualifying criteria for indicator organisms. A secondary organism, *Pontoporeia hoyi*, was selected as complementary to the lake trout because it was indicative of oligotrophic system quality at another sensitive, integrative node, namely the mud-water interface of the demersal zone. To provide a practical means for management application of the lake trout as an oligotrophic ecosystem surrogate, a Dichotomous Key was devised and subsequently upgraded to a menu-driven computer based expert system. This system was designed explicitly for ecosystem managers to rapidly detect the state of health of an oligotrophic ecosystem. It focused specifically on questions dealing with the niche characteristics and habitat requirements of the lake trout. An optional printed output not only described the relative state of the system, but in addition, underlined the areas of greatest degradation and pointed out the current information needs. Preliminary testing of the Dichotomous Key on each of the Great Lakes has shown its value as a first logical and necessary step in the process of system rehabilitation.

Key Words: Fish management, Lake trout, Indicators, Bioindicators

129.Environment Canada. 1990. Environmental indicators: Opinions of potential users. Technical Report Series No. 117. Performed under contract by Western Environmental and Social Trends, Ottawa. NTIS No. MIC-91-02035/HDM. Available from National Technical Information Service, Springfield, VA. Sponsored by Canadian Wildlife Service, Strategies and Scientific Methods Branch, and Sustainable Development Branch; and Environment Canada, Corporate Policy Group. Environment Canada, Ottawa, Ontario. 86 pp.

This qualitative study asked opinion leaders familiar with environmental matters across Canada for their views on environmental indicators developed to provide Canadians with a better understanding of environmental conditions and trends within the context of sustainable development. The methodology, results, and analysis of the opinion research are summarized.

130.Environment Canada. 1991. Report on Canada's progress towards a national set of environmental indicators: State of the Environment Report Series no. SOE 91-1. State of the Environment Reporting SSC-EN1-11/91-1E; ISBN-0-662-18394-0. Environment Canada (Indicators Task Force), Ottawa, Ontario. 108 pp.

Environmental indicators, like economic indicators, are important tools for translating quantities of data into succinct information that can be readily understood and used by decision makers and the general public. The Organization for Economic Cooperation and Development (OECD) has taken the first step in leading an international initiative to develop a series of indicators, and Canada is beginning to work on developing a similar series. This report presents a brief overview of efforts now under way to

develop consistent, reliable indicators to measure the quality of our environment, the stresses placed on it, and the steps taken to prevent or reduce those stresses.

Forty-three indicators in 18 issue areas are presented in the annex of this report.

131.**Environmental Protection Agency.** 1987. Unfinished business: A comparative assessment of environmental problems. U.S. Environmental Protection Agency, Office of Policy Analysis and Office of Policy, Planning, and Evaluation. Washington, DC.

132.**Environmental Protection Agency.** 1988. Future risk: Research strategies for the 1990's. SAB-EC-88-048. U.S. Environmental Protection Agency, Science Advisory Board, Washington, DC.

133.**Environmental Protection Agency.** 1990. Region 10 environmental indicators: FY 89 report. EPA/910/9-90/018. U.S. Environmental Protection Agency, Seattle, WA. 182 pp.

This is EPA Region 10's third annual summary of environmental indicators for air, water, and land media. The Region's programs in air, water, toxics, pesticides, and hazardous waste are attempting to characterize their progress in addressing environmental degradation via the measures described in the report. The FY 89 report builds on the FY 88 document with the addition of (1) FY 89 data; (2) new measures and deletions; and (3) new programmatic areas in which indicators have been developed, including underground injection control (UIC), accidental releases, and terrestrial environments. Each chapter includes an introduction providing pertinent background information for each environmental indicator.

134.**ESSA (Environmental Social Systems Analysts, Ltd.).** 1982. Review and evaluation of adaptive environmental assessment and management. EN 21-36/1983E. Environment Canada, Ottawa.

135.**Evans, D.O., G.J. Warren, and V.W. Cairns.** 1990. Assessment and management of fish community health in the Great Lakes: Synthesis and recommendations. J. Great Lakes Res. 16(4):639-669.

A conceptual framework for evaluating the effects of toxic contaminants on fish communities in the Great Lakes includes general ecosystem principles that define the hierarchical structure, homeostatic mechanisms, and general stress syndromes as well as the effects of anthropogenic stressors at various levels in the ecosystem. The large number of influences on ecosystem behavior has obscured direct relationships between stressors and system reactions. A broad assessment of ecosystem health in the Great Lakes should incorporate field-oriented studies, toxicological data, and knowledge about human interactions with the environment.

136.**Eyles, J.** 1990. Objectifying the subjective: The measurement of environmental quality. Social Indicat. Res. 2:139-153.

The paper begins by examining the nature and measurement of environmental quality (EQ) pointing to the tensions between insider and outsider accounts and lay and expert perceptions. Lay accounts are seen as particularly crucial in residential environments and quality of life (QoL) research into these fields is assessed. But QoL and EQ are seen as closely related phenomena. While there are exist important concepts and approaches (e.g., relating to the nature of places and the significance of contextual data), it is argued that ethnographic investigations and the theory of structuration may help reconcile the tensions and that all approaches will lead to better interpretation, understanding and explanation of the nature of the subjective world.

137.**Fairweather, P.** 1991. Statistical power and design requirements for environmental monitoring. Aust. J. Mar. Freshwater Res. 42(5):555-567.

This paper discusses, from a philosophical perspective, the reasons for considering the power of any statistical test used in environmental biomonitoring. Power is inversely related to the probability of making a Type II error (i.e., low power indicates a high probability of Type II error). In the context of

environmental monitoring, a Type II error is made when it is concluded that no environmental impact has occurred, even though one has. Type II errors have been ignored relative to Type I errors (the mistake of concluding that there is an impact when one has not occurred), the rates of which are stipulated by the *a* values of the test. In contrast, power depends on the value of alpha, the sample size used in the test, the effect size to be detected, and the variability inherent in the data. Although power ideas have been known for years, only recently have these issues attracted the attention of ecologists and methods been available for calculating power easily.

By understanding statistical power, researchers are able to improve to improve environmental monitoring and to inform decisions about actions arising from monitoring in three ways. First, it allows the most sensitive tests to be chosen from among those applicable to the data. Second, preliminary power analysis can be used to indicate the sample sizes necessary to detect an environmental change. Third, power analysis should be used after any nonsignificant result is obtained to judge whether the result can be interpreted with confidence or the test was too weak to examine the null hypothesis properly. Power procedures are concerned with the statistical significance of tests of the null hypothesis, and they lend little insight, on their own, into the workings of nature. Power analyses are, however, essential to designing sensitive tests and correctly interpreting their results. The biological or environmental significance of any result, including whether the impact is beneficial or harmful, is a separate issue.

The most compelling reason for considering power is that Type II errors can be more costly than Type I errors for environmental management. This is because the commitment of time, energy, and people to fighting a false alarm (a Type I error) may continue only in the short term until the mistake is discovered. In contrast, the cost of not doing something when in fact it should be done (a Type II error) will have both short- and long-term costs (e.g., ensuing environmental degradation and the eventual cost of its rectification). Low power can be disastrous for environmental monitoring programs.

138.**Feder, A., and W. Manning.** 1979. Living plants as indicators and monitors. Pages 1-14. In: W. Heck, S. Krupa, and S. Linzon, eds. Handbook for the Assessment of Air Pollution Effects on Vegetation. Air Pollution Control Association, Pittsburgh, PA.

139.**Finn, J.** 1976. Measures of ecosystem structure and function derived from analysis of flows. J. Theor. Biol. 56:363-380.

Several measures of ecosystem structure and function are derived from the application of economic input-output analysis to ecosystem compartment models. Total system throughflow (TST) is defined as the sum of all compartmental throughflows. Average path length of the i-th inflow (APL-1) is defined as the average number of compartments through which the i-th inflow passes. Average path length for an average inflow (APL) is the mean of APL-1 weighted according to the size of the inflows. APL is shown to be equal to TST divided by the sum of all inflows. TST can be partitioned into a portion resulting from cycled flow (TST-c) and a portion resulting from low straight through the system (straight throughflow TST-s). The portion of APL from cycled flow divided by the portion from straight throughflow is the cycling index (CI). This index indicates how many times further than the straight throughflow path length an average system inflow will travel because of cycling. Three simple ecosystem models are examined to demonstrate the usefulness of these measures in explaining ecological phenomena.

140.**Forster, E., M. Matthies, L. Peichl, and W. Mucke.** 1991. A Meta database of environmental monitoring programmes — concept and evaluation. Toxicol. Environ. Chem. 30(1-2):101-107.

Eighty-one environmental monitoring programs have been randomly selected and stored in a meta database. The programs were compared by their concept, sample and site description, sample treatment, analytical methods, and information exchange. The data fields are based on a detailed questionnaire, which is oriented to the guidelines for specimen banking. The programs were classified on the basis of the main environmental compartments considered: air, soil, water, and biota. Most include the measurement of pollutants in one or more media, and some include measurements of biological or physical effects. Program comparison was difficult because of the differences in concept, site descriptions, sample treatments, and analytical methods. Based on this study, a harmonization of long-term monitoring programs, conducted by the state governments of Germany, should be undertaken.

Key Words: Environmental monitoring programs, Meta database

141.**Fox, D., J. Bernabo, and B. Hood.** 1987. Guidelines for measuring the physical, chemical, and biological condition of wilderness areas. General Technical Report RM-146. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

This report presents appropriate scientific protocols to measure current conditions of air quality related values (AQRVs) in wilderness areas. These protocols are intended to be guidelines for quantifying the existing status of AQRVs, monitoring for changes from these existing conditions, and subsequently, evaluating whether the changes are naturally occurring or the result of human-caused air pollution/chemical deposition. Measurements taken to monitor condition are divided into several categories: atmospheric environment, soils and geology (including aquatic chemistry), and vegetation. When a specific pollutant is not identified or for such concerns as acid deposition that may cause ecosystem-level effects, basic and long-term monitoring is recommended.

142.**Franz, E.H.** 1981. A general formulation of stress phenomena in ecological systems. Pages 49-54. In: G. W. Barrett and R. Rosenberg, eds. Stress Effects on Natural Ecosystems. John Wiley & Sons, Chichester.

The concept of stress was new to the lexicon of biomedical and social sciences in the first half of the twentieth century. With antecedent usages in middle English and physics, Sir William Osler identified stress and strain as basic factors in angina pectoris—a relationship which he attributed to hard work and worry! In physics, these terms had been given precise definitions according to Hooke's law of elasticity. The law relates the deformation of metals to the load producing it; stress is the independent variable or cause, and strain is the dependent variable or effect.

Routine inspection of the contemporary literature in ecology suggests that stress phenomena are of increasing interest. It also reveals that ecologists subscribe to several formulations of the stress concept and to different definitions of the term. The fundamentals of some traditional approaches are reviewed, concluding with the introduction of a general formulation for ecological systems.

143.**Freedman, B.** 1989. Environmental Ecology: The Impacts of Pollution and Other Stresses on Ecosystem Structure and Function. Academic Press, San Diego, CA.

The central focus of this book is on the ecological impacts of anthropogenic stresses. Besides the introductory chapter, there are eleven others: Air pollution; Toxic elements; Acidification; Forest decline; Oil pollution; Eutrophication of freshwater; Pesticides; Harvesting of forests; Loss of species richness; Ecological effects of warfare and; Effects of stress on ecosystem structure and function. A bibliography containing over 1500 references and an index organized by biological, chemical, geographical, and subject categories are also included.

144.**Freedman, B.** 1992. Environmental stress and the management of ecological reserves. Pages 303-308. In: J. Willison, S. Bondrup-Nielsen, C. Drysdale, T. Herman, N. Munro, and T. Pollock, eds. Science and the Management of Protected Areas. Elsevier, Amsterdam.

Ecological reserves are established for the conservation of valued ecological heritage, which could include rare and endangered species and their habitat, endangered ecosystems, or typical representatives of widespread natural ecosystems. However, ecological reserves are continuously subjected to natural and anthropogenic stresses of multifarious types and intensities, and in the face of such stress change is inevitable. Consequently, ecological heritage cannot be protected by simple–minded management such as the delineation of reserve boundaries, or the prohibition of harvesting of biological or other natural resources. The appropriate management of protected areas must also include a close, adaptive attention to the likely ecological response to changes in environmental stresses that will occur naturally or, more likely, as a result of an increasing intensity of human activities.

145.**Freytag, G.** 1978. The significance of amphibia and other lower invertebrates as indicators for changes in ecosystems: Observations at Lake Balaton, Hungary. (In German). Salamandra 14(4):203-206.

Observations for 20 years on amphibians and other lower invertebrates of the Tihany Peninsula (Lake Balaton, Hungary) reveal a remarkably close correlation with different methods of mosquito control and with mass tourism.

146.**Friedel, M.** 1991. Range condition assessment and the concept of thresholds: A viewpoint. J. Range Manage. 44(5):422-426.

Dissatisfaction persists with current approaches to range condition and trend assessment. Sometimes assessed condition does not truly represent the past or the potential of range. One of the likely causes is a failure to re-examine and change, if necessary, the theoretical basis of assessment, in line with developing understanding of ecological processes. The concept of thresholds of environmental change appears to provide a reasonable alternative in some circumstances to the concepts of gradual retrogression and secondary succession that are currently accepted. The author suggests that environmental change can be discontinuous, with thresholds occurring between alternative states. Once a threshold is crossed to a more degraded state, the former state cannot be attained without significant management effort, such as prescribed burning, ploughing, or herbicide application, rather than by simple grazing control. Examination of data from extensive monitoring programs and from a study of grazing impact, as well as more general sources of information, indicates that thresholds of change may be identifiable in arid rangelands. A practical means of monitoring proximity to thresholds is available and, with the aid of multivariate analysis, the effects of spatial variability and season can be separated from those of management. The potential of this approach deserves investigation in a wider variety of environments.

Key Words: Succession, Site potential, Ordination, Classification, Trend

147.**Friend, A.** 1988. Federal government databases relevant for environmental risk management. Pages 63-89. In: C. Fowle, A. Grima, and R. Munn, eds. Information Needs for Risk Management. University of Toronto, Toronto.

148.**Fritz, J.** 1990. A Survey of Environmental Monitoring and Information Management Programmes of International Organizations. United Nations Environment Program (UNEP), Global Environmental Monitoring System. Harmonization of Environmental Measurement (HEM) Office, Munich, Hartmut Keune, Director. UNEP HEM, Munich.

This report provides a summary of international environmental monitoring programs, including EMAP. The three core sections of the report are: (1) monitoring and research programs, which describes the activities of 45 programs; (2) data and information systems programs, which describes 21 programs devoted to data integration; and (3) harmonization programs, which summarizes the activities of 12 organizations involved in developing standards and harmonization information. Information provided for monitoring programs includes type of program, geographic area of implementation, program objectives, data management, and cooperation with other national or international agencies.

149.**Frost, T.M., S.R. Carpenter, T.K. Kratz, and J. Magnuson.** 1992. Choosing ecological indicators of condition: Effect of taxonomic aggregation on sensitivity to stress and natural variability. Pages 215-228. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

To assess overall ecosystem condition, it is necessary to choose indicators of environmental stress that incorporate two basic, and potentially contradictory, properties. Ecological indicators should be sensitive to the variety of anthropogenic stresses that could occur. At the same time, such indicators must be reasonably predictable in unperturbed ecosystems; some natural benchmark is necessary against which to assess a deviation resulting from stress. If sensitive parameters of ecosystem condition also exhibit greater levels of unpredictable variability, the choice of ecological indicators will involve a compromise between two conflicting factors.

150.**Fuentes, E., B. Kronberg, and H. Mooney.** 1991. The west coasts of the Americas as indicators of global change. Trends Ecol. Evol. 6(7):203-204.

This "news and comment" feature discusses the issues of being able to distinguish landscape changes caused by management from those resulting from global climate change, which would require both monitoring and the development of whole-system models. The idea behind using the west coasts of North and South America as global climate change indicators is that they are similar but disjunct ecosystems in which a known variable differs. This approach has proved successful in the past in distinguishing between management- and naturally-induced landscape changes.

151.**Gelinas, R., and J. Slaats.** 1989. Selecting indicators for state of the environment reporting: Draft report. Technical Report Series No. 8. NTIS No. MIC-90-06282/HDM. Strategies for Scientific Methods Branch. Canadian Wildlife Service, Ottawa, Ontario. 28 pp.

The federal government has recently established a national state of the environment (SOE) reporting program to provide a better understanding of environmental conditions and trends to Canadians. An important step in the program is to identify which indicators will be used to represent the state of the environment. This report defines the indicators and describes the role of SOE reporting and indicators, discusses the desirable characteristics of SOE indicators, and describes current and proposed indicator research.

Keywords: Environmental monitoring, Environmental education

152.**General Accounting Office.** 1991. Wildlife management: Problems being experienced with current monitoring approach. GAO/RCED-91-123. General Accounting Office, Washington, DC. 8 pp.

The Forest Service's management indicator species approach to monitoring, as currently practiced, appears to have several practical drawbacks and can be prohibitively expensive to implement. Furthermore, Forest Service officials responsible for conducting monitoring in the field have said that even when planned data collection efforts are completed by using this monitoring approach, the data can have limited usefulness because observed population changes in the species being monitored often cannot be related to overall habitat conditions or the effects of Forest Service management actions. Forest Service headquarters officials recognize that practical problems have been experienced but believe these difficulties have stemmed more from the way that management indicator species principles were applied, rather than from fundamental weaknesses with the concept itself. The officials said they are attempting to improve their direction to field staff and believe that with revised direction many of the problems observed can be resolved.

153.**Gentile, J.H., and M.W. Slimak.** 1992. Endpoints and indicators in ecological risk assessments. Pages 1385-1399. In: D. McKenzie, D.E. Hyatt, and J. McDonald. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

The U.S. Environmental Protection Agency (EPA) is beginning to develop ecological risk assessment guidelines that will be used within EPA to conduct ecological risk assessments. This work began in early 1988 by identifying appropriate ecological endpoints of concern that can be used in assessing risk. EPA's current ecological assessments fall into four broad categories: prediction of chemical risks, prediction of project impacts, retrospective analyses of site-specific impacts, and the monitoring of ecological changes. The framework for ecological risk assessments includes the hierarchy of biological organization - from the ecosystem down to the individual organisms - and emphasizes the use of assessment endpoints (indicators) at one level and measurement assessment endpoints at another.

This framework permits both a holistic and a reductionist approach. Assessment endpoints as defined by this effort are equivalent to the use of indicators for purposes of interpreting environmental conditions.

154.**Gerritsen, J., and B. Patten.** 1985. System theory formulation of ecological disturbance. Ecol. Modell. 29:383-397.

Ecological disturbance is defined in the context of a dictionary definition and state-space system theory. Disturbance can be partitioned into cause and effect. The cause is the exogenous disturbance, and its effect is unusual behavior of system state or output, with respect to nominal behavior. A disturbance can act on input, state, or the coupling parameters (process) of a system and is observed by change in state or output. Another attribute of the system model, the response function, which determines state, can also be changed indirectly as a result of disturbance.

Both timing and magnitude of phenomena are important in determining nominal behavior and deviations from nominal. Systems and behavior are hierarchical such that disturbances at any given level are not necessarily disturbances at higher or lower levels of organization. For an event or extended phenomenon to be considered a disturbance, it must have three properties, two of timing and one of magnitude, relevant to the level at which disturbance is manifested: (1) low frequency of recurrence with respect to the temporal scale, (2) low temporal predictability with respect to the level's time scale, and (3) production of a significant deviation from nominal outputs or state. Simple models of well-known ecological phenomena illustrate different classes of disturbance: (1) change of state; (2) change of state followed by change of transition function; (3) change of input; and (4) change of input followed by change of state and transition function.

155.**Giersch, C.** 1991. Sensitivity analysis of ecosystems—an analytical treatment. Ecol. Modell. 53(1-2):131-146.

Parameter sensitivities of mathematical models of ecosystems are studied analytically. A procedure for analytical calculation of relative sensitivities is developed, and summation properties of sensitivities with respect to parameters in which the model equations are homogeneous are derived. A simple plant-herbivore system is used to illustrate analytical calculation of parameter sensitivities and the type of information that can be obtained from the approach.

156.**Gilbert, R.** 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold, New York.

157.**Gilbertson, M.** 1990. Freshwater avian and mammalian predators as indicators of environmental quality. Environ. Monitor. Assess. 15(3):219-224.

The objective of this paper is to outline (1) the advantages and disadvantages of using four avian and mammalian predators, the bald eagle, osprey, mink, and otter, as indicators of environmental quality and (2) the kinds of information on these species that could be collected to make a defensible scientific case for regulatory action. This paper starts from the premise that if these species are present and maintaining their populations, then aquatic environmental quality is probably satisfactory.

158.**Godron, M., and R. Forman.** 1983. Landscape modification and changing ecological characteristics. Pages 12-28. In: H. Mooney and M. Godron, eds. Disturbance and Ecosystems: Components of Response. Springer-Verlag, New York.

The authors have two objectives: (1) to use some of the most encompassing or fundamental ecological concepts to pinpoint emergent patterns when comparing the natural landscape with the major types of human-modified landscapes, and (2) to focus more specifically on how the structural characteristics of landscapes change along a gradient of increasing human modification.

159.**Goldsmith, B.** 1991. Synthesis. Pages 269-271. In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

This postlude to the book presents a checklist of questions regarding issues that should be addressed when embarking on a monitoring program.

160.**Goldsmith, B.** 1991. Preface. Pages IX-XIV. In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

This preface to the book outlines the composition of a good monitoring program. A discussion of the newly fashionable discipline of monitoring is also included.

161.**Goldsmith. B., ed.** 1991. Monitoring for Conservation and Ecology. Chapman and Hall, London.

This book covers aspects of environmental monitoring from the local scale to the national scale. Chapters include discussions on definitions of monitoring, development of a rationale for monitoring, aspects concerning wildlife, bird, and butterfly monitoring, and use of environmental indicators for national-level monitoring.

162.**Graham, R.L., M.G. Turner, and V. Dale.** 1989. CO_2-induced climate change and forest resources. Pages 233-241. In: R.D. Noble, J.L. Martin, and K.F. Jensen, eds. Air Pollution Effects on Vegetation Including Forest Ecosystems. Proceedings of the Second US-USSR Symposium. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Broomall, PA.

The objective of this paper is to examine potential forest responses to increases in atmospheric CO_2 and to CO_2-induced climatic change. Forest responses to CO_2 and climate may be examined by using five biotic paradigms: biosphere, biome, ecosystem, stand, and tree. Each paradigm has its own spatial and temporal scale and its own set of unique phenomena responsive to CO_2 and climate change. First these paradigms are used to review forest responses to CO_2 and climate. Next, the linkages between these paradigms and the implications of these linkages for future research on the impact of elevated atmospheric CO_2 and climate change on forest resources are described.

163.**Graham, R., C. Hunsaker, R. O'Neill, and B. Jackson.** 1991. Ecological risk assessment at the regional scale. Ecol. Appl. 1(2):196-206.

Ecological risk assessments are used by policymakers and regulatory agencies to balance and compare ecological risks associated with environmental hazards. An approach for regional-scale ecological risk assessment is described and demonstrated by modeling environmental risks associated with elevated ozone in a forested region. The demonstration illustrates (1) how a regional-scale risk assessment might be done, (2) the importance of spatial characteristics in considering regional-scale risk, and (3) the necessity of considering terrestrial and aquatic linkages. Generic problems often encountered when doing regional assessments, the foremost of which is the frequent lack of region-specific and spatial data, are also highlighted. In the demonstration, two levels of elevated ozone and five different at-risk regional features are considered (forest cover, forest edge, forest interior, landscape pattern, and lake water quality). The mechanism for impacts on these features is ozone-induced stress in coniferous trees, patches of which can then be killed by bark beetle attacks. A stochastic spatial model of land-cover change is developed to evaluate the risks of significant changes in the selected ecological features as a consequence of these ozone-triggered beetle attacks. Risk to regional water quality of lakes is evaluated by linking the land-cover output from the spatial stochastic model to an empirical water-quality model that is sensitive to land-cover changes within a lake's watershed. The risk analysis shows that those environmental features that are sensitive to the location of coniferous forest (such as forest edge) are at risk of a significant change as a result of ozone-induced conifer mortality, even though overall coniferous forest cover is only slightly affected. The analysis also suggests a high probability of changes in regional water quality of lakes as a consequence of location-specific forest-cover change.

Key Words: Adirondack region, Bark beetle infestation, Disturbance, Ecological risk assessment, Regional risk assessment, Risk assessment demonstration, Scale

164.Granatstein, D., and D. Bezdicek. 1992. The need for a soil quality index: Local and regional perspectives. Am. J. Altern. Agric. 7(1-2):12-16.

Our knowledge of soil is based primarily on quantitative analysis of isolated physical, chemical, and biological properties. However, the interaction of these quantitative aspects determines soil quality. Integrative tools are needed by researchers, farmers, regulators, and others to evaluate changes in soil quality from human activity at a local and global level. An index needs to be adaptable to local or regional conditions. For example, the parameters needed to determine changes in soil quality may differ between a semi-arid wheat field and a rice paddy. Suitable reference points and optimum ranges are needed for soil quality attributes. The present challenge is to integrate a suite of soil tests into a meaningful index that correlates with productivity, environmental, and health goals.

Key Words: *Soil health, Soil condition, Soil analysis*

165.Graves, B.M., and P.L. Dittberner. 1986. Variables for monitoring aquatic and terrestrial environments. Biological Report 86(5), National Ecology Research Center. NTIS No. PB87-113916/GAR. U.S. Fish and Wildlife Service, Fort Collins, CO. 63 pp.

This manual provides general conceptual guidelines for designing habitat monitoring projects and identifying key variables that may indicate habitat quality. References are provided that lead to more detailed discussions of important topics. The field of habitat monitoring is quite broad and appropriate field methods may vary from site to site. Hence, the manual cannot provide a step-by-step procedure for habitat monitoring. Rather, it provides a framework and general principles; designers of individual monitoring programs must integrate and adapt these to specific circumstances.

166.Gray, J. 1980. Why do ecological monitoring? Mar. Poll. Bull. 11:62-65.

Recently, criticism has been raised against ecological monitoring on the grounds that obtaining the basic data - the species lists and species abundances - is time-consuming or that ecological monitoring is relatively insensitive. The insensitivity arises because usually only absence of species can be used; this is true because natural changes in abundance of species over time (the background noise) are difficult to separate from pollution effects. The feeling seems to be that if effects of pollutants could be detected in individuals at the physiological or biochemical level before abundance changes are observed, then such techniques for monitoring are preferable.

Much money has been wasted on conducting surveys in the guise of obtaining so-called "baselines," which because of their inadequate survey design could never fulfill the stated goal of detecting effects of a particular pollutant. The question "How can one come up with a passable ecological monitoring program that can be expected to answer the questions being posed?" is approached by first considering alternatives to ecological monitoring.

167.Gray, J. 1989. Effects of environmental stress on species of rich assemblages. Biol. J. Linnean Soc. 37:19-32.

Selye's widely used model of responses of individual organisms to a stressor is not appropriate for describing effects at the population or community level. At the ecosystem level a number of functional responses have been suggested by Rapport, Regier, and Hutchinson, but detailed analysis shows that, in general, functional responses are not sensitive to early detection of impending ecosystem damage.

Three clear changes in community structure occur in response to stressors. These are reduction in diversity, retrogression to dominance by opportunistic species, and reduction in mean size of the dominating species. Statistically significant reductions in diversity occur rather late in the sequence of increased stressor impact. The first stages of impact are clearly shown by moderately common species, yet most attention has concentrated on the common species. Species that dominate in heavily stressed habitats are often species complexes, and the possible genetic mechanisms causing this are considered.

Although changes in the mean size of the dominant organisms can be shown in experiments, there is no clear evidence that recorded reductions in the size of North Atlantic and North Sea plankton are induced by human-made stressors.

Key Words: Stress, Diversity, Dominance, Size

168.**Green, R.** 1984. Statistical and nonstatistical considerations for environmental monitoring studies. Environ. Monitor. Assess. 4:293-301.

In environmental studies statistics is too often used as a salvage operation or as an attempt to show "significance" in the absence of any clear hypothesis. Good design is needed, not fancier statistics. Too often we pursue short-term problems that are in fashion rather than study long-term environmental deterioration that really matters. Since change, often unpredictable change, is an intrinsic part of nature, it is pointless to fight all environmental change. We must choose our level of concern and then influence environmental change where we can. The judgement on whether a given change is bad cannot be left to the statistician or to statistical tests; the politician in consultation with the ecologist is responsible for it. The statistical significance of a hypothesized impact-related change should be tested against year-to-year variation in the unimpacted situation rather than against replicate sampling error. This is another argument for long-term studies. Attributes of good design and appropriate criterion and predictor variables are discussed.

169.**Grodzinski, W., and T. Yorks.** 1981. Species and ecosystem level bioindicators of airborne pollution: An analysis of two major studies. Water Air Soil Poll. 16:33-53.

Bioindication of air pollution effects has received considerable attention in recent years. The attention has been almost entirely focused on individual species, and relatively little notice has been given to ecosystem-level process and function monitors. Long-term research projects in the Niepolomice Forest in southern Poland and the Colstrip area in southeast Montana, U.S.A., were analyzed for both organism- and system-level indicators and monitors for Sulfur, trace element, and fluoride pollution originating in nearby coal-fired industrial processes. Species of lichens exhibited changes in morphology and survival, and pine species exhibited pollutant accumulation in needles at both sites. Declines in Scotch pine growth in Poland of up to 20% were compared with declines in western wheatgrass rhizome biomass in Montana to illustrate system-wide effects on primary productivity. Directly observable declines in decomposition rate were noted for both sites at higher pollution levels and tied to system-wide occurrences of nutrient deficiency and toxicant buildup in soil pools. Pollutant increases in deer antler composition, changes in grasshopper dietary patterns, and lichen density and health were postulated to have system-level implications as well.

170.**Gutman, G.** 1991. Monitoring land ecosystems using the NOAA Global Vegetation Index data set. Paleogeogr. Paleoclimatol. Paleoecol. (also called Global and Planetary Change Section V.4) 90:195-200.

The Global Vegetation Index (GVI) data set produced by NOAA from Advanced Very High Resolution Radiometer measurements for 1985-1988 was used to derive the temporal variability of surface characteristics of diverse ecosystems over the globe. The GVI data were screened for residual cloud contamination and haze. The viewing geometry was restricted to within 25° of nadir. The results are demonstrated by using monthly means of the satellite derived parameters spatially averaged over 250 km x 250 km. Phenology of land ecosystems as manifested by the surface albedo, greenness and temperature is analyzed. A color-composite technique for mapping global ecosystems is introduced.

171.**Haberern, J.** 1992. A soil health index. J. Soil Water Conserv. 47(1):6.

In this viewpoint article, the author stresses the importance in maintaining a high quality of soil condition. He discusses the soil health index, being created by the Rodale Institute, which will be a report card that documents the gains and losses in soil quality worldwide.

172.**Haedrich, R.** 1975. Diversity and overlap as measures of environmental quality. Water Res. 9:945-952.
It is argued that indices of diversity (information function H) and overlap (percentage similarity PS) can be used together to assess environmental quality. The method is tested by using data on demersal fishes from nine Massachusetts estuaries and embayments. Annual diversity ranged from H (log e) = 0.4 to 2.4, with low diversities in areas of apparent high pollution and higher diversities in areas of lesser pollution. Where annual diversity is low, little seasonal change is reflected in a high PS from season to season; where annual diversity is high, a relatively lower PS indicates a greater degree of change. To calculate both H and PS the number of individuals in each species in a sample is required. This data should be considered important in the conduct of faunal surveys that contribute to an environmental impact statement.

173.**Haire, M. S., N.N. Panday, D.K. Domotor, and D.G. Flora.** 1992. Chesapeake Bay water quality indices. Pages 1115-1134. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Although current monitoring program results provide scientists and technical staff with invaluable information concerning the health of the Bay system, difficulties are encountered when relaying this information to concerned citizens and legislative officials. The Maryland Department of the Environment (MDE) has pursued the development of water quality indices to simplify the results of the monitoring program and make them understandable to the lay audience.

The two water quality indices intended to describe the environmental quality of the Chesapeake Bay and its tributaries are (1) a "nutrient loading index," which documents the amount of nutrients entering the Chesapeake Bay from point and nonpoint sources and (2) a "eutrophication index," which incorporates the important parameters of overenrichment into a single value that represents water quality response to nutrient controls. Indices were developed for the Patuxent Estuary, the Potomac Estuary, and the mainstem Chesapeake Bay. This report describes the development and results of these water quality indices.

174.**Halford, G.S., and P.W. Sheehan.** 1991. Human response to environmental change. Int. J. Psychol. 26(5):599-611.

A range of factors affect human response to environmental change. They include the information available, understanding of the phenomenon, the nature of the decision-making processes implied, and the motivation for change. One major factor affecting decision making is that scientific information is not fully and accurately disseminated through society. The media have an important role in this process but cannot disseminate all of the necessary information in the manner required and do not reliably present information that cannot be misinterpreted. Further, scientific uncertainty about and complexity of biosphere changes complicate the process of reaching a rational decision. The mental model that people have of their world tends to be maintained unless it is contradicted by experienced events; thus, global change is likely to be understood only to the extent that it affects everyday life. Much of human reasoning is essentially analogical rather than having a standard logic, and its validity depends on finding a suitable analogical model. It is suggested that risk, or defense situations may provide useful analogies. Finally, we need to consider the motivational problems created by the sacrifices that must be made to deal with the problem effectively.

175.**Hamblin, A., ed.** 1992. Indicators for agroecological regions in Australia. Pages 68-74. In: A. Hamblin, ed. Environmental Indicators for Sustainable Agriculture. Bureau of Rural Resources, Dept. Primary Industry and Energy, Queen Victoria Terra, Australia.

176.**Hamblin, A.** 1992. Environmental indicators for sustainable agriculture: Workshop conclusions. Pages 83-85. In: A. Hamblin, ed. Environmental Indicators for Sustainable Agriculture. Bureau of Rural Resources, Dept. Primary Industry and Energy, Queen Victoria Terra, Australia.

177.**Harris, H.J., P.E. Sager, H.A. Regier, and G.F. Francis.** 1990. Ecotoxicology and ecosystem integrity: The Great Lakes examined. Environ. Sci. Technol. 24(5): 598-603.

This article assesses the contribution of ecotoxicology to the study of stressed ecosystems. The article overviews the concept of ecosystem integrity and how to assess it and discusses stress ecology and the interconnections between environmental stressors.

178.**Harrison, E.A.** 1976. Bioindicators of pollution: A bibliography with abstracts. NTIS/PS-76/0868. National Technical Information Service, Springfield, VA. November.

This bibliography presents abstracts relating to the use of microorganisms, animals, plants, and fishes to detect air and water pollution. Some of the organisms discussed are algae, bacteria, aquatic plants, oysters, snails, clams, insects, annelida, amphibians, beaver, and fungi. (This updated bibliography contains 189 abstracts, 22 of which are new entries to the previous edition.) The bibliography covers the period 1964 to October 1976.

179.**Hart, B., ed.** 1982. Water quality management: Monitoring programs and diffuse runoff. Water Studies Centre. Chisolm Institute of Technology and Australian Society for Limnology, Melborne, Australia.

180.**Hart, K., and J. Cairns, Jr.** 1984. The maintenance of structural integrity in freshwater protozoan communities under stress. Hydrobiologia 108(1):171-180.

The structural assimilative capacity (ability to maintain biological integrity under stress) of protozoan communities from nine lakes in the area of the University of Michigan Biological Station, Pellston, Michigan, and six stations at Smith Mountain Lake, Virginia, were studied (1) to determine if communities from lakes of differing trophic state differ in their ability to assimilate various amounts of copper sulfate and (2) to explore the possible influence of average density of individuals and/or qualitative differences in the types of species present on any observed differences in assimilative capacity.

In both the northern Michigan and Smith Mountain Lake Studies, a trend in response was demonstrated along the eutrophic-oligotrophic gradient; eutrophic communities had a greater structural assimilative capacity than did oligotrophic communities. Both mean species density and community composition appear to be important factors in the ability to maintain structural integrity.

Key Words: Assimilative capacity, Protozoans, Communities, Eutrophication, Artificial substrates, Colonization.

181.**Harwell, M., W. Cooper, and R. Flaak.** 1992. Prioritizing ecological and human welfare risks from environmental stresses. Environ. Manage. 16(4):451-464.

The ecological systems of the Earth are subjected to a wide array of environmental stresses resulting from human activities. The development of appropriate environmental protection and management policies and the appropriate allocation of resources across environmental stresses require a systematic evaluation of relative risks. The data and methodologies for comprehensive ecological risk assessment do not exist, yet we do have considerable understanding of ecological stress-response relationships. A methodology is presented to utilize present knowledge for assignment of relative risks to the ecological systems and human welfare from environmental stresses. The resultant priorities, developed for the EPA's relative risk–reduction project, highlight global climate change, habitat alteration, stratospheric ozone depletion, and species depletion as the highest environmental risks, significantly diverging from the current emphasis by EPA and the public on toxic chemical issues. Enhanced attention to ecological issues by EPA and development of ecological risk assessment methodologies that value ecological and economic issues equitably are key recommendations.

Key Words: Ecological risk assessment, Relative risk reduction, EPA, Welfare risks

182.Harwell, M., C. Harwell, and J. Kelly. 1986. Regulatory endpoints, ecological uncertainties, and environmental decision making. Pages 993-998. In: Oceans 86 Proceedings. Marine Technology Society, Washington, DC.

183.Harwell, M., C. Harwell, D. Weinstein, and J. Kelly. 1987. Anthropogenic stresses on ecosystems: Issues and indicators of response and recovery. ERC-153, Ecosystems Research Center. Cornell University, Ithaca, NY.

184.Harwell, M., C. Harwell, D. Weinstein, and J. Kelly. 1990. Characterizing ecosystem responses to stress. Pages 91-115. In: W. Grodzinski, E.B. Cowling, and A.I. Breymeyer, eds. Ecological Risks: Perspectives from Poland and the United States. National Academy Press, Washington, DC.

Environmental risk assessment and management involve the use of methodologies to assess risks to the health of biological systems, especially the stresses from human activities. The use of appropriate ecological indicators to measure environmental effects of these stresses can allow a realistic evaluation of risks.

185.Harwell, M., and C. Harwell. 1989. Environmental decision-making in the presence of uncertainty. Pages 516-540. In: S. Levin, M. Harwell, J. Kelly, and K. Kimball, eds. Ecotoxicology: Problems and Approaches. Columbia University Press, New York.

This chapter covers many topics related to sources of uncertainty in the making of environmental decisions. Sections include: (1) Effects of chemicals on ecosystems: (a) Direct biological effects, (b) indirect biological effects, (c) ecosystem-level effects, (d) recovery processes; (2) sources of ecological uncertainty: extrapolation issues (from microcosms, models and intact ecosystems); and (3) ecological information to improve decision making.

186.Havas, M. 1990. Rapporteur's report of workgroup: Chemical indicators. Environ. Monitor. Assess. 15:287-288.

This conference workgroup summary defines a chemical indicator and discusses approaches to chemical monitoring.

187.Hayden, F.G. 1991. Instrumental valuation indicators for natural resources and ecosystems. J. Econ. Iss. 25(4):917-934.

The purpose of this article is to present a general instrumental methodology for determining value indicators with an application to natural resources and ecosystems. The article uses the knowledge base of the Social Fabric Matrix and the principles of general System Analysis.

Subtopics include: Valuation measurement as indicator creation; Indicator design standards; Policy analysis paradigm; Valuation; Norms and control valuation; Biodiversity valuation; Stability valuation; Ecodevelopment evaluation; Restoration costs and; Restoration valuation. EMAP and the Agroecosystem Resource Group are mentioned in the article.

188.Hekstra, G. 1983. Indicators in complex systems. Environ. Monitor. Assess. 3(3-4):369-374.

This article briefly discusses aspects of indicators and monitoring. Subtopics include: Indication as a general term; Factors and trends; Ecosystem parameters used as indicators; Diversity and stability; Flows of matter, energy, and information and; Lines of research.

189.Hellawell, J.M. 1977. Change in natural and managed ecosystems: Detection, measurement, and assessment. Proc. Royal Soc. London Ser. B 197:31-57.

Change is an intrinsic property of ecosystems. To achieve effective conservation, acceptable rates and directions of change need to be determined. A preliminary step is the development of methods for detecting, measuring, and assessing the significance of ecological change.

Prolonged surveillance of "natural" and artificially modified systems is necessary to distinguish those elements of change that are short-term fluctuations (cyclical or stochastic) from those that are part of the long-term, perhaps irreversible, trends. Criteria for selecting appropriate parameters (e.g., biocoenoses, community diversity, populations of indicator species, or production estimates) are required, together with appropriate techniques for monitoring them.

Although few ecosystems are totally isolated from anthropogenic influence, those that remain largely unaffected serve as reference systems against which changes in intensively exploited or unmanaged (i.e., unprotected) ecosystems may be compared.

190.**Hellawell, J.M.** 1986. Biological Indicators of Freshwater Pollution and Environmental Management. Elsevier Applied Science Publisher, London.

This book is a comprehensive review of stresses to aquatic ecosystems. The sections dealing with indicators generally refer to individuals or indicator species as environmental indicators. The chapter on biological indicators has sections on selection of indicators (providing characteristics of ideal and good indicators, and factors that affect indicator reliability), populations as indicators, community structure as an indicator, and functional changes in communities. Also discussed are the ecological consequences of imposed environmental stresses to aquatic ecosystems.

191.**Hellawell, J.M.** 1991. Development of a rationale for monitoring. Pages 1-14. In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

"Monitoring" has become an omnibus term and is sometimes applied, almost indiscriminately, to a range of disparate activities. These may include, for example, attempts to describe prevailing environmental conditions; the occurrence, distribution and intensity of pollution; or the status of ecological communities or populations of species or simply to provide a watching brief on the countryside at large.

Because "monitoring" is a process, not a result, a means to an end rather than an end in itself, it should not be surprising to find that so many kinds are undertaken.

Implicit in the rationale for most monitoring activities is a recognition of the potential for change. One is concerned, therefore, to secure a means of detecting a change, of establishing its direction, and of measuring its extent or intensity. This stage may prove to be the simpler part of a monitoring process: often it is more difficult to assess the significance of the change that has been encountered. Monitoring schemes, especially those concerned with ecological change, may founder through lack of adequate criteria to determine significance, and even well-established procedures for pollution monitoring may, in reality, be based on largely arbitrary limits of acceptability for given pollutant concentrations.

This chapter, above all, stresses the importance of establishing clearly defined objectives to ensure the development of a successful monitoring strategy.

192.**Herendeen, R.** 1990. System level indicators in dynamic ecosystems: Comparison based on energy and nutrient flows. J. Theor. Biol. 143(4):523-554.

System—wide indicators of ecosystem structure and function depend strongly on the choice of flow variable, or numeraire. The author compares two such indicators, exergy and ascendancy, by using biomass energy or elemental nitrogen as flow variable. Comparison is for steady-state (data from Cone Spring and Tayozhny Log Bog). In both systems, measured flows are available in terms of biomass energy; nitrogen flows are imputed by calculating dynamic nitrogen intensities (analogous to energy intensities). The author finds that when using these two flow variables steady-state normalized ascendancy differs as much for one ecosystem as it does for two different ecosystems in which the same flow variable is used. This implies that the question of flow variable choice needs to be resolved before strong conclusions can be made about intersystem comparisons. For dynamic behavior, nitrogen-based exergy shows no more, and sometimes less, variation over time than does energy-based exergy. Both nitrogen- and biomass-based ascendancy follow variations in system stock and

show little additional variation. Analyzing the size, concentration, and structural components of exergy and ascendancy aids in understanding these behaviors. Trophic positions are also compared by using the two flow variables.

193.**Hermann, K. M.J. Hewitt, and D.J. Norton.** 1991. Using existing sampling frames in a comprehensive national monitoring program. In: GIS/LIS '90. Geographic Information Systems/Land Information Systems Annual Conference, Anaheim, Ca. American Congress for Surveying and Mapping, Falls Church, Va.

194.**Herricks, E., and D.J. Schaeffer.** 1985. Can we optimize biomonitoring? Environ. Manage. 9:487-492.

Biomonitoring is an element of environmental management that must become more sophisticated to meet the demands of legislation and public concern for environmental safety. Data collection and analysis techniques must improve if environmental scientists are to take full advantage of the information content of field and laboratory biomonitoring efforts. Issues associated with biomonitoring addressed in this article include test system selection and the data characteristics of various biomonitoring techniques. The authors identify optimization as a possible approach to resolving conflicts between legal defensibility, scientific accuracy, and the requirements of environmental managers.

Key Words: Biomonitoring, Bioassay, Toxicity testing, Bioassessment

195.**Herricks, E., and D.J. Schaeffer.** 1987a. Selection of test systems to evaluate the effects of contaminants on ecological systems. Civil Engineering Studies, Environmental Engineering Studies No. 17. University of Illinois, Urbana.

196.**Herricks, E., and D.J. Schaeffer.** 1987b. Selection of test systems for ecological analysis. Water Sci. Technol. 19(11):47-54.

Biological monitoring programs developed for ecosystem management, including experimental testing and descriptive assessments, can be improved through careful selection of test systems. Test systems are a defined analysis unit employed to examine or assess. Test systems may range from simple biochemical assays to experimental manipulation of ecological systems. The authors have developed an efficient methodology for selecting test systems to assess the ecological system effects of chemicals. The process includes the recognition of ecosystem critical factors, identification of potential measures for these factors, and selection of appropriate metrics for experimentation or assessment. A decision tree, which leads to two methods for test system selection, is proposed.

Key Words: Biomonitoring, Bioassay, Bioassessment, Environmental assessment, Toxicity testing

197.**Herricks, E., D.J. Schaeffer, and J. Perry.** 1988. Biomonitoring: Closing the loop in the environmental sciences. Pages 351-366. In: S. Levin, M. Harwell, J. Kelly, and K. Kimball, eds. Ecotoxicology: Problems and Approaches. Columbia University Press, New York.

For the purpose of this chapter, biomonitoring is defined as the analysis of the performance of living systems' structures to provide essential information for decision making. Although some form of biomonitoring has been used for hundreds, if not thousands, of years, a cohesive approach to the design and use of biomonitoring programs is a recent development. This chapter discusses biomonitoring programs, emphasizing program designs that coordinate data collection and facilitate information retrieval. The role of biomonitoring is highlighted in the context of environmental management and regulation. The authors suggest that both control theory and decision science can be used to refine biomonitoring programs to optimize the use of data in the environmental sciences, management, and regulation.

198.**Herrmann, R., and R. Stottlemyer.** 1991. Long-term monitoring for environmental change in United States National Parks — A watershed approach. Environ. Monitor. Assess. 17(1):51-65.

The U.S. National Park Service (NPS) is faced with direct questions about the condition of National Park natural resources. The watershed approach to long-term monitoring of natural and remote areas within the National Parks has provided important data for detecting both spatial and temporal changes in environmental conditions. These data collections allow the partitioning of cause and effect relationships of ecological change within a given watershed. They also serve to meet both reference and early warning objectives. Success in advancing a number of "acid precipitation" goals has demonstrated the usefulness of these integrated watershed data for inter-ecosystem comparison and for analogy between watersheds. Because of the NPS experience, the watershed program is proposed as a model for focusing the National Park Service's inventory and monitoring program initiative. This approach provides to park researchers and resource managers the needed tools for dealing with today's complex local, regional, and global natural resources issues.

199.**Hildebrand, S.G., L.W. Barnthouse,, and G.W. Suter II.** 1987. The role of basic ecological knowledge in environmental assessment. Pages 51-67. In: S. Draggan, J. Cohrssen, and R. Morrison, eds. Preserving Ecological Systems: The Agenda for Long-term Research and Development. Praeger, New York.

This chapter primarily discusses local environmental impacts and the NEPA procedure, using some case studies as examples of environmental impacts assessment of power projects, etc. However, the authors also summarize the arguments for ecosystem-level assessment and discuss the National Acid Precipitation Assessment Program as an integrated assessment of the impact of acid rain on ecosystems. Suggestions for further research include long-term studies of the response of ecosystems to criteria concentrations of pollutants and their subsequent recovery or adaptation.

200.**Hilden, M., and D. Rapport.** 1993. In Press. Four centuries of cumulative cultural impact on a Finnish river and its estuary: An ecosystem health approach. J. Mar. Sci.

201.**Hill, A.** 1975. Ecosystem stability in relation to stresses caused by human activities. Can. Geogr. 19:206-220.

The increasing size of the human population, together with rising technological levels, is imposing substantial pressures on the biosphere. The intensity of human exploitation of the earth's surface is producing serious conflicts between short-term benefits to human's and the biosphere's capacity to provide benefits in perpetuity. In these circumstances, it is crucial that a greater understanding of the levels of manipulation be developed that can be imposed on ecosystems without producing serious and often harmful transformations. The ability of ecosystems to withstand human-induced stresses is an aspect of system stability that urgently requires research. Current generalizations regarding the vulnerability of major biomes, such as the tundra or tropical rainforest, to human impacts are not supported by precise data on the reactions of ecosystems to various types of human activity. Moreover, there is an absence of knowledge on how many aspects of ecosystem structure and functioning influence stability.

The objective of this paper is to evaluate the current status of research on ecosystem stability. The major portion of this research has been undertaken by ecologists, and there have been comparatively few contributions from disciplines with a traditional interest in the human-environment theme, such as geography. However, there is some evidence of a recent revival of interest in environmental issues among geographers. The literature on ecosystem stability reveals a number of areas in which the knowledge and techniques of geographers could be particularly important. The current review places some emphasis on the role of spatial organization and abiotic aspects of ecosystems in relation to stability in the hope that geographers may be encouraged to contribute more actively to these and other aspects of this important research theme.

202.**Hinds, F.** 1984. Towards monitoring of long-term trends in terrestrial ecosystems. Environ. Conserv. 11:11-18.

Ecological monitoring designs have at least three identifiable difficulties that must be overcome if the design is to be successful:

1. The major ecological difficulty is in selecting and quantifying specific biotic conditions or activities within the continuous spatial and temporal flux that characterizes life.
2. The major statistical difficulty is specifying appropriate replication-standards in a world that is full of unique places.
3. The major difficulty with monitoring in general is that it is expensive.

This tripartite requirement for ecologically relevant, statistically credible, and cost-effective monitoring methods is very stringent, and failure to meet one or more of these requisites is at the root of many problems in ecological monitoring. A particularly clear example surfaced in the Organization for Economic Cooperation and Development (OECD) monitoring programs, where a reviewer remarked that none of the national programs seemed to have had statistical analysis in mind.

In this paper, some important ecological and statistical considerations are outlined. These suggestions are the result of several years of research aimed at developing cost-effective methods that are in principle capable of detecting slowly paced ecological change.

203.**Hirvonen, H.** 1992. The development of regional scale ecological indicators: A Canadian Approach. Pages 901-916. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

This paper briefly describes the background to the instigation of national-scale ecological indicators in Canada and puts these into context with local to continental planning scales. Discussion then focuses on the need for and development of a national-scale ecological framework within which ecological indicators can be presented and communicated to the intended audience.

The federal government, through a major review of its environmental agenda (The Green Plan), is forging a strategy to move Canada toward sustainable development by integrating environmental considerations into decision making. In addition, Canada has embarked on two major initiatives aimed at informing the public of the current state and trend of the health of the country's environment: the production of a national State of the Environment Report every 5 years and a National Environmental Indicators Project useful for planning for major resource sectors as well as general communication. The development of broad national-scale ecological indicators is pivotal to all these activities.

National- and large-scale regional planning are discussed in terms of regional environmental problems rather than from a local or global environmental perspective. Stress, exposure, and response indicators are put in the context of the spatial ecological framework of the 15 ecozones that comprise Canada. Rationale for the use of ecozones is given. The qualitative procedure used to roll up ecozone-level indicators from more-detailed data bases is illustrated. Discussion centers on desired characteristics of these indicators. An argument is presented that perhaps adherence to statistically valid indicators at these general levels is not prudent.

The position presented is that the primary function of broad scale indicators is to communicate, at a general level, the health of the nation's major ecological zones. These indicators do not direct or assess ecological research; they may serve to measure the relative success or failure of policy and program initiatives. In most instances, their scientific credibility is based on derivation from more-detailed data bases. Thus, caveats associated with collation and synthesis are vital.

Emphasis is placed on the need to determine the "critical level of communication" of regional- and national-scale indicators. If environmental science cannot be communicated with clarity to an informed public the value of that science should be questioned.

204.**Hodson, P.V.** 1990. Indicators of ecosystem health at the species level and the example of selenium effects on fish. Environ. Monitor. Assess. 15:241-254.

Chemical monitoring of aquatic ecosystems describes the chemical exposures of aquatic biota and measures the success of pollution control. However, meeting water quality criteria cannot ensure that aquatic biota are protected from the effects of unexpected chemicals, mixtures, and interactions between toxicity and environmental stressors.

Biological monitoring is an obvious solution because aquatic biota integrate spatial and temporal variations in exposure to many simultaneous stressors. Top predators, typical of specific ecosystems (e.g., lake trout in cold-water oligotrophic lakes) indicate whether environmental criteria have been met. The presence of naturally reproducing, self-sustaining, and productive stocks of edible fish demonstrates a high-quality environment. If these conditions are not met, there is a clear sign of environmental degradation. Specific changes in population structure and performance may also diagnose which life stage is affected and the nature of the stressor.

Unfortunately, environmental managers cannot rely solely on populations, communities, or ecosystems to indicate chemical effects. The lag between identifying a problem and finding a cause may destroy the resource that we wish to protect, particularly where chemicals are persistent.

A solution to this dilemma is the measurement of primary or secondary responses of individual organisms to chemical exposure. Because toxicity at any level of organization must start with a reaction between a chemical and a biological substrate, these responses are the most sensitive and earliest sign of chemical exposure and effect.

Application of this idea requires research on molecular mechanisms of chemical toxicity in aquatic biota and adaptation of existing mammalian diagnostic tools. Because relevance of biochemical responses to populations and ecosystems is not obvious, there is a need to study the links between chemical exposure and responses of individuals, populations, and ecosystems.

The recognition of chemical problems and cause-effect relationships requires the integration of chemical and biological monitoring, using the principles of epidemiology to test the strength of relationships and to identify specific research needs. The contamination of a reservoir with selenium and the resulting impacts on fish populations provide an excellent example of this approach.

205.**Hoffman, R.** 1992. Technological barriers: A commentary. Environ. Monit. Assess. 20:185-187.

This note is an attempt to establish a framework for linking the technologies of measurement and the technologies for representing an understanding of human/environment systems and making the understanding accessible to stakeholders in environmental issues. The author describes a systems model and discusses system indicators which are observations of the state of the system. The author also stresses that the systems model plays a crucial role in providing the linkage between observations of state variables (indicators) and the understanding needed for effective interpretation of the observations. The systems model serves to define a set of state of the environment indicators.

206.**Hofstra, J.J., and L. Van Liere.** 1992. The state of the environment of the Loosdrecht Lakes. Hydrobiologia 233:11-20.

The Loosdrecht Lakes are a system of shallow, interconnected peat lakes in the center of The Netherlands. The main environmental functions of the Loosdrecht lakes are nature and recreation. From the point of view of Dutch policy, a Specific Environmental Quality should be set for these lakes. The most serious environmental problem of the area is eutrophication. The Loosdrecht lakes have, by increasing external phosphorous loading, undergone changes, from clear lakes with few macrophytes, followed by a period of abundant characean growth, to turbid lakes dominated by cyanobacteria and detrital matter. Eutrophication was counteracted by use of sewerage systems and dephosphorization of the supply water. The resultant decrease in external phosphorus loading did not result in a decrease in turbidity caused by suspended particles.

The eutrophication of the lake ecosystems was described as occurring in phases. One of those phases, occurring around 1940, has been used as an ecological reference. By means of a graphical presentation technique, the so-called "AMOEBE-approach," the state of the environment of the Loosdrecht lakes has been visualized. Thirty-two ecological parameters, including both biotic and abiotic factors, have been selected and quantified. Concrete target values for these parameters have been derived from historical reports and from Lake Western Loenderveen, a less eutrophic lake located close to the Loosdrecht lakes.

The general conclusion is that the state of the environment of the Loosdrecht lakes is far from what is required with respect to a Specific Environmental Quality, because many of the selected parameters, such as water transparency, total phosphorous, mineral nitrogen, cyanobacteria, bream, pike, macrophytes, birds, and otter, deviate by over an order of magnitude from their desired levels.

Key Words: Eutrophication, Loosdrecht Lakes, Amoebe-approach, Water quality, Ecological assessment

207.**Holling, C.** 1973. Resilience and stability of ecological systems. Annu. Rev. Ecol. Syst. 4:1-24.

The purpose of this review is to explore both ecological theory and the behavior of natural systems to see if various perspectives of behavior can yield various insights useful for both theory and practice.

208.**Holling, C., ed.** 1978. Adaptive Environmental Assessment and Management. Wiley, Chichester, England.

This book is a report on efforts to develop an adaptive approach to environmental impact assessment and management. It is written for policymakers and managers who are dissatisfied with the traditional procedures and principles and who seek some effective and realistic alternatives.

The study was initiated by a workshop convened in early 1974 by SCOPE (Scientific Committee on Problems of the Environment). The workshop was attended by individuals with an often bewildering range of experience, concerns, and styles—precisely those ingredients that are so useful at the beginning of an analysis in defining the full range of issues and possibilities. Three particularly relevant questions emerged:

1. What, if anything, does our understanding of the nature and behavior of ecological systems have to say about the issues, limitations, and potential of environmental assessment?
2. What can be done to bridge the abyss currently separating technical impact assessment studies from actual environmental planning and decision making?
3. To what extent, and under what circumstances, do present methods provide useful predictions of impact?

Although the focus of this book is environmental assessment, its central message is that the process itself should be replaced. It attacks myths of environmental management and assessment, and discusses among other topics, development of contemporary assessment techniques and the issue of uncertainty. The book is divided into two parts: (1) the approach and (2) case studies.

209.**Holling, C.** 1986. The resilience of terrestrial ecosystems: Local surprise and global change. Pages 292-317. In: W. Clark and R. Munn, eds. Sustainable Development of the Biosphere. Cambridge University Press, Cambridge, England.

Adequate explanations of long-term global changes in the biosphere often require an understanding of how ecological systems function and of how they respond to human activities at local levels. Outlined in this chapter is one possible approach to the essential task of linking physical, biological, and social phenomena across a wide range of spatial and temporal scales. It focuses on the dynamics of ecological systems, including processes responsible for both increasing organization and for occasional disruption. Special attention is given to the prevalence of discontinuous change in ecological systems, and to its origins in specific nonlinear processes interacting on multiple time and space scales. This ecological scale of analysis is linked "upward" to the global scale of biogeochemical relationships and the "Gaia" hypothesis, and "downward" to the local scale of human activities and institutions.

210.**Holmberg, T. and S. Karlsson.** 1992. On designing socioecological indicators. Pages 89-106. In: U. Svedin and B.H. Aniansson, eds. Society and the Environment: A Swedish Research Perspective. Series: Ecology, Economy, & Environment 2. Kluwer Academic Publishers, Dordrecht, The Netherlands.

There is a need for indicators which capture the essential parts of society in the maladjustments of its physical relations to nature. The socio-ecological indicators should contribute to the control mechanisms that are urgently needed if society is to be able to redirect itself to a path of development which is subordinated to sustainable interactions with nature. An analysis of various factors important to the design of socio-ecologic indicators is performed here. An important aspect of the socio-ecological indicators is that they will focus on parts situated early in the cause-effect chain. This implies better possibilities for foresight when dealing with the global, complex or diffuse problems in connection to sustainability. The indicators can be useful in many situations: as a support for discussions among decision makers and the general public, as part of environmental impact analysis, and as a tool in evaluation of various plans or projects.

211.**Hope, C., and J. Parker.** 1990. Environmental information for all: The need for a monthly index. Energy Policy 18(4):312-319.

Society is not well served by existing sources of environmental information. Although reasonably comprehensive, they are not easy to use. Several recent reports have highlighted the need to devise new ways of reporting the state of the environment. This article introduces a monthly Environmental Index, similar in form to the Retail Price Index, which is designed to compete with economic statistics for attention in the media. It gives some suggestions for the components of the Index, and proposes a weighting method, as a basis for discussion.

Key Words: Environment, Statistics, Index

212.**Hope, C., J. Parker, and S. Peake.** 1992. A pilot environmental index for the U.K. in the 1980s. Energy Policy 20(4):335-343.

A pilot environmental index with nine components is constructed for the United Kingdom. Public opinion poll results are used to assign weights to the components in the overall index. The index remains roughly constant for the period 1980 to 1988. Different sets of opinion poll results produce very similar index values, suggesting that this may be a feasible weighting method. Implications for policymaking are discussed.

213.**House, M.** 1989. A water quality index for use in the operational management of river water quality in Europe. Pages 159-168. In: D. Wheeler, M. Richardson, and J. Bridges, eds. Watershed 89: The Future for Water Quality in Europe. [Series: Advances in Water Pollution Control (1989)].

214.**House, M.** 1990. Water quality indices as indicators of ecosystem change. Environ. Monitor. Assess. 15:255-263.

The operational management of water quality requires a methodology that can provide precise information on cycles and trends in water quality objectively and reproducibly. Such information can be provided by the adoption of a water quality indexing system. The continuous scale afforded by a water quality index (WQI) allows changes in river water quality to be highlighted. At the same time, the subdivision of this scale into a series of water quality and water use categories provides an easy means of relating information to the government and to the public. The development of four WQIs is outlined. These have been applied to data for a number of river reaches in the United Kingdom. The results of these applications indicate the utility of these indices in the classification of water quality and the monitoring of ecosystem change.

215.**Hren, J., C. Oblinger-Childress, J. Norris, T. Chaney, and D. Myers.** 1990. Regional water quality: Evaluation of data for assessing conditions and trends. Environ. Sci. Technol. 24(8):1122-1127.

Although large amounts of water quality data have been collected, the problems of aggregating them into one data base for broad water quality assessments are unknown. The U.S. Geological Survey in 1984 undertook a study in Colorado and Ohio to determine how well these data could be used to address such questions as "What are existing water quality conditions?", "How have they changed?", and "How do these conditions and changes relate to natural and human-induced activities?".

The major finding of this study was that few areas in either state had adequate numbers of samples or sampling sites for the constituents evaluated. This was because the benefits of aggregating data collected by various agencies were limited because of either the nature (e.g., effluent samples) or quality of the data with respect to regional assessments. Furthermore, more data were collected for gross indicators of water quality (e.g., dissolved solids) than for constituents specifically related to toxic contamination (e.g., organic compounds).

216.**Huffman, E.** 1990. Workgroup issue paper: Indicators and assessment of agricultural sustainability. Environ. Monitor. Assess. 15:303-305.

Sustainability is emerging as one of the most fundamental concepts for assessing the overall state of an agricultural production system. Essentially, this concept assumes that if a production system is sustainable indefinitely, then it is acceptable. However, almost any system is sustainable if sufficient resources are committed to it! Thus, it's obvious that an uncritical adoption of the idea is not acceptable.

217.**Hunsaker, C.T.** 1993. In Press. New concepts in environmental monitoring: The question of indicators. Sci. Total Environ.

Current environmental issues such as declining biodiversity, sustainability of ecosystems, and global atmospheric change are manifestations of multiple stresses. The need to establish baseline ecological conditions as a reference for assessing future change has grown more acute with the increasing complexity and scale of environmental issues. In the United States the Environmental Monitoring and Assessment Program is an interagency effort to provide a long-term monitoring program to determine status and trends in ecological resources at regional and national scales. This paper discusses the indicator framework for this monitoring program, the linkage between indicator selection and successful assessment, and the current status of indicator selection.

218.**Hunsaker, C.T., and D.E. Carpenter, eds.** 1990. Ecological indicators for the Environmental Monitoring and Assessment Program. EPA/600/3-90/060, Office of Research and Development. U.S. Environmental Protection Agency, Research Triangle Park, NC.

The purpose of this document is threefold: (1) to inform potential EMAP data users of the approach proposed to describe ecological condition; (2) to define a strategy for evaluating, prioritizing, and selecting indicators that will facilitate coordination and integration among each of six EMAP resource categories; and (3) to seek expert advice and environmental data sets from the scientific community that are needed to better characterize the spatial and temporal variability of the proposed indicators on a regional scale.

219.**Hunsaker, C.T., D.E. Carpenter, and J.J. Messer.** 1990. Ecological indicators for regional monitoring. Bull. Ecol. Soc. Am. 71(3):165-172.

Because we currently lack an integrated approach to monitoring indicators of ecological condition and exposure to pollutants, we cannot determine whether the frequency and extent of the problems are increasing on a regional scale, whether such patterns are warning indicators of significant long-term changes in ecosystem structure or function, or whether they are associated with changes in ambient pollution levels. The need to establish baseline conditions against which future changes can be documented with confidence has grown more acute with the increasing complexity, scale, and social importance of environmental issues such as acid deposition, global atmospheric change, and declining biodiversity. In 1988 the U.S. Environmental Protection Agency (EPA) Science Advisory Board recommended that a program be implemented within the EPA to monitor ecological status and trends,

as well as to develop innovative methods for anticipating emerging problems before they reach crisis proportions. A recent report from the National Research Council (1990) confirms the need for strengthening regional and national monitoring.

220.**Hunsaker, C., R. Graham, G. Suter II, R. O'Neill, et al.** 1989. Regional ecological risk assessment: Theory and demonstration. Environmental Science Division. ORNL Publication No. 3273. Oak Ridge National Laboratory, Oak Ridge, TN.

221.**Hunsaker, C.T., R.L. Graham, and R.V. O'Neill.** 1990. Assessing ecological risk on a regional scale. Environ. Manage. 14(3):325-332.

Society needs a quantitative and systematic way to estimate and compare the impacts of environmental problems that affect large geographic areas. This paper presents an approach for regional risk assessment that combines regional assessment methods and landscape ecology theory with an existing framework for ecological risk assessment. Risk assessment evaluates the effects of an environmental change on a valued natural resource and interprets the significance of those effects in light of the uncertainties identified in each component of the assessment process. Unique and important issues for regional risk assessment are emphasized; these include the definition of the disturbance, the assessment boundary definition, and the spatial heterogeneity of the landscape.

Key Words: Regional risk, Landscape ecology, Impact analysis, Environmental assessment

222.**Huntley, B.J., E. Ezcurra, E. Fuentes, K. Fujii, P. Grubb, W. Haber, J. Harger, M. Holland, S. Levin, J. Lubchenco, H. Mooney, V. Nerenov, I. Noble, H. Pulliam, P. Ramakrishnan, P. Risser, O. Sala, J. Sarukhan, and W. Sombroek.** 1992. A sustainable biosphere: The global imperative. Bull. Ecol. Soc. Am. 73(1):7-13.

This commentary addresses research priorities for establishing sustainability. Among the research priorities are areas related to ecological indicators, ecosystem response to stress, and documentation of the state of Earth's biotic systems.

223.**Hutchinson, T., and K. Meema, eds.** 1986. Effects of Acid Deposition on Forests, Wetlands, and Agricultural Ecosystems. Proceedings of a workshop. Springer Verlag, New York.

224.**Hutton, M.** 1982. The role of wildlife species in the assessment of biological impact from chronic exposure to persistent chemicals. Ecotoxicol. Environ. Saf. 6:471-478.

Assessments of chemical toxicity have regularly placed reliance on experimental studies that employ environmentally unrealistic exposure regimes. This approach ignores the long-term low-level nature of environmental exposure that facilitates the development of factors that modify the toxicity of such chemicals. Examples of such adaptive mechanisms will be taken from the author's own studies. Factors discussed include the development of protective trace element interactions in target organs, the induction of specific metal-binding proteins, and the alteration of the distribution of chemicals at the organ and organelle levels. Exposure-response investigations in wildlife are not restricted to the organism level; the impact of an environmentally released chemical on breeding success and population dynamics can also be investigated. Disadvantages and problems associated with this kind of study, such as multiple pollutant exposure and variability in response, will also be considered.

225.**Hytteborn, H., ed.** 1979. The Use of Ecological Variables in Environmental Monitoring. Report PM 1151. National Swedish Environmental Protection Board, Stockholm.

226.**Inhaber, H.** 1974. Environmental quality: Outline for a national index for Canada. Science 186:798-805.
In 1972, a small working group was set up in the Canadian Federal Department of the Environment to try to devise an overall environmental quality index (EQI). To take account of as many viewpoints as possible, more than 50 scientists, engineers, and administrators dealing in environmental matters were consulted. It was decided to express all data in the form of an index, defined as a unitless number that

ranged from 0 (best possible environmental condition) to increasing numbers for progressively worse environmental quality. In this way, several indices could be combined to give an overall picture of environmental quality. With this index, a value of 1 generally means that (1) an objective (or standard) is being met, (2) the index is at its highest level according to a particular scale of values, or (3) a certain environmental condition is equal to a national average. It was not possible to be consistent with respect to the criteria throughout the entire EQI because of the wide variety of data and the general lack of official standards.

227.**Inhaber, H.** 1976. Environmental Indices. John Wiley & Sons, Inc., New York.

This book provides an overview of environmental quality indices and is written in popular style. An introductory chapter gives an overview on environmental indices that discusses how an index works, how much is background, and a national vs an international index. Other chapters include: Economic indices; "What's been done so far?"; Air quality indices; Water indices; Land indices (recreation, forestry, etc.); Biological indices; Aesthetic indices and; Other environmental indices.

228.**Ivanovici, A.M., and W. Wiebe.** 1981. Towards a working definition of stress: A review and critique. Pages 13-27. In: G.W. Barrett and R. Rosenberg, eds. Stress Effects on Natural Ecosystems. John Wiley & Sons, Chichester, England.

The impact of human activity on the natural environment and methods of assessing such impact have been widely discussed in recent years. However, the difficulties in assessing impact—especially rapidly and at sublethal levels—have not been resolved. Despite widespread recognition that an accurate assessment of detrimental environmental impact or "stress" is difficult without consideration of different levels of organization (including ecosystem, physiological, and biochemical responses), much research has concentrated on ecosystem response alone (e.g., changes in community structure), in spite of the need for long periods of time before changes can be detected. Much faster response times have been found at physiological and behavioral levels than at the ecosystem level. Although several workers have shown that responses at the biochemical level are detectable even earlier, many studies of organisms in perturbed environments have shown that a number of biochemical techniques have not been as successful as hoped.

This paper reviews and critiques the concept of stress and also discusses one biochemical variable that is felt to warrant closer study, the adenylate energy charge (AEC). The authors examine the potential application of AEC to impact assessment at organism level within a population and at the community group level.

229.**Izrael, Y.A., L. Filipova, G. Insarov, F. Semevsky, and S. Semenov.** 1988. Disturbance of terrestrial ecosystems stability due to global-scale anthropogenic impacts. Environ. Monitor. Assess. 11:239-246.
Intact natural ecosystems are fairly stable objects. In the course of natural selection proceeding against the background of synecological interactions (trophic, competitive, symbiotic, etc.), a respective complex of coadapted species forms, each being maximally accommodated to its habitat. Such a complex is of specific composition and possesses stable structural characteristics. Fairly regular processes of changes in these characteristics, specific to the given type of environmental conditions, are observed in non-stationary cases.

The authors analyze probable causes of the loss of stability in natural systems exposed to human-made impacts of a global scale, in particular structural instability, landscape (disruptive) instability, and conductive instability.

The study of the mechanisms ensuring biosphere sustainability and stability of its elements is a vital ecological problem. There are applied aspects in the problem solution since identification of human-induced instability is feasible only on the basis of precise knowledge of the natural mechanisms of weak points of the relevant natural process. This circumstance makes the problem of stability one of the focal questions of applied ecology.

230.**Izrael, Y.A., and R. Munn.** 1986. Monitoring the environment and renewable resources. Pages 360-375. In: W. Clark and R. Munn, eds. Sustainable Development of the Biosphere. Cambridge University Press, Cambridge, England.

Reliable knowledge about how the biosphere has actually responded to human actions is a prerequisite for effective social responses to environmental problems. Lack of such knowledge is a major impediment to the design of sustainable development strategies. In this chapter the authors explore how environmental monitoring systems can be made more useful for the management of long-term interactions between development and environment. They begin with a review of objectives for integrated monitoring of the physical, chemical, and biological components of the biosphere. The problems of linking local and global scales of observations are discussed, as are issues on the optimization of monitoring systems. Special attention is devoted to how monitoring systems can be designed to help address the problems of timely detection of potentially irreversible trends and the identification of unexpected environmental impact.

231.**Izrael, Y.A., and F.Y. Rovinski.** 1988. Integrated background monitoring in the USSR. Environ. Monitor. Assess. 11:225-238.

The whole biosphere of the earth is faced with an increasing anthropogenic pressure. Humankind uses natural resources for its physical and spiritual demands so widely that undesirable effects appear not only in separate regions but embrace the whole biosphere as well. As a rule, such processes develop slowly. They have an irreversible character and to avoid them, preventive decisions are needed. For that purpose, comprehensive and systematic information on the state of the biosphere is needed.

The integrated background monitoring system has been implemented and is in operation in the USSR. Structurally, the integrated background monitoring system is divided into three groups: background stations on land; background stations on fresh water and; background stations on inland and periphery seas.

All of the data received from these stations are analyzed and correlated at the Natural Environment and Climate Monitoring Laboratory of the USSR State Committee for Hydrometeorology and Control of the Natural Environment, the USSR Academy of Sciences, and in other scientific institutes of the State Committee. The information serves for the assessment of the state of the environment, prediction of anthropogenic effects, and for evaluation of the measures taken to prevent pollution of the biosphere at national and international levels.

The information is shared in a wide international exchange within the framework of several international organizations (UNEP, WMO, UNES, ECE, CMEA, and others) and of the bilateral agreements on cooperation in the field of environmental protection (USA, France, Sweden, FRG, CMEA Member Countries).

232.**Jacobs, J.** 1975. Diversity, stability and maturity in ecosystems influenced by human activities. Pages 187-207. In: W. van Dobben and R. Lowe-McConnell, eds. Unifying Concepts in Ecology. Dr. W. Junk B.V. Publishers, The Hague, The Netherlands.

In discussions of the human impact on ecosystems, it is usually argued that man interferes with mature equilibrated situations, thereby reducing diversity and destroying inherent mechanisms of stability. In this argument, it is tacitly assumed that (1) the majority of ecosystems are undisturbed and more or less mature prior to human intervention, (2) mature systems are more complex and stable than immature systems, and (3) humans act as an external, unnatural force on natural ecosystems. The author attempts to show that these implications are not necessarily correct or at least are very one-sided. Selected evidence is presented that human impact affects diversity, stability, maturity, and organization in all possible directions and quantities and that humans, though unique, are to be regarded as an integrated, natural component of ecosystems if their role is to be fully understood.

The article includes a subsection on major effects of man in ecosystems in which effects are divided into four categories: 1) transient perturbations, (2) chronic shifts of environmental conditions, (3) energy and nutrient relations, and (4) manipulation of species. Regarding chronic changes, the author points out that no general statement is possible regarding how such chronic human-made developments influence diversity, stability, etc. The author then gives examples of the effects of chronic pollution by a small city on stream benthic organisms and the study of bird fauna along a city-to-country gradient.

233.**Janikowski, R.** 1991. Method for evaluating noneconomic effects of air pollution. Environ. Monitor. Assess. 16(2):151-161.

The basic premise underlying the approach presented in the paper is the assumption that humans are unique beings that can evaluate. The environment is described as a system of resources satisfying human needs. The assessment of the effects of environmental pollution derives from the fact that there is, or will be, non-satisfaction of needs resulting from a reduction in environmental resources.

234.**Jassby, A.D., and T.M. Powell.** 1990. Detecting changes in ecological time series. Ecology 71:2044-2052.

Some practical techniques are discussed for analyzing time series whose statistical properties change with time. The authors consider how principal component analysis can reduce the multidimensional nature of certain series and, in particular, apply this technique to the analysis of changing seasonal patterns. Discussions of trends, changes in oscillatory behavior, and "unusual" events follow. The problem of making inferences regarding causation is briefly considered. A call for flexibility in approach concludes the article.

235.**Jeffrey, D.** 1990. Biomonitoring of catastrophes. Environ. Monitor. Assess. 14:131-137.

The time seems appropriate to try to couple the technical literature, attitudes, and behavior associated with large scale potential accidents with what we now know of bioindicator systems. Some good case histories exist, for example, with respect to oil pollution events and unplanned releases of radioactivity. In other situations, there is work to be done, much of which should be commissioned by industry or government.

236.**Jeffrey, D., and B. Madden.** 1991. Bioindicators and Environmental Management. Academic Press, San Diego, CA.

This book is a compilation of conference papers. Major topics covered in the book are: bioindicators, industry, and administration; biomonitoring of the Chernobyl accident; monitoring long-term/large-scale environmental trends; and basic research problems.

237.**Jennings, M.D., and J.P. Reganold.** 1991. A theoretical basis for managing environmentally sensitive areas. Environ. Conserv. 18(3):211-218.

A three-step approach of different geographical scales (i.e. watershed, state, and region) was used in a series of studies to facilitate examination of the relationship between political structure and ecological theory. When viewed collectively, these studies showed that, although there is a political basis for regulating sensitive areas, attempts at regulation lack a theoretical and applied basis in "systems-thinking" and ecological science. To begin forging a stronger link between political and scientific bases for environmentally sensitive are (ESA) planning, two major ecological theories relevant to sensitive area management—hierarchy and subsidy/stress—were reviewed. These theories, when used in concert, were shown to be applicable in making objective choices concerning privately held ESAs in the Pacific Northwest. They can be used as a theoretical scientific basis for ESA planning, providing both qualitative and quantitative models. Hierarchy theory can provide guidelines for ESA planning by linking biophysical processes and patterns directly to appropriate scales of political jurisdiction. Subsidy-stress theory can be used to set specific performance standards that are needed in regulation of sensitive areas.

238.**Jernelov, A., and R. Rosenberg.** 1976. Stress tolerance of ecosystems. Environ. Conserv. 3:43-46.

Ecosystem sensitivity to stress is one of many questions that are of fundamental importance when predicting ecosystem response through the use of analogy. It is also a question of leading importance in fundamental ecological considerations. The authors raise it here because scientists disagree about the answer, and because this disagreement discloses a basic lack of understanding that must be overcome.

Following the concept of stability, together with the assertion that species living under extreme conditions are already subject to severe stress and consequently are more vulnerable to additional stress factors, it is frequently argued that, for example, the Baltic must be regarded as more susceptible than, for example, the North Sea, and thus requires stricter rules for protection. This argument is partly based on the idea that a system with high stability is less sensitive to additional stress than an unstable system. By examining the logic and content of the word stability and using examples from different ecosystems, the authors put forward conclusions that are drawn from their experience with regard to stress tolerance of ecosystems.

239.**Johnson, A.R.** 1988. Evaluating ecosystem response to toxicant stress: A state space approach. Pages 275-285. In: Aquatic Toxicology and Hazard Assessment: 10th Volume. ASTPM STP 971. American Society for Testing and Materials, Philadelphia.

Ecosystems can be regarded as complex biogeochemical systems maintained in a state of thermodynamic nonequilibrium by the flow of materials and energy. The state of such a system at any given time is generally assumed to be characterized by a finite set of measurable quantities. If these variables are taken to be the components of a vector, the instantaneous state of an ecosystem can be represented by a single point in an abstract multidimensional space. As an ecosystem undergoes changes in state, changes in the position of the corresponding vector will result, tracing out a state trajectory over time.

Within a state space representation, the response of an ecosystem to a perturbing influence, such as a toxicant, can be viewed as a displacement of the state vector away from its unperturbed trajectory. Such an approach was used to analyze data from a study of the response of experimental ponds and microcosms to chronic additions of a coal-derived synthetic oil. Ecosystem-level response surfaces and dose-response curves were derived based upon the average separation (distance of displacement) of exposed ecosystems relative to controls. The results exhibited patterns analogous to those observed in classical toxicology based on organismal response and could be used to define acceptable exposure conditions. The state space approach described here provides a coherent and objective framework for summarizing a large multivariate data set and should be of general use in providing both qualitative and quantitative descriptions of the behavior of perturbed ecosystems.

Key Words: State space analysis, Ecotoxicology, Microcosms, Ponds, Synthetic oil

240.**Johnson, A.R.** 1988. Diagnostic variables as predictors of ecological risk. Environ. Manage. 12(4):515-523.

The state of an ecosystem may be represented by a multidimensional state record, x. The goal of ecosystem management is to ensure that the ecosystem remains within some set of X of acceptable states, such that x is a part of X. Because ecosystem management decisions must be based on limited knowledge, a small number of diagnostic variables must be found that accurately reflect ecosystem state. If the vector of diagnostic variables w is found to be within a specified set, the state vector x is predicted to be within X. The selection and use of such diagnostic variables is examined in the context of an aquatic ecosystem simulation model. Techniques used in searching for diagnostic criteria include multiple linear regression, discriminant analysis, and visual inspection of graphical data displays. The adequacy of a diagnostic criterion as a predictor of ecological risk is demonstrated to be a function of the associated rates of type I and type II statistical errors. A simple cost-benefit analysis is undertaken to illustrate one approach for choosing an optimal balance between these error rates.

Key Words: Diagnostic variables, Risk, Error rates, Cost-benefit, Multiple regression, Discriminant analysis

241.**Johnson, M.L., D.G. Huggins, and F. DeNoyelles, Jr.** 1991. Ecosystem modeling with LISREL: A new approach for measuring direct and indirect effects. Ecol. Appl. 1(4):383-398.

Evaluating the effects of toxicants in ecosystems is difficult despite numerous attempts to develop field and laboratory tests. The problem appears to be lack of an analytical methodology capable of taking advantage of the available experimental designs. Therefore, the authors propose a technique for modeling ecosystems-linear structural modeling with LISREL. LISREL is a path analytical technique that is more flexible than classical path analysis. Modeling with LISREL involves placing ecosystem structure and function into a framework of concepts and indicator variables. Concepts are theoretical constructs that are placed into a cause-and-effect network to reflect true ecosystem structure. Concepts are "indicated" by indicator variables; these are the measured variables in the ecosystem. LISREL incorporates measurement error into the modeling process by establishing a portion of the variance of each indicator variable as measurement error. The framework of concepts and indicators in a cause-and-effect network becomes a hypothesis that is tested using LISREL. LISREL also provides a determination of the total, direct, and indirect effects of the variables on each other. A measure of ecosystem stability is provided as part of the modeling process.

Key Words: Causal processes, Disturbance, Ecosystem, Ecotoxicology, LISREL, Modeling, Path analysis

242.**Jones, K.** 1990. The Environmental Monitoring Program—An ecological monitoring program for the 1990's and beyond. Pages 669-681. In: GIS/LIS 90 - Technical Papers. Geographic Information Systems/Land Information Systems Annual Conference, November 5-10, Anaheim, CA. American Congress on Surveying and Mapping, Falls Church, VA.

Over the past several years we have become increasingly concerned about the condition of the environment. However, recently the focus in concern has shifted from local scales (e.g., condition in individual wetlands) to regional, continental, and global scales (e.g. global climate change), and from individual resources (e.g., timber) to a more holistic ecological approach. Although data are available that allow for local (e.g. effluent compliance by an individual factory) and gross, large scale (e.g. global circulation and climate models) assessments, data necessary to make regional scale assessments are generally lacking. This results from deployment of sampling designs that optimize assessments at these scales. Of those monitoring projects designed to make assessments at regional scales, the focus has been on answering questions about specific resources (e.g. timber production in forests); none have a holistic ecological approach. The Environmental Monitoring and Assessment Program (EMAP), a program being coordinated by the Environmental Protection Agency, but developed by a number of Federal agencies, institutes, and universities, will focus on regional and national scale assessment of ecological resources over periods of years to decades.

243.**Jorgensen, S.E.** 1992. Ecological indicators and ecosystem modelling. Pages 201-211. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Useful models are currently available in the field of environmental management. However, up to now, it has not been possible to develop models to cope with the problem of changes in species composition. A few examples of how important species composition is as ecological indicators are given as a basis for the modeling effort.

Results of a recently developed modeling approach that is able to make predictions on species composition, are presented and four case studies (i.e., four different lakes where this approach has been used) are presented. However, the application of the approach may be applied more generally.

244.**Karlen, D., N. Eash, and P. Unger.** 1992. Soil and crop management effects on soil quality indicators. Am. J. Altern. Agric. 7(1-2):48-55.

People are becoming more aware that our soil resources are as vulnerable to degradation as air or water, but criteria are needed to learn how soil quality is changing. The objectives in this review are: (1) to illustrate that interactions between human and natural factors determine soil quality, (2) to identify indicators that can be used to evaluate human–induced effects on soil quality; and (3) to suggest soil and crop management strategies that will sustain or improve soil quality. The physical, chemical, and biological processes and interactions within the soil are critical factors affecting all indicators of soil quality. The biological processes are especially important because they provide much of the resiliency or buffering capacity to ameliorate stress.

Key Words: Soil tilth, Conservation tillage, Cover crops, Crop rotations

245.**Karr, J.R.** 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6):21-27.

Human activities have had profound, and usually negative, influences on freshwater fishes from the smallest streams to the largest rivers. To assess negative effects of human activities on fishes, some studies have attempted to use water quality as a surrogate for a more comprehensive biotic assessment. A more refined biotic assessment program is required for effective protection of freshwater fish resources. The assessment system proposed here uses a series of fish community attributes related to species composition and ecological structure to evaluate the quality of an aquatic biota. In preliminary trials this system accurately reflected the status of fish communities and the environment supporting them.

246.**Karr, J.R.** 1987. Biological monitoring and environmental assessment: A conceptual framework. Environ. Manage. 11:249-256.

Direct biological monitoring is essential for effective environmental assessment. Past approaches to biomonitoring are too simplistic (e.g., toxicity testing and indicator species) or conceptually invalid (diversity indexes), whereas assessments that use ecological guilds integrate ecological principles to a greater extent. The best long-term approach is development of suites of metrics, like those used in the index of biotic integrity (IBI), to reflect individual, population, community, and ecosystem attributes in an integrative framework. Efforts to use the conceptual content of IBI in a wider diversity of habitats should be encouraged and followed up with effective control action.

Key Words: Biological monitoring, Biotic integrity, Bird communities, Environmental assessments, Fish communities, Guilds, Indicator species, Water resources

247.**Karr, J.R.** 1991. Biological integrity—A long-neglected aspect of water resource management. Ecol. Appl. 1(1):66-84.

Water of sufficient quality and quantity is critical to all life. Increasing human population and growth of technology require human society to devote more and more attention to protection of adequate supplies of water. Although perception of biological degradation stimulated current state and federal legislation on the quality of water resources, that biological focus was lost in the search for easily measured physical and chemical surrogates. The "feasible and swimmable" goal of the Water Pollution Control Act of 1972 (PL 92-500) and its charge to "restore and maintain" biotic integrity illustrate that law's biological underpinning. Further, the need for operational definitions of terms like "biological integrity" and "unreasonable degradation" and for ecologically sound tools to measure divergence from societal goals has increased interest in biological monitoring. Assessment of water resource quality by sampling biological communities in the field (ambient biological monitoring) is a promising approach that requires use of ecological expertise. One such approach, the Index of Biotic Integrity (IBI), provides a broadly based multiparameter tool for the assessment of biotic integrity in running waters. IBI based on fish community attributes has now been applied widely in North America. The success of IBI has stimulated the development of similar approaches using other aquatic taxa. Expanded use of ecological expertise in ambient biological monitoring is essential to the protection of water resources. Ecologists have the expertise to contribute significantly to those programs.

Key Words: Biological integrity, Biological monitoring, Fish community, Index of Biotic Integrity (IBI), Indexes of degradation, Indicators, Water pollution, Water resources

248.**Kay, D.** 1990. Book review: Environmental monitoring assessment and management—The agenda for long-term research and development. J. Rural Stud. 6(4):450-451.

This is a positive review for a book that points to some of the pitfalls of past monitoring programs. The reviewer agrees with most of the problems that the book identifies and supports the author's notion of where future research should be headed, such as synergistic effects of toxins and effects of pollutants on non-target species.

249.**Kay, J.J.** 1991a. A nonequilibrium thermodynamic framework for discussing ecosystem integrity. Environ. Manage. 15(4):483-495.

During the last 20 years, our understanding of the development of complex systems has changed significantly. Two major advancements are catastrophe theory and nonequilibrium thermodynamics with its associated theory of self-organization. These theories indicate that complex system development is nonlinear, discontinuous (catastrophes), not predictable (bifurcations), and multivalued (multiple development pathways). Ecosystem development should be expected to exhibit these characteristics.

Traditional ecological theory has attempted to describe ecosystem stress response by using some simple notions such as stability and resiliency. In fact stress-response must be characterized by a richer set of concepts. The ability of the system to maintain its current operating point in the face of the stress must be ascertained. If the system changes operating points, there are several questions to be considered: Is the change along the original developmental pathway or a new one? Is the change organizing or disorganizing? Will the system return to its original state? Will the system flip to some new state in a catastrophic way? Is the change acceptable to humans?

The integrity of an ecosystem does not reflect a single characteristic of an ecosystem. The concept of integrity must be seen as multidimensional and encompassing a rich set of ecosystem behaviors. A framework of concepts for discussing integrity is presented in this article.

Key Words: Integrity, Stress-response, Nonequilibrium, Stability, Thermodynamics

250.**Kay, J.J.** 1991b. The concept of ecological integrity, alternative theories of ecology, and implications for decision-support indicators. Pages 23-58. In: P. Victor, J. Kay, and H. Ruitenbeek. Economic, Ecological, and Decision Theories: Indicators of Ecologically Sustainable Development. Canadian Environmental Advisory Council, Environment Canada, Ottawa.

The subject of this paper is indicators of ecological sustainability. To discuss this subject, an appreciation of the state of ecology is required. Ecology as a science is at a formative stage, in much the same state as physics at the time of Galileo. We await the insight of a Newton. There is little consensus in theoretical ecology about what the important characteristics of ecosystems are. In spite of this, there is the beginning of an empirical understanding of the effects of environmental change on ecosystem development and hence sustainability. This paper will explore some recent advances in our understanding of the development of complex systems, their implications for our understanding of how ecosystems develop, a framework for discussing ecosystem integrity, and current theories related to integrity and the measures they suggest. A basic premise of this discussion is that if economic development is to be sustainable then it should enhance the integrity of ecosystems, or at the very least not erode ecosystem integrity.

251.**Kay, J.J.** 1992. Thermodynamics and measures of ecological integrity. Pages 159-182. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19, October 1990. Elsevier, Essex, England.

Integrity of an ecosystem refers to its ability to maintain its organization. Measures of integrity should reflect the organizational state of an ecosystem. Ecosystem organization has two distinct aspects, functional and structural. Function refers to the overall activities of the ecosystem. Structure refers to the interconnection between the components of the system. Measures of both these aspects of organization will be presented in this paper.

Recent work suggests that self-organization in biological systems is necessitated by the second law of thermodynamics. Thus, organization tends to increase ecosystem degradation of energy. Measures of ecosystem organization should, therefore, reflect energy usage and degradation in ecosystems. Measures of energy utilization in the ecosystem food web and by the ecosystem will be presented.

Measures of function would indicate the amount of energy being captured by the system and the way in which it is being degraded (for example respiration vs evapotranspiration). Measures of structure would indicate the way in which energy is moving through the system. For example, measures of the amount of recycling in the system, the effective trophic levels of species, and the average specialization of the resource niche all reveal something about how energy is being used in the ecosystem.

Examples of the application of these measures to the development of ecosystems and the examination of stress effects will be presented. How these measurements can be used to assess ecosystem integrity will be discussed.

252.**Keddy, C., and T. McCrae.** 1989. Environmental databases for state of the environment reporting: Conservation and protection headquarters. Report No. 9, Strategies and Scientific Methods, SOE Reporting Branch. Canadian Wildlife Services, Environment Canada, Ottawa.

253.**Keddy, P.A.** 1991. Biological monitoring and ecological prediction: From nature reserve management to national state of the environment indicators. Pages 249-267. In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

The techniques for biological monitoring are well-developed, as shown by examples in the preceding chapters. This chapter will explore two further issues: first, How do we decide what to measure? and, second, What do we do with the data once it is collected? By examining these questions, we may make modifications to our biological monitoring programs and growing computer data bases. The issues addressed are the following.

1. The selection of the state variables to be monitored. With more than a million species on the planet, we cannot possibly monitor each one. Moreover, given predictions that a quarter of these species may be extinct by the end of the next century, we cannot possibly monitor even the threatened ones. How do we choose what to monitor? The author suggests that a greater emphasis be placed on macro-scale state variables.

2. The interaction between monitoring and decision-making. Monitoring is by its very nature post hoc (i.e., it can only tell us what has already happened). However, to wisely manage the biosphere, we need to predict future events. What is the relationship between biological monitoring, prediction, and decision making?

254.**Kelly, J.R., and M.A. Harwell.** 1989. Indicators of ecosystem response and recovery. Pages 9-39. In: S. Levin, M. Harwell, J. Kelly, and K. Kimball, eds. Ecotoxicology: Problems and Approaches. Springer-Verlag, New York. 547 pp.

The authors focus on the fundamental issue of how to characterize an ecosystem's response to disturbance and its subsequent recovery when the stress is removed. Thus, the role of this chapter is partially introductory for the book as a whole. It presents the basic aspects on which the body of an adequate ecological risk assessment would rest for any given ecological disturbance. Initially, principal characterization of ecosystem exposure, response, and recovery are discussed in depth; the scope of characterization examined here contrasts with that actually conducted for ecosystem and/or stress-specific problems addressed in succeeding book chapters. The reality is that characterization of these elementary aspects rarely has been achieved to a desired level for a risk assessment. Yet, critically, the three basic concerns — exposure, response, and recovery — fundamentally affect the choice of parameters and methods to measure ecological change. From these considerations, the final focus is on the qualities of indicators of ecological effects from anthropogenic and chemical stress.

255.**Kelly, J.R., and M.A. Harwell.** 1990. Indicators of ecosystem recovery. Environ. Manage. 14(5):527-545.
Assessment of ecological changes relative to disturbance, either natural or human-induced, confronts a fundamental problem. Ecosystems are complex, variable, and diverse; consequently, the need for simplification to essential features that would characterize ecosystems adequately is generally acknowledged. Yet there is no firm prescription of what to measure to describe the response and recovery of ecosystems to stress. Initial focus is provided by identifying relevant ecological endpoints (i.e., ecological changes of particular relevance to humans). Furthermore, the authors suggest generic purposes and criteria to be considered in making choices of ecological indicators that relate to those endpoints. Suites of indicators, with a variety of purposes, are required to assess response and recovery of most ecosystems and most stresses. The authors suggest that measures of certain ecosystem processes may provide special insight on the early stages of recovery; the use of functional indicators to complement other biotic indicators is highlighted in an extended example for lotic ecosystems.

Key Words: Ecological indicators, Stress, Scale, Recovery, Ecosystem processes

256.**Kelly, J., T. Duke, M. Harwell, and C. Harwell.** 1987. An ecosystem perspective on potential impacts of drilling fluid discharges on seagrasses. Environ. Manage. 11(4):537-562.

Potential effects of oil drilling fluid discharges on *Thalassia* seagrass ecosystems were examined using seagrass core microcosms. Observed experimental effects, summarized in this article, included changes in both autotrophic (*Thalassia* and epiphyte) and heterotrophic (dominant benthic macroinvertebrates) species and the processes of primary productivity and decomposition. The physical disturbance related to greater turbidity and sedimentation caused some effects; other effects seemed to be a direct response to the toxic constituents of drilling fluids. Using these experimental results and the case of *Thalassia* and drilling fluids as a case study, the authors explore general methodological and philosophical issues for ecotoxicology and, furthermore, focus on the challenge of providing a scientific basis for judging acceptability of environmental changes likely to ensue from human activities.

Key Words: Seagrass, Drilling fluids, Ecotoxicology, Risk assessment

257.**Keough, M., and G. Quinn.** 1991. Causality and the choice of measurements for detecting human impacts in marine environments. Aust. J. Mar. Freshwater Res. 42(5):539-554.

The choice of biological indicator variables to be measured in detecting human impacts on the environment is a critical one. The usual community-level measures (species richness and diversity) generally have questionable theoretical justification, have no demonstrable causal links to the impact, and are dependent on the taxonomic expertise available. Results from trampling experiments on an intertidal rocky shore demonstrate that these measures are also insensitive in detecting impacts that clearly affect populations of individual species. The need for experimental work that identifies which indicator variables are causally linked to human impacts and, therefore, which will be useful in monitoring is emphasized.

258.**Kerekes, J.J.** 1992. Aquatic research and long–term monitoring in Atlantic Canada's national parks. Pages 411-416. In: J. Willison, S. Bondrup–Nieslen, C. Drysdale, T. Herman, N. Munro, and T. Pollock, eds. Science and the Management of Protected Areas. Elsevier, Amsterdam.

Relatively pristine waters resources, protected from direct human influence within national parks offer a unique opportunity for scientific research. One type of research is the comparison of limnological data obtained in a large number of waterbodies. Such measurement may explain cause and effect relationships concerning the condition of these waters. Another approach is the continuous monitoring of selected waterbodies that describes "average" conditions, annual and temporal variations of physical, chemical and biological features allowing the detection of long–term changes. Both strategies have been used by the Canadian Wildlife Service in National Parks in the Atlantic Region.

259.**Kerr, A.** 1990. Canada's National Environmental Indicators Project: Background Report. Environment Canada, Sustainable Development and State of the Environment Reporting Branch, Ottawa, Ontario.

260.**Kerr, S., and L. Dickie.** 1984. Measuring the health of aquatic ecosystems. Pages 279-284. In: V. Cairns, J. Nriagu, and P. Hodson, eds. Contaminant Effects on Fisheries. John Wiley & Sons, Inc., New York.

The authors deal with the feasibility of assessing ecological health at the community level of biological organization. In particular, they demonstrate that a theoretical basis exists to support the possibility of deriving useful indices of community health and that both theoretical and empirical support exists for the criterion chosen.

261.**Kickert, R., and P.Miller.** 1979. Responses of ecological systems. Pages 1-45. In: W. Heck, S. Krupa, and S. Linzon, eds. Handbook for the Assessment of Air Pollution Effects on Vegetation. Air Pollution Control Association (APCA), Pittsburgh, PA.

262.**Kimball, K., and S. Levin.** 1985. Limitations of laboratory bioassays: The need for ecosystem level testing. Bioscience 35(3):165-171.

Laboratory bioassays provide a first step in testing for chemical effects on ecosystems but are inadequate for predicting effects on natural populations and on ecosystem-level features. For these purposes we need microcosm studies, controlled experimental manipulations of whole ecosystems, and a sound theoretical basis for extrapolation.

263.**Kimmins, J.** 1990. Interpreting the long-term significance of short-term environmental monitoring data — The need for ecosystem management models like Forcyte and Forecast. Pages 1063-1071. In: H. Lund and G. Preto, eds. Global Natural Resource Monitoring and Assessments: Preparing for the 21st Century. American Society for Photogrammetry and Remote Sensing, Bethesda, MD.

Short term monitoring and assessment data provide a "snapshot" of ecosystem condition. For many aquatic ecosystems, in which "natural" directional change is normally slow, a series of such "snapshots" can provide an ecologically meaningful measure of anthropogenically-induced change. In contrast, most forest ecosystems are changing more or less continuously as they recover from some earlier disturbance. Monitoring of forests should therefore be based on comparisons between the temporal patterns of expected ecosystem change, and the actual condition as revealed by monitoring.

Patterns of expected change can be inferred from long-term monitoring data, if appropriate data exist. In the absence of such empirical evidence, ecosystem-level models can be used to simulate these "temporal fingerprints" of recovery from disturbance. Because most forest ecosystems are subject to both anthropogenic and natural disturbances, such models should simulate the impacts of both forest management and a variety of natural perturbations. The FORCYTE (FORest Nutrient Cycling and Yield Trend Evaluator) model can simulate such "temporal fingerprints" associated with a wide variety, frequency, and intensity of management disturbance factors. A new model, FORECAST (FORestry and Environmental Change ASsessmenT), will, in addition, simulate the effects of acid rain, climate change, and physical damage to soils.

264.**Kimmins, J.** 1990. Monitoring the condition of the Canadian forest environment: The relevance of the concept of "ecological indicators." Environ. Monitor. Assess. 15:231-240.

The Canadian forest environment is characterized by high spatial and temporal variability, especially in the west. Our forests vary according to climate, landform, and surficial geology and according to type of, intensity of, extent of, and the time since the last disturbance. Most Canadian forests have had a history of repeated acute, episodic disturbance from fire, insects, wind, diseases, and/or logging, with a frequency of disturbance varying from a few decades to many centuries. These sources of variability have resulted in a complex and continually changing mosaic of forest conditions and stages of successional development.

Monitoring the "quality" of this dynamic forested landscape mosaic is extremely difficult, and in most cases the concept of a relatively simple index of forest ecosystem quality or condition (i.e., an "ecological indicator") is probably inappropriate. Such ecological indicators are better suited for monitoring chronic anthropogenically induced disturbances that have continuous effect (e.g., acid rain, heavy metal pollution, air pollution, and the greenhouse effect) in ecosystems that, in the absence of such chronic disturbance, exhibit very slow directional change (e.g., lakes, higher-order streams, and rivers).

Monitoring the effects of a chronic anthropogenic disturbance to forest ecosystems to determine if a sustained, directional alteration of environmental "quality" results will require a definition of the expected pattern of episodic disturbance and subsequent recovery therefrom (i.e., patterns of secondary succession in the absence of chronic disturbance). Only when we have such a "temporal fingerprint" of forest ecosystem condition for "normal" patterns of disturbance and recovery can we determine if the ecosystem condition is being degraded by chronic human-induced alteration of the environment. Thus, degradation is assessed in terms of deviations from the expected temporal pattern of conditions rather than in terms of an instantaneous assessment of any particular condition. The concept of "ecological rotation" (the time for a given ecosystem to recover from a given disturbance back to some defined successional condition) is useful for the definition of "temporal fingerprints". This requires information on the intensity of disturbance, the frequency of disturbance, and the rate of recessional recovery. Only when all three of these are known or estimated can statements be made as to whether the ecosystem is in a long-term sustainable condition or not.

The somewhat overwhelming complexity of this task has led forest ecologists to use ecosystem-level computer simulation models. Appropriately structured and calibrated models of this type can provide predictions of the overall temporal patterns of ecosystem structure and functions that can be expected to accompany a given frequency and character of episodic disturbance. Such models can also be used to examine the long-term consequences of chronic disturbances such as acid rain and climatic change. Predictive ecosystem-level models should be used in conjunction with some method of satisfying the inherent spatial biophysical variability of the forest environment, such as the biogeoclimatic classification system of British Columbia.

265.**Kimmins, J.** 1990. Workgroup issue paper: Indicators and assessment of the state of forests. Environ. Monitor. Assess. 15:297-299.

This article briefly addresses the factors affecting the condition of forest ecosystems and the use of models to assess forests.

266.**Klopatek, J., J. Kitchings, R. Olsen, K. Kumar, and L. Mann.** 1981. A hierarchical system for evaluating regional ecological resources. Biol. Conserv. 20:271-290.

A methodology has been developed to measure the ecological quality of potential wilderness areas under the U.S. Department of Agriculture (USDA) Forest Service's Roadless Area Review and Evaluation (RARE-II) Program. Four major parameters were chosen to quantify land areas located anywhere in the conterminous United States. These are (1) vegetation, (2) avian communities and the quality of habitat provided by an area, (3) mammal communities, and (4) endangered or threatened species. The results are shown for the Douglas-fir ecoregion of the United States and are used in a conflict matrix to segregate identified tracts according to their ecological ratings and energy and mineral resource ratings.

267.**Koeman, J.** 1991. From comparative physiology to toxicological risk assessment. Comp. Biochem. Physiol. 100C(1/2):7-10.

Comparative physiology may help to improve toxicologists' ability to assess and predict toxicological risks of chemicals. Three main lines of approach have been distinguished (1) comparative research concerning the toxicokinetics of chemicals in different species, (2) research concerning ecophysiological characteristics, and (3) studies aimed at the identification of biological markers that can be used to signal toxic effects in both experimental and free-living populations of organisms.

Some limiting conditions have to be fulfilled in order to make comparative physiology valuable from a toxicological point of view.

268.**Kolasa, J., and S.T.A. Pickett.** 1992. Ecosystem stress and health: An expansion of the conceptual basis. J. Aquat. Ecosyst. Health 1(1):7-14.

The assessment of the ecosystem health and departures from it requires clarity of what the system, its structure, dynamics, and healthy conditions are. Available definitions provide inadequate tools to acquire this clarity and may lead to arbitrary diagnoses of ecosystem health but such diagnoses can be overturned on a variety of scientific, philosophical, or political grounds.

Nested hierarchy of ecosystem structure compounds the difficulty in the assessment of stress and health because both states may occur simultaneously at different hierarchical levels: with stress at one level being a necessary condition of health at another.

An approach based on a formal definition of system change is advanced. First, a conceptual model identifies a self–maintaining minimum interactive structure (MIS) at each level of ecosystem organization. Components of MIS are complementary, coordinated, and exchanging information — they are integrated. Function is defined as a contribution of a component to the maintenance of the whole. In this context health is viewed as persistence of the system at a given temporal and spatial scale. Impairment of the function is stress and is contrasted with change of system structure (loss, addition, or replacement of components of MIS) which is disturbance. Stress can be measured directly by changes of function or indirectly by changes in integration. Even though undesirable from the human point of view, a changed system may again be considered healthy.

Key Words: Definition (of stress), Ecosystem function, General theory, System organization

269.**Koonce, J.F.** 1990. Commentary on fish community health: Monitoring and assessment in large lakes. J. Great Lakes Res. 16(4):631-634.

Although ecosystem models have often been applied to fish communities, these communities are more loosely organized than are entire ecosystems, therefore, are subject to different criteria of system health. Indicators of ecosystem health, such as lake trout, have frequently been identified, but the end use of information about ecosystem health based on these indicators is not always specified. Thus management actions are not always specified.

270.**Koskimies, P.** 1989. Birds as a tool in environmental monitoring. Ann. Zool. Fennici 26(3):153-166.

This paper reviews the use of birds as a tool in environmental monitoring by discussing the value of birds as biological indicators and by describing the integrated bird monitoring program in Finland. The paper emphasizes the central role of the interpretation of data. It is important that environmental authorities are aware of this interpretation.

Birds are useful biological indicators of, for example, broad-scale habitat changes and environmental contaminants. Birds are especially suitable for detecting unexpected changes that cannot be observed by measuring preselected physical and chemical parameters and for monitoring biological, often cumulative and nonlinear consequences of many environmental changes acting simultaneously.

In Finland, about 15 study projects that monitor the regional population ecology of birds have been integrated to give maximal opportunity for data record linkage across projects. The breeding and wintering resident species are the most important populations for monitoring. The interpretation of results, the most important part of monitoring, tries to confirm cause-effect relationships between birds and their environment. Useful approaches to find the reasons for bird population changes include use of indicator species, comparison of species with similar ecologies, and partitioning the total population change into different population processes. Knowing the reasons for changes is necessary to prevent negative environmental changes that influence both nature and human well-being.

271.**Krantzberg**, G. 1990. Rapporteur's report of work group: Indicators at community or systems level. Environ. Monitor. Assess. 15:283-284.

This summary of a conference workgroup briefly reports on aspects of monitoring and approaches to identifying indicators.

272.**Kreisel**, W. 1984. Representation of the environmental quality profile of a metropolitan area. Environ. Monitor. Assess. 4(1):15-33.

The spatially and temporally varying environmental quality of a metropolitan area is described by means of empirically derived environmental indices. The approach is based on the principles of benefit analysis and consists of a number of logical steps, including the selection, the measurement and determination of the spatial distribution, and the normalization (scaling) of the selected environmental indicators. To derive composite indices, the normalized indicators are weighted, based on the Delphi technique, and subsequently aggregated. The results are given by means of isopleths, including single and composite index isopleths plotted by computer on common maps.

273.**Kremen**, C. 1992. Assessing the indicator properties of species assemblages for natural areas monitoring. Ecol. Appl. 2(2):203-217.

The diversity of organisms and complexity of ecosystems prevent thorough inventory and monitoring of protected areas, yet sound databases are needed to manage ecosystems for long-term persistence. One strategy is therefore to focus monitoring on indicator organisms, but guidelines are lacking for selecting appropriate species or groups. This paper presents a simple protocol based on ordination techniques for establishing the indicator properties of a group of organisms and for selecting an indicator species subset for more intensive monitoring. Use of ordination allows inclusion of many more taxa than have been traditionally used for natural areas monitoring, and need not rely on detailed knowledge of species biology. As an example, the author studied the indicator properties of a butterfly taxocene in a rain forest in Madagascar. Butterflies have been suggested as particularly good environmental indicators due to their sensitivity to micro-climate and light level changes, and their interactions as larvae and adults with different sets of host plants. The indicator properties of butterfly assemblages were evaluated in this study with respect to a known pattern of environmental heterogeneity along topographic/moisture and disturbance gradients. Butterfly assemblages were found to be excellent integrators of heterogeneity due to the topographic/moisture gradient, limited indicators of heterogeneity due to anthropogenic disturbance, and poor indicators of plant diversity. The protocol defined in this study is widely applicable to other groups of organisms, spatial scales, and environmental gradients. By examining the environmental correlates of the distribution of species assemblages, this protocol can assess the indicator properties of target species groups.

Key Words: Diversity, Dominance, Ecological monitoring, Indicator species assemblage, Madagascar, Natural areas conservation, Ordination, Rarity, *Satyrinae*, Tropical butterflies

274.**Kuchenberg**, T. 1985. IJC Conference: Measuring the health of the ecosystem. Environment 27(2):32-37.

This article summarizes some of the issues raised at the October 1984 workshop sponsored by the International Joint Commission Transboundary Monitoring Network. Concepts surrounding environmental and ecosystem monitoring and definitions of monitoring terms are also discussed.

275.**Kutz, F., and R. Linthurst.** 1990. A systems-level approach to environmental assessment. Toxicol. Environ. Chem. 28:105-114.

This paper presents an overview of the rationale, goals, and primary elements of the Environmental Monitoring and Assessment Program (EMAP), which represents a long-term commitment to periodically assess and document the condition of the ecological resources of the United States. EMAP is being designed by the U.S. Environmental Protection Agency's (EPA) Office of Research and Development. The program will serve a spectrum of decision makers who require information to set environmental policy, program managers who require an objective basis for allocating research and monitoring funds, scientists who desire a broader understanding of ecosystems, and those interested in evaluating the effectiveness of the U.S. environmental policy.

Key Words: Ecological resources, Environmental assessment, Status and trends, Ecological indicators and endpoints, Geographic information system

276.**Kutz, F., R.A. Linthurst, C. Riordan, M. Slimak, and R. Frederick.** 1992. Ecological research at EPA: New directions. Environ. Sci. Technol. 26(5):860-866.

This article describes the development of strategies for ecological research within the EPA's Office of Research and Development. The Ecological Risk Assessment Program, EMAP, and the use of indicators are overviewed.

277.**Landres, P.B.** 1983. Use of the guild concept in environmental impact assessment. Environ. Manage. 7(5):393-398.

This paper attempts to clarify and expand several ideas concerning use of the guild concept in environmental impact assessment. Background material on the concept and examples of its use are given. For purposes of environmental assessment a resource-based guild approach is suggested to be preferable to a taxonomic-based approach. Validity of the guild concept, problems in classifying species into guilds, implications of guild membership, and usefulness of guild analyses are discussed. The author concludes that a thorough knowledge of both its limitations and benefits will enable researchers to fully use the guild concept for understanding organizational processes in communities and ecosystems and for assessing environmental impacts.

Key Words: Guild concept, Environmental assessment

278.**Landres, P.** 1992. Ecological indicators: Panacea or liability? Pages 1295-1318. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators, held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

This paper examines two ecological uses of indicator species: to assess population trends for other species of interest and to monitor habitat "quality" or the "health" of an ecosystem. Several U.S. federal agencies are currently using ecological indicators, and eminent scholars advocate their use. These applications of ecological indicators are based on two assumptions. First, assessing one or several indicator species is a cost-effective alternative to monitoring all the species in an ecosystem. Second, indicator species provide a sufficiently precise and accurate assessment of other species, an entire community, or an ecosystem.

Analysis of current uses of ecological indicators refutes both assumptions. For a single conspicuous, easily recognized, and currently used indicator species, the cost of determining yearly population change is shown to be over $1 million. In addition, neither conceptual nor empirical studies support extrapolating the population trend of an indicator species to other species.

Several problems arise in using an indicator species to monitor or assess habitat quality. First, population density of an indicator is a tenuous index of habitat quality. Second, usefulness of an indicator in one geographic area cannot be extrapolated to other areas. Third, managing an area for an indicator probably maintains only those resources needed by that species, ignoring resources needed by other species. In particular, problems with high trophic-level mammalian and avian "umbrella" species are discussed. Fourth, indicators chosen by arbitrary or confounded criteria destroy any effectiveness and credibility of an indicator. Fifth, with no clear and agreed upon definition for the phrase "habitat quality," it is difficult or impossible to judge the efficacy of an ecological indicator.

As currently used, ecological indicators are not adequate to assess population trends of other species or habitat quality of natural systems. Despite this conclusion, ecological indicators will continue to be used; eight recommendations are offered to make their use more rigorous, credible, and effective.

Finally, an ecosystem-based approach to monitoring and assessment that relies on ecosystem indicators is presented as an alternative to the use of status quo ecological indicators. Concepts of ecosystem "health" and "stress," defining and selecting ecosystem indicators, and problems with this approach are all discussed.

279.**Landres, P.B., J. Verner, and J. Thomas.** 1988. Ecological uses of vertebrate indicator species: A critique. Conserv. Biol. 2:316-328.

Plant and animal species have been used for decades as indicators of air and water quality and agricultural and range conditions. Increasingly, vertebrates are used to assess population trends and habitat quality for other species. This paper reviews the conceptual bases, assumptions, and published guidelines for selection and use of vertebrates as ecological indicators. The authors conclude that an absence of precise definitions and procedures, confounded criteria used to select species, and discordance with ecological literature severely weaken the effectiveness and credibility of using vertebrates as ecological indicators. In many cases, the use of ecological indicator species is inappropriate, but when their use is necessary, the following recommendations will make their application more rigorous: (1) clearly state assessment goals; (2) use indicators only when other assessment options are unavailable; (3) choose indicator species by explicitly defined criteria that are in accord with assessment goals; (4) include all species that fulfill stated selection criteria; (5) know the biology of the indicator in detail, and treat the indicator as a formal estimator in conceptual and statistical models; (6) identify and define sources of subjectivity when selecting, monitoring, and interpreting indicator species; (7) submit assessment design, methods of data collection and statistical analysis, interpretations, and recommendations to peer review and; (8) direct research toward developing overall strategy for monitoring wildlife that accounts for natural variability in population attributes and incorporates concepts from landscape ecology.

280.**Langlois, C., M. Leveille, and L. Lapierre.** 1990. Assessment of St. Lawrence ecosystem quality: Use of biochemical, histological, chemical and ecological indicators. In: Physiological and Biochemical Approaches to the Toxicological Assessment of Environmental Pollution. Annual Conference on Physiological Approaches to the Toxicological Assessment of Environmental Pollution, August 27-31, 1990. Royal Netherlands Chemical Society, Utrecht, The Netherlands.

The Ecosystem Assessment Program of the St. Lawrence Action Plan has two major objectives: to assess the current state of health of the aquatic ecosystems in the St. Lawrence River and to establish a monitoring network on a long-term basis. The study area in 1989 comprised the three major riverine lakes: Lake St. Francois downstream of the international (US–Canada) section of the river and of the Great Lakes basin, Lake St. Louise at the confluence of the Ottawa River and the St. Lawrence, and Lake St. Pierre, downstream of the Montreal metropolitan area. Fish and benthic communities were studied to identify potential effects of toxic inputs on their integrity. This assessment was made by using ecological, biochemical, histological, and chemical indicators.

281.**Larson, D.P., D.L. Stevens, A.R. Selle, and S.G. Paulsen.** 1991. Environmental Monitoring and Assessment Program - Surface Waters: A northeast lakes pilot. Lake Reserv. Manage. 7(1):1-11.

282.**Leak, W.B.** 1992. Vegetative change as an index of forest environmental impact. J. For. 90(9): 32-35.

This article focuses on monitoring change in site productivity to detect stress on forests. Site change is a likely consequence of many sources of stress, and represents a long-term effect that is not easily remedied. The discussion suggests that environmental influences that alter forest site conditions can best be detected by the same methods and measures that have proven useful in site evaluation. In other words, measures currently used to detect important spatial differences in forest sites will also be the measures most likely to detect site changes over time resulting from environmental effects. After a review of site evaluation approaches, vegetative community and height growth are presented as methods to measure site-related impact. Data on vegetative change on the Bartlett Experimental Forest are examined as an example of how vegetative change could, with further analysis, be used to assess environmental impact.

283.**Leatherland, J., and R. Sonstegard.** 1984. Great Lakes coho salmon as an indicator organism for ecosystem health. Mar. Environ. Res. (abstract only) 14(1-4):480.

The Great Lakes are annually stocked with a common genetic strain of coho salmon (*Oncorhynchus kisutch*). In the lake environments, the coho has a defined life cycle and food source and as such is an ideal sentinel animal for monitoring for the presence of bioaccumulable xenobiotics and the pathobiological effects of environmental toxicants. Annual synchronized collections of sexually mature coho indicate that each lake has its own pathobiological signature (i.e., thyroid function, liver pathology, serum ion levels, growth, gonadal somatic indices, and fecundity). Field epizootiological studies were summarized with specific reference to pathobiological responses in feral coho, relay studies (fish to fish, fish to rat), and point chemical toxicity assays. These investigations have led to cohort epidemiological studies of people who consume Lake Ontario coho salmon. Strategies for environmental monitoring of aquatic organisms, laboratory cause-effect studies, and human epidemiology are being developed.

284.**Lefohn, A.S., and D.S. Shadwick.** 1991. Ozone, sulfur dioxide, and nitrogen dioxide trends at rural sites located in the United States. Atmos. Environ. 25:491-501.

The authors have investigated the existence of trends for ozone, sulfur dioxide, and nitrogen dioxide at rural sites in the U.S. For the ozone analysis, at 54 of the 77 sites (70%) for the 10-year analysis (1979-1988) and at 118 of 147 sites (80%), there was no indication of trends, either positive or negative. For the 10-year analysis, ozone sites in the Southern and Midwestern forestry regions showed more positive than negative significant slope estimates. For the 5-year analysis, similar results were obtained, except that the mid-Atlantic region also experienced more positive than negative significant slope estimates. In most of the agricultural regions, there were not many significant trends in either the 10- or 5-year analysis. However, for the agricultural Appalachian region, 50% and 34% of the trends, respectively, were significant and there were more positive than negative significant ozone trends for both the 10- and 5- year periods. For sulfur dioxide, there was an indication of trends at 37 of 64 sites (58%) for the 10-year analysis (1978-1987). For the 5-year analysis (1983-1987), with at least 4 years of data, there was no indication of trends at 115 of 137 sites (84%). For sites in some regions of the U.S., there is an indication that sulfur dioxide concentrations have declined for both the 5- and 10- year periods, but the rate of decline on an aggregate basis has slowed in the 5-year period. There is a strong indication that the sulfur dioxide level decreased at many sites in the Midwest forestry and the Corn Belt agricultural regions for the 10-year period. In the Southern forestry and Appalachian agricultural regions, many sites showed a decrease in the index for the 10-year, but not the 5-year, period. The lack of monitoring data for nitrogen dioxide made any conclusion extremely tenuous.

Key Words: Trends, Ozone, Sulfur Dioxide, Nitrogen dioxide, Cumulative exposure, Agriculture, Forestry.

285.**Letourneau, C., and J. Castonguay.** 1988. Use of biological indicators for evaluating environmental stress. Report No. INFO-0248(E), NTIS No. DE90629986/HDM. Atomic Energy Control Board, Ottawa, Ontario. 68 pp.

This report examines the usefulness of biological analyses for evaluating environmental stress. All forms of stress are addressed; particular attention, however, is paid to the use of biological analyses to evaluate the impact on the environment from radioactive releases of the nuclear industry. First, the authors review different biological analyses that are grouped into two approaches: the holistic approach (biotic and diversity indices) and the reductionist approach ("biological indicators" per se). Second, they compare the usefulness of plants and animals as indicators based on the established criteria. This report ends with a compilation of letters received from different organizations that outline the present use of biological indicators in Canada for evaluating environmental stress.

286.**Levin, S.** 1983. Ecological factors and the selection of indicator and test species for impact assessment. ERC Rep. No. 12. Ecosystems Research Center, Cornell University, Ithaca, NY. 11 pp.

In this report, the author acknowledges the increased attention on examining ecological impacts on ecosystem structure and function, but still thinks there is value in identifying particular species or groups of species for intensive laboratory or field testing, and as indicators for monitoring. The report focuses on acceptable criteria for selection of such species, and stresses the importance of such criteria.

287.**Levin, S.** 1992. Orchestrating environmental research and assessment. Ecol. Appl. 2(2):103-116.

When pressing national environmental problems must be solved, and serve as the justification for large infusions of public funds, mechanisms must be found to assure that the requisite research and assessment are performed. Large, managed programs seem to offer a way to direct energies in the needed directions, but individual creativity and intellectual curiosity must also be fostered through investigator-initiated studies. Research results cannot be achieved to meet imposed deadlines, and assessment in the face of uncertainty must be given due attention. This paper introduces five subsequent papers, four of which present perspectives on the National Acid Precipitation Assessment Program, as a model for coordinated research and assessment programs, and one that presents plans for a national and international research effort on biodiversity.

Key Words: Acid deposition, Acid precipitation, Acid rain, Biodiversity, Environmental assessment, Environmental research, Global change, NAPAP, Pollution

288.**Levin, S., M. Harwell, J. Kelly, and K. Kimball, eds.** 1989. Ecotoxicology: Problems and Approaches. Columbia University Press, New York. 547 pp.

Ecotoxicology is the science that seeks to predict the impacts of chemicals on ecosystems. This involves describing and predicting ecological changes ensuing from a variety of human activities that involve release of xenobiotic and other chemicals to the environment. A fundamental principle of ecotoxicology is the notion of change. Ecosystems themselves are constantly changing as a result of natural processes, and it is a challenge to distinguish the effects of anthropogenic activities against this background of fluctuations in the natural world. With the frustratingly large, diverse, and ever-emerging sphere of environmental problems that ecotoxicology must address, the approaches to individual problems also must vary. In part, as a consequence, there is no established protocol for application of the science to environmental problem solving.

The book contains chapters on problems and approaches to ecotoxicology, indicators of ecosystem response and recovery, responses of ecosystems to chemical stress, biomonitoring, decision making, and regulatory frameworks for ecotoxicology.

289.**Levin, S., K. Kimball, W. McDowell, and S. Kimball.** 1984. New perspectives in ecotoxicology. Environ. Manage. 8(5):375-442.

The task of regulating potentially harmful chemicals in the environment is currently hindered by the lack of appropriate concepts and methods for evaluating the effects of anthropogenic chemicals on ecosystems. Toxicity tests at the molecular and physiological levels have been used successfully as indicators of adverse effects on test organisms and have been extrapolated to humans to establish a basis for risk assessment. However, laboratory measurements of effects on individuals do not translate readily into potential effects on natural populations, in part because natural populations interact with other populations and with the physical environment. Even more difficult to assess are the deleterious impacts of anthropogenic chemicals on ecosystems because of effects on species interactions diversity, nutrient cycling, productivity, climatic changes, and other processes.

Effects on ecosystems resulting from chemical stresses are outside the realm of classical toxicology, and an ecosystem-level perspective is essential for the consideration of such effects; however, the science that deals with ecosystem-level effects, ecotoxicology, is still developing. This article synthesizes the topics discussed at a workshop on ecotoxicology held by the Ecosystems Research Center at Cornell University. Topics covered include: the regulatory framework in which ecotoxicological research must be applied; ecosystem modification of toxicant fate and transport; how ecosystem composition, structure, and function are influenced by chemicals; methods currently available for predicting the effects of chemicals at the ecosystem level; and recommendations on research needs to enhance the state of the science of ecotoxicology.

Key Words: Ecotoxicology, Environmental regulation, Fate and transport of anthropogenic chemicals, Keystone and critical species

290.**Lewis, J.** 1976. Long-term ecological surveillance: Practical realities in the rocky littoral. Oceanogr. Mar. Biol. Annu. Rev. 14:371-390.

In spite of the existence of several papers, the general paucity of time-series data for the littoral is such that if chronic effects are henceforth to be assessed we need to measure the degree of change taking place from natural baselines whose levels and stability have themselves, for the most part, still to be determined. The progressive attainment of these objectives, and those of interpretation that will surely follow, will demand much manpower and time. Neither is in abundant supply, and it becomes imperative, therefore, to find strategies of investigation that maximize limited resources by directing them in those areas in which the most information can be gained. The details of any strategy will vary with the habitat and its populations, the potential for using different methods and criteria, and the type and level of existing knowledge. This paper attempts to evolve a low-cost strategy for the rocky littoral, but before considering that habitat in particular, there remain, in the context of aims and resources, some further essential points of general applicability that should weigh heavily whenever a program of biological monitoring is contemplated. At the very least, these considerations indicate that such work should not be undertaken lightly.

291.**Linthurst, R., L. Jackson, K. Thornton, and J. Messer.** 1992. Integrated monitoring for ecological condition: Issues of scale, complexity, and future change. Pages 1421-1442. In: D. McKenzie, D.E. Hyatt, and J. McDonald. Ecological Indicators. Proceedings of the International Symposium On Ecological Indicators, held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

The Environmental Monitoring and Assessment Program (EMAP) is part of the Office of Research and Development's (ORD) response to both the SAB recommendations and agency theme of "Managing for Results." EMAP represents the foundation for ORD's Ecological Risk Assessment Program. This paper will briefly describe EMAP, highlighting some of the design features that make it unique for addressing large-scale environmental problems and discuss three issues or concerns raised about the EMAP: scale of resolution, assessing complex ecological problems, and anticipating future ecological problems.

292.**Liverman, D., M. Hanson, B. Brown, and R. Merideth.** 1989. Global sustainability: Towards measurement. Environ. Manage. 11:133-143.

The widespread interest in the concept of sustainable environment and development has been accompanied by the need to develop useful systems of measurement. This paper discusses the use of indicators which might be used to assess such conditions. Our characteristics or criteria for desirable global sustainability indicators are (1) sensitivity to change in time, (2) sensitivity to change across space or within groups, (3) predictive ability, (4) availability of reference or threshold values, (5) ability to measure reversibility or controllability, (6) appropriate data transformation, (7) integrative ability, and (8) relative ease of collection and use. The authors discuss the basis of these characteristics and examine two categories of indicators (soil erosion and population) and two specific indicators (physical quality of life index and energy imports as a percentage of consumption) for their value as sustainability measures.

Key Words: Global sustainability, Indicators, Measurement

293.**Loehle, C.** 1991. Managing and monitoring ecosystems in the face of heterogeneity. Pages 144-159. In: J. Kolasa and S. Pickett, eds. Ecological Heterogeneity. (Series: Ecological Studies: Analysis and Synthesis 86). Springer-Verlag, New York.

Problems of air and water pollution have become sufficiently acute and extensive that piecemeal solution of the problems is no longer adequate. It has become clear that even if each city meets clean air and water standards for human health, regional ecosystems may be degraded. It is thus necessary to monitor and manage the environment on a regional or even global basis. At this scale, however, heterogeneity of all types becomes almost overwhelming. Spatial heterogeneity, multi-level phenomena, multiple management activities, and multiple time scales interfere with the abilities of managers and regulatory agencies to detect and prevent environmental deterioration. This chapter addresses strategies for dealing with complexity and heterogeneity, largely in the context of environmental protection.

294.**Loehle, C., J. Gladden, and E. Smith.** 1990. An assessment methodology for successional systems. I. Null models and the regulatory framework. Environ. Manage. 14(2):249-258.

Standard procedures for evaluating environmental impact involve comparison between before and after conditions or scenarios, or between treatment and control site pairs. In many cases, however, endogenous directional change (natural succession) is expected to occur at a significant rate over the period of concern, particularly for human-made systems such as impoundments. Static evaluations do not provide an adequate approach to such problems. A new evaluation frame is proposed. Nominal system behavior over time is characterized by a stochastic envelope around a nominal trajectory. The authors show that both the state variance and the sampling variance can change over time. In this context, environmental regulations can be framed as constraints, targets, or conformance to ideal trajectories. Statistical tests for determining noncompliance are explored relative to process variance, sample error, and sample size. Criteria are elucidated for choosing properties to monitor, sample size, and sampling interval.

Key Words: Stochastic models, Monitoring, Statistical tests, Experimental design

295.**Loehle, C., and E.P. Smith.** 1988. An assessment methodology for successional systems. II. Statistical tests and specific examples. Environ. Manage. 14(2):259-268.

This paper presents a dynamic framework for environmental assessment when the system under study is undergoing successional change. Successional differences between sites for which one wishes to detect a difference because of a treatment are essentially confounding factors. The authors show how successional changes over this study period or resulting from differences in study site plot ages can be factored out by developing a null model of expected behavior over time. The null model for change in state with time is characterized in terms of a stochastic envelope around a nominal trajectory. Specific tests for the detection of trends associated with succession are described and illustrated on example data. It is concluded that the methods developed work particularly well for laboratory microcosm data.

Key Words: Monitoring, Statistical analysis, Null models, Stochastic models, Hypothesis testing

296.**Loehr, R.** 1991. Assessing and managing environmental risk. Environ. Prog. 10(2):M2.

This editorial briefly addresses the emergence of environmental risk assessment to improve environmental management and environmental decision-making.

297.**Loftis, J.C., G.B. McBride, and J.C. Ellis.** 1991. Considerations of scale in water quality monitoring and data analysis. Water Resour. Bull. 27(2):255-264.

An assumption of scale is inherent in any environmental monitoring exercise. The temporal or spatial scale of interest defines the statistical model that would be most appropriate for a given system and thus affects both sampling design and data analysis. Two monitoring objectives that are strongly tied to scale are the estimation of average conditions and the evaluation of trends. For both of these objectives, the time or spatial scale of interest strongly influences whether a given set of observations should be regarded as independent or serially correlated and affects the importance of serial correlation in choosing statistical methods. In particular, serial correlation has a much different effect on the estimation of specific period-means. For estimating trends, a distinction between serial correlation and trend is scale-dependent. An explicit consideration of scale in monitoring system design and data analysis is, therefore, most important for producing meaningful statistical consideration.

Key Words: Water quality, Monitoring, Statistics, Trends

298.**Loftis, J.C., C.H. Taylor, and P.L. Chapman.** 1991. Multivariate tests for trends in water quality. Water Resour. Res. 27:1419-1429.

Several methods of testing for multivariate trend have been discussed in the statistical and water quality literature. The authors review both parametric and nonparametric approaches and compare their performance using synthetic data. A new method, based on a robust estimation and testing approach suggested by Sen and Puri, performed very well for serially independent observations. A modified version of the covariance inversion approach presented by Dietz and Killeen also performed well for serially independent observations. For serially correlated observations, the covariance eigenvalue method suggested by Lettenmaier was the best performer.

299.**Long, E.R., and M.R. Buchman.** 1989. An evaluation of candidate measures of biological effects for the National Status and Trends program. National Oceanic and Atmospheric Administration (NOAA) Technical Memo. NOS OMA 45. U.S. Department of Commerce, Rockville, MD.

The National Status and Trends Program analyzes three media--sediments, bottomfish, and bivalves--routinely at sites nationwide. The present evaluation included biological tests of two of those media: sediments and fish. Data from the various biological tests were compared with each other and with the chemical data in various statistical procedures. The study concluded that no single measure of biological effects can suffice for determining the biological effects of pollution. The measures evaluated in this document are: chemical analyses of surficial sediments; solid phase sediment toxicity test with an amphipod; sediment elutriate toxicity test with the larvae of mussels and sea urchins; sediment pore water toxicity test with a polychaete; taxonomic analyses of benthic community structure; analyses of sedimentological and biological characteristics with sediment profiling photography; fish collection, tissue chemical analyses, aryl hydrocarbon hydroxylase analyses, and plasma steroid hormone analyses; fish blood micronucleated erythrocyte analyses and; fish liver cytochrome P-450 and ethoyresorufinn-O-deethylase (EROD) enzyme analyses.

300.**Loucks, O.L.** 1985. Looking for surprise in managing stressed ecosystems. Bioscience 35(7):428-432.

Both natural and anthropogenic sources of stress can produce unanticipated and unprecedented ecosystem responses, such as a new equilibrium with long-term effects. Ecosystem models that simulate the prospective outcomes of management help to analyze responses to stress mitigation but cannot usually anticipate surprises—the emergence of new stable states. In managing stressed systems, we should therefore consider both what we predict and what we cannot predict.

301.**Lubchenco, J., A. Olsen, L. Brubaker, S. Carpenter, M. Holland, S. Hubbell, S. Levin, J. MacMahon, P. Matson, J. Melillo, H. Mooney, C. Peterson, H. Pulliam, L. Real, P. Regal, P.Risser.** 1991. The sustainable biosphere initiative: An ecological research agenda. A report from the Ecological Society of America. Ecology 72(2):371-412.

In this document, the Ecological Society of America proposes the Sustainable Biosphere Initiative (SBI), an initiative that focuses on the necessary role of ecological science in the wise management of Earth's resources and the maintenance of Earth's life support systems. This document is intended as a call-to-arms for all ecologists, but it also will serve as a means to communicate with individuals in other disciplines with whom ecologists must join forces to address our common predicament.

Portions of the document address responses to stress, the effects of scale, and ecological indicators.

Key Words: Biological diversity, Biosphere, Ecological research, Environmental decision-making, Global change, Research agenda, Research funding, Research priorities, Sustainability, Sustainable ecological systems

302.**Lugo, A.** 1978. Stress and ecosystems. Pages 62-101. In: J. Thorp and J. Gibbons, eds. Energy and Environmental Stress in Aquatic Systems. Department of Energy Symposium Series, CONF 771114. Technical Information Service, Department of Energy, Oak Ridge, TN.

The literature dealing with issues of stress as it affects ecosystems is reviewed. Definitions of stress are discussed. Models and literature examples are presented to illustrate the push-pull (positive-negative) effects of most stressors and to suggest that the point of attack and the type of stressor determine the rate of response of the ecosystem. Stressors with high-quality energy (highly concentrated energy sources) that divert low-quality in a system appear to have a greater impact than stressors with low-quality energy (diluted energy sources) that impact high-quality energy flows. It is suggested that ecosystem complexity (including species diversity, physiognomy, three-dimensional organization, etc.) is a function of the balance between energies that contribute to growth and organization and those that contribute to disorder. The classification of environments by their "energy signatures" (the sum of all incoming energy flows into a system and the pattern of their delivery expressed on equal energy-quality basis) is presented as the best way to arrange and analyze ecosystems hierarchically according to their capacity to develop complexity and to tolerate stress. The patterns of ecosystems response to stressors, including positive, steady-state, and declining responses and possible extinction, are discussed. It is argued that, to solve the problems of ecosystem management and the issues of environmental impact, studies and analyses must be done at the level of the ecosystem and care should be taken to quantify both the stressor and the stress with units of comparable energy quality.

303.**Lund, H.** 1986. A primer on integrating resource inventories. General Technical Report WO-49. U.S. Department of Agriculture, Forest Service, Washington, DC.

This document provides a comprehensive overview of how to perform an integrated resource assessment. It contains sections on the four levels of assessment: multilocation, multilevel (agency), multiresource, and temporal. The section on temporal integration discusses how inventories can provide trend data and eventually the validation of predictions and assumptions. It describes how resource inventories can be used as foundations for monitoring, which serves to determine if planning objectives are being met or to detect unplanned changes in the resource base. The document also lists the criteria for determining what should be monitored and gives options and recommendations for identifying information needs for temporal integration.

304.**Lund, H., and G. Preto, eds.** 1990. Global Natural Resource Monitoring and Assessments: Preparing for the 21st Century. American Society for Photogrammetry and Remote Sensing, Bethesda, MD.

305.**Macdonald, G., and L. Sertorio, eds.** 1990. Global Climate and Ecosystem Change. [Series: NATO Advanced Science Institute Series, Series B, Physics 240 (1990)]. Plenum Publishing, New York.

306.**MacDonald, I.A.W.** 1992. Vertebrate populations as indicators of environmental change in southern Africa. Trans. R. Soc. S. Africa 48(P1):87-122.

Two categories of historical change in vertebrate populations are analyzed: species decline resulting in inclusion in local Red Data Books and changes in distribution and abundance of what are often common species, as revealed by regional surveys. The former category of change tends to reflect radical anthropogenic influences (e.g., habitat transformation, persecution, and overuse). The latter generally reflects the more widespread forms of habitat modification (e.g., bush encroachment, the spread of alien trees into formerly treeless biomes, and desertification through overgrazing of semiarid rangelands). Destruction of vleis and marshes has been important throughout the region. Any long-term climatic change that might have occurred over the last two centuries is not reflected by changes in vertebrate populations. Several vertebrate changes do, however, indicate a general tendency for increased density of the woody plant component of savanna communities. This trend is consistent with the predicted response of these communities to the observed global increase in the atmospheric concentration of global carbon dioxide. Short-term variations in annual rainfall have given rise to significant fluctuations in vertebrate populations. Vertebrates could be particularly useful in monitoring future climatic change in which the effects of such change can be predicted in terms of alterations in the relative abundance of woody and herbaceous vegetation. Continuous monitoring of bird populations would probably be the most effective approach to detecting such changes. The effects of a wide range of other factors, as detailed in this analysis, must be filtered out before variations in vertebrate populations can be attributed to climatic change.

307.**Mace, T.** 1991. Multistage remote sensing for a national environmental monitoring program database. Pages 691-700. In: GIS/LIS '90 - Technical Papers. Geographic Information Systems/Land Information Systems Annual Conference, Anaheim, Ca. American Congress on Surveying and Mapping, Falls Church, VA.

308.**Machlis, G.** 1992. The contribution of sociology research to biodiversity research and management. Biol. Conserv. 62:161-170.

This article discusses in general the contribution of sociology to biodiversity issues, but also includes a short section describing its inputs to monitoring and assessment techniques such as social indicators as anticipators of ecosystem change.

309.**Magurran, A.** 1988. Ecological Diversity and Its Measurement. Princeton University Press, Princeton, NJ.

This book is a comprehensive analysis of the different types of diversity indices. Chapters cover the following topics: diversity indices and species abundance models; sampling; choosing and interpreting diversity measures; a variety of diversities; and the empirical value of diversity measures.

310.**Maher, W., and R. Norris.** 1990. Water quality assessment programs in Australia: Deciding what to measure, and how and where to use bioindicators. Environ. Monit. Assess. 14:115-130.

Effective water quality assessment programs require the formulation of common objectives between managers who are making decisions and scientists who are obtaining the information on which those decisions are to be made. The data collected must be appropriate for use in the decision-making process. After the objectives have been formulated, a number of testable hypotheses can be proposed and evaluated in terms of what information is required for decision making.

From a management perspective, it is important to know if an impact occurs and what management strategy to adopt to reduce or eliminate the impact. When bioaccumulators are to be used to indicate environmental quality, the organisms proposed need to be fully evaluated ahead of time. Communities, which are often used to asses level of impact, have the capacity to assimilate pollutants and will function under pollutant stress. Thus, managers should make value judgments about when a community structure or function has shifted from acceptable to adverse. Bioassays in which the effects of pollutants on growth, biochemistry, and behavior are measured give an indication of the sublethal effects of a pollutant, but it is difficult to set limits that managers can use.

Difficulties in using chemical and biological data mainly arise from a lack of appreciation of environmental heterogeneity. The data obtained must meet the needs for statistically testing certain hypotheses. Before programs can be designed to meet statistical needs, the potential sources of variability must be considered. Once the minimum differences that are seen to be important have been determined, the number of replicates needed can be calculated. Data verification is also needed because if the validity of data is questioned, any decisions that have been made based on those data will also be suspect. Finally, programs should be designed to minimize the sampling effort/cost to meet the objectives.

311.**Maher, W., ed.** 1990. Workshop on ecological indicators of the state of the environment held at the international symposium on biomonitoring of the state of the environment, Canberra, Australia. Environ. Monitor. Assess. 14(2-3):107-399.

Papers presented at the Workshop on Ecological Indicators of the State of the Environment held in Canberra, Australia, are organized into three sections: (1) protocols and programs; (2) biological assessment of impact and; (3) use and relevance of toxicity data. The majority of the papers deal with organisms or physiology as environmental indicators and on a relatively small scale of study.

312.**Makarewicz, J.C.** 1991. Photosynthetic parameters as indicators of ecosystem health. J. Great Lakes Res. 17(3):333-343.

Thirty-three limnological variables, including the photosynthesis parameters P_{max} and Alpha, were monitored for 2 years in the nearshore and offshore of Lake Ontario. In the nearshore, P_{max} and Alpha varied seasonally and were higher during the summer and early autumn and lowest in the winter and spring of 1986-1987. No seasonal variability of the photosynthetic parameters were observed in the offshore and nearshore in 1987-1988. P_{max} varied during the winter, a period of decreased biological activity and, ostensibly, less variability. Multiple regression analysis suggested that over 25% of the variability in P_{max} was predicted by temperature. Both the large number of variables that are either correlated or have been experimentally determined to affect P_{max} and Alpha and the similarity of the photosynthetic parameters within the various Great Lakes of differing trophic status suggests that the use of the photosynthetic parameters as indicators of "ecosystem health" is weak at best.

Key Words: Indicators, Bioindicators, Photosynthesis, Lake Ontario

313.**Malatini, S., and G. Pinchera.** 1986. Environmental indicators: A comparison of international trends. (in Italian; summary in English, French, Italian). Ing. Ambientale 15(5):247-272.

In order to preserve, maintain and reclaim environmental quality, and to assess the results of past actions, on an international as well as on a national or local level, a tested environmental accounting system is required. Usually, unlike economics or energy surveys, environment accounting, where performed, does not rely on tested sets of indicators, in a single country, or standardized, and thus comparable, at an international level. Some international agencies (OCSE, UNECE, CEE, and so on), at different degrees of advancement, are devoting great efforts to develop sets of indicators and similar systems. This article reviews achievements and trends to this aim, in some industrialized countries, as well as formulations and selected sets of indicators provided by some international agencies to assess both state and changes over time of environmental quality.

314.**Man and the Biosphere.** 1979. Long-term Monitoring in Biosphere Reserves. U.S. Man and the Biosphere Program. Washington, DC.

315.**Margalef, R.** 1975. Human impact on transportation and diversity in ecosystems: How far is extrapolation valid? Pages 237-241. In: Proceedings of the First International Congress of Ecology: Structure, Functioning and Management of Ecosystems. The Hague, 8-14 September, 1974. Centre for Agricultural Publishing and Documentation, Wageningen, The Netherlands.

This article briefly outlines generalized responses of ecosystems and communities to resource exploitation, organic pollution, thermal pollution, radioactivity, and chemical pollution. Also, the idea of stress in homeostatic ecosystems using an aquatic ecosystem as an example is discussed.

316.**Marshall, T., R.A. Ryder, C.J. Edwards, and G.R. Spangler.** 1987. Using the lake trout as an indicator of ecosystem health: Application of the dichotomous key. Great Lakes Fishery Commission Technical Report. No. 49. Ann Arbor, MI.

The lake trout, *Salvalinus namaycush* (Walbaum), has been proposed for use as an indicator of ecosystem quality for the Great Lakes basin. To apply the concept for the effective management of aquatic systems, a dichotomous key has been devised, which is designed to pose critical questions pertaining to the lake trout, its aquatic community associates, and its environment. Specifically, the questions refer to the niche characteristics and habitat requirements of healthy lake trout stocks. Responses to these questions provide the requisite information from which the current state of ecosystem health is assessed. It was assumed that the lake trout, with its rigorous environmental requirements, would serve as an apposite surrogate for a health oligotrophic system.

The dichotomous key has been designed as a menu-driven computer program that may be implemented easily by the ecosystem manager and layman alike. It is an interactive program in that the users may revise their inputs as new information becomes available. The program also provides the rationale behind each of the questions in the key as well as bibliographic documentation for the rationale.

Use of the dichotomous key program should provide a greater perception of which particular stresses are adversely affecting ecosystem "health." In addition, the program tends to draw low profile stresses to the user's attention, that may be critical to the persistence of a healthy ecosystem.

317.**McCallum, D.B., and V.T. Covello.** 1989. What the public thinks about environmental data. EPA J. May/June:22-23.

This article briefly discusses which professional groups are the most trusted sources of information about environmental risk, and also covers the issue of communicating risk to the public.

318.**McCarthy, J., S. Adams, B.D. Jimlnez, and L.R. Shugart.** 1989. Environmental monitoring of biological markers in animals and plants. Pages 187-196. In: R. Noble, J. Martin, and K. Jensen, eds. Air Pollution Effects on Vegetation. U.S. Forest Service Northeastern Experiment Station, Broomall, PA.

In an environmental monitoring plan, a suite of biomarkers is measured in wild animal or plant species sampled from areas of suspected contamination and from pristine reference areas. Based on the magnitude and pattern of the biomarker responses, the environmental species offer the potential of serving as sentinels that demonstrate the presence of bioavailable contaminants, and as surrogates that indicate potential human exposure and effects, and predictors of long-term ecological effects.

319.**McCracken, R.J.** 1989. Indicators for assessing changes in natural resources in developing countries. AID-PN-ABB-193, NTIS No. PB89-202782/HDM. Report presented at Impact Indicators Workshop, Arlington, VA., June 20, 1988. Agency for International Development, Washington, DC. 59 pp.

The sustainability of the natural resource base is being seriously threatened in many developing countries by local efforts to meet basic needs for food, fiber, and fuelwood. The paper suggests eight illustrative indicators for assessing the impact of AID agricultural and forestry projects on natural resources: soil productivity maintenance, land use and management, vegetative cover and plant health, agroforestry and fuelwood supply, rangeland condition and trends, water supply, environmental quality, and accelerated general degradation processes. Appendices cover procedures, data items, and costs for natural resource inventories in the United States; Geographic Information Systems with digitized map information; costs of soil surveys, digitized maps, and GISs; estimated costs for remote sensing of natural resources; and a U.S. Department of Agriculture water erosion prediction project being developed to replace the universal soil loss equation. The report includes a 5-page bibliography.

320.**McKenzie, D.H., D.E. Hyatt, and J.V. McDonald.** 1992. Ecological Indicators. Elsevier, Essex, England.

An international symposium on ecological indicators was developed to explore both the potential of ecological indicators and the issues surrounding their development and implementation. The symposium presented state-of-the-art science information on the identification, application, research, and development of appropriate indicators to describe and evaluate ecological status. The use of ecological indicators is crucial to providing improved information on the condition of the environment and to the success of the Environmental Monitoring and Assessment Program (EMAP). The symposium was designed to help ensure that the indicators used in the program have the strongest possible basis of technical information from the international body of knowledge.

Keywords: Biological indicators, Ecosystems, Environmental monitoring, Research and development

321.**McIntyre, A.** 1984. What happened to biological effects monitoring? Mar. Poll. Bull. 15(11):391-392.

There seems to be a feeling in some quarters that biological effects monitoring has not lived up to its early promise and, indeed, that, in spite of significant efforts in recent years, it has not even gotten properly off the ground. This view perhaps arises from the fact that, although a number of large-scale national and international programs are in operation, these do not usually have effective biological components. This editorial attempts to put the topic into perspective.

322.**Menzel, D.** 1987. Summary of experimental results: Controlled ecosystem pollution experiment. Bull. Mar. Sci. 27:142-145.

This article provides a summary of results from ecosystem pollution experiments describing effects on heterotrophy, phytoplankton, zooplankton, and chemistry.

323.**Messer, J.J.** 1989. Keeping a closer watch on ecological risk. EPA J. May/June:34-36.

This article addresses the questions that need to be posed in order to asses current environmental problems and the status of ecological resources. The application of environmental risk assessment to this problem is discussed, as well as a brief summary of EMAP's role.

324.**Messer, J.J.**1992. Indicators in regional ecological monitoring and risk assessment. Pages 135-146. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

325.**Messer, J.J., R. Linthurst, and W. Overton.** 1991. An EPA program for monitoring ecological status and trends. Environ. Monitor. Assess. 17(1):67-78.

Despite hundreds of millions of dollars spent annually in the United States on environmental monitoring, policy makers and decision makers seldom have ready access to the monitoring data they need to prioritize research and assessment efforts or to assess the extent to which current policies are meeting the desired objectives. EPA is currently conducting research to evaluate options for establishing an integrated cooperative monitoring program, with participation by federal, state, and private entities. Such a program could result in annual statistical reports and interpretive summaries on the status and trends in indicators of adverse disturbance and corresponding "health" of the nation's ecosystems on the regional and national scale.

326.**Messer, J.J., R.A. Linthurst, and C. Riordan.** 1989. A national program for environmental monitoring and assessment. Pages 211-215. In: R.D. Noble, J.L. Martin, and K.F. Jensen, eds. Air Pollution Effects on Vegetation: Including Forest Ecosystems. Proceedings of the Second US-USSR Symposium. U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station, Broomall, PA.

This article provides background on the need for a national level monitoring program and describes the formation of EMAP and describes the approach it should take.

327.**Meybeck, M., D. Chapman, and R. Helmer.** Global Freshwater Quality — A 1st Assessment. 360 pp. Basil Blackwell, Cambridge, MA.

This book contains chapters on anthropogenic impacts on water quality, lake sediments as indicators of anthropogenic impact, and global water quality assessment.

328.**Michener, W., R. Feller, and D. Edwards.** 1987. Development, management, and analysis of a long-term ecological research information base: Example for marine macrobenthos. Pages 173-188. In: T. Boyle, ed. New Approaches to Monitoring Aquatic Ecosystems. ASTM STP 940. American Society for Testing and Materials, Philadelphia.

As one of eleven Long-Term Ecological Research Program sites in the nation (designated by the National Science Foundation), the Belle W. Baruch Institute for Marine Biology and Coastal Research has developed a flexible system for the management and analysis of ecological data. The Baruch Data Management System (BDMS) contains over 4 years of data collected from ecological research on coastal and estuarine habitats. Important design features of information bases for long-term monitoring are described.

Because temporal variability is an inherent part of ecological data sets, it is important to delineate those periods when sampling must be intensified and periods when sampling can be decreased without compromising documentation of the processes under question. Examples of analyses of temporal variability for one of the biological data sets (macrobenthos) are presented, and a case is made for the importance of long-term monitoring efforts to the generation of process-related experiments.

Key Words: Benthic invertebrates, Database management, Ecology, Estuarine systems, Information base, Statistical methods, Temporal variation

329.**Middleton, J.** 1987. Measures of ecosystem disturbance and stress in landscapes dominated by human activities. Pages 177-181. In: M.R. Moss, ed. Landscape Ecology and Management. Proceedings of the First Symposium of the Canadian Society for Landscape Ecology and Management, held at the University of Guelph, May 1987. Polyscience Publications, Inc., Montreal.

From the point of view of an ecosystem ecologist, human activity affects landscapes by imposing on them a new regime of stress and disturbance. Thus by studying stress and disturbance in landscapes, we may learn how our activities will affect any given landscape. Ecologists have studied disturbance for a long time, but there is no consensus on how such studies should proceed. A recent compilation of work in the field includes the following statement: "...although there is much scattered information on the subject of disturbance ... there is no compilation and synthesis of this information; nor is there any work which develops a broad framework for theory incorporating disturbance and its effect".

This paper is one illustration of a piece of research aimed at developing a theoretical framework for understanding disturbance in ecosystems and is directed toward a practical method for measuring it. The author discusses the need for a quantitative method for measuring ecosystem disturbance, and the development of such an index is described.

330.**Millard, S.** 1987. Environmental monitoring, statistics, and the law: Room for improvement. Am. Stat. 41:249-253.

Concerns over environmental degradation have led to legislation such as the Clean Water Act, the Clean Air Act, the Resource Conservation and Recovery Act, and the Comprehensive Environmental Response, Compensation, and Liability Act. Federal and state laws have mandated the creation of numerous monitoring programs to ensure or determine the integrity of the environment. Unfortunately, many of the resulting monitoring programs shed little light on the questions that they were meant to help answer because they are based on poor environmental designs and a superficial knowledge of statistics. This article briefly discusses some past environmental monitoring designs and current regulations for monitoring at hazardous waste sites. The deficiencies of many monitoring programs are linked to the need to improve the status of the career category "statistician" in the sphere of the environmental sciences.

Key Words: Environmental Protection Agency, Groundwater monitoring, Power, Sampling design, Statistician, Type I error, Type II error

331.**Miller, D.R.** 1984. Distinguishing ecotoxic effects. Pages 15-22. In: P. Sheehan, D. Miller, G. Butler, and P. Bourdeau, eds. Effects of Pollutants at the Ecosystem Level. John Wiley & Sons, New York.

This chapter discusses the subjects related to ecotoxic effects: (1) nature of the problem, (2) identifying parameters to monitor, (3) mathematical background, (4) estimating baseline level, and (5) detecting change.

332.**Miller, S.** 1978. Federal environmental monitoring: Will the bubble burst? Environ. Sci. Technol. 12(12):1264-1269.

This article discusses the environmental monitoring situation (primarily in reference to the U.S. Environmental Protection Agency) as of the late 1970s. It covers issues such as deficiencies in monitoring, and quality assurance.

333.**Mills, K., and D. Schindler.** 1986. Biological indicators of lake acidification. Water Air Soil Pollut. 30:779-789.

Indicator taxa are identified, based on both synoptic surveys and whole lake acidification experiments, for lake acidification in the pH 6.0 to 5.0 range. Acidobiontic diatoms (e.g., *Asterionella ralfsii*, *Fragillaria acidobiontica*), periphyton (*Mougeotia* and related species), macroinvertebrates (e.g., *Hyalella azteca*, *Orconectes sp.*), leeches and cyprinid fishes (e.g., *Pimephales promelas* and *Notropis cornutus*) are identified as target organisms during early phases of lake acidification.

334.**Milne, B.T.** 1992. Indications of landscape condition at many scales. Pages 883-897. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Ft. Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Erosion, the birth and death of plants, and habitat selection by animals create patch shapes and spatial distributions of mass, density, and patch area that often lack characteristic length scales and therefore display power-law behavior as a function of scale. In such cases, fractal geometry provides a mathematical framework for relating the finely detailed patterns of landscapes to coarse levels of resolution. Variation in the fractal geometry of landscapes throughout the eastern United States is related to land use practices. Measures of the fractal aggregation of landscape cover types (1) are used to detect disturbance or change at specified levels of resolution, (2) are used to map the contribution that each point makes to the statistical properties of the entire pattern, (3) provide a basis for simulation studies of foraging in complex landscapes, and (4) imply that source-sink relationships are also scale-dependent. The measures indicate that each point occurs in a unique scale-dependent context. Consequently, species that have similar habitat requirements but that operate at different scales (by virtue of differences in home range area) are likely to occupy different places in the landscape. Multiple levels of resolution may be needed to assess the condition of landscapes in an ecologically meaningful way.

335.**Minns, C.K.** 1992. Using technology to assess regional environmental information. Environ. Monit. Assess. 20:141-158.

Distinctions between holistic and prescriptive technologies, and holistic and reductionist science are a backdrop to examination of two widespread environmental problems: eutrophication of the Bay of Quinte, Lake Ontario, and acidification of lakes in eastern Canada. Evidence is presented on a shift from prescriptive toward holistic approaches. Holistic solutions to technological limitations are discussed with emphasis on the interactive procedures people use to solve problems, rather than on the physical tools which are often employed in a prescriptive manner. Local gathering and integration of environmental information is presented as the key to macro-environmental assessments. Recommendations stress (1) the need for ecologists in every ecosystem, (2) training with emphasis on problem-solving techniques, (3) wide-spread use of microcomputers, a potent holistic technology, to transfer information and concepts, and (4) local selection of indicators with the advice that they be simple and biotic.

336.**Mooney, H.** 1991. Biological response to climate change: An agenda for research. Ecol. Appl. 1(2):112-117.

Our knowledge of the structure and the functioning of terrestrial ecosystems on a global scale is not developed to a sufficient degree to understand—much less predict—the consequences of climate change either on the systems themselves or on subsequent atmospheric interactions. In many regards, we have lagged behind the atmospheric scientists, and to a certain degree the oceanographers, in establishing a global understanding of the dynamics of our respective systems. This is partly because of the inherently greater complexity of biotic systems, and the lack of appropriate tools to measure regional biotic processes. These tools are now becoming available and with them a better understanding of terrestrial and atmospheric interactions is developing. Even as these capabilities become a reality, we must be realistic in recognizing that we have so far to go along the road to understanding that useful predictive capacity may elude us for a long time to come.

What we now need to do is act on the recommendations that have been emerging over the past few years and develop a global program to document more precisely the distribution, structure, and quantity of the earth's biotic systems, their principal functional properties, and—most difficult of all—their changing nature. To do this we will have to (1) perfect some of the emerging new tools for assessing these properties, (2) fill some of the gaps in our knowledge about the relevant processes, and (3) establish an international network of long-term observations and large-scale ecosystem manipulations. We have been aware of these needs and shortcomings for some time, and we must move from plans to concerted international action.

Key Words: Atmospheric CO_2, Global climate change, Large-scale experiments, Plant productivity, Species distribution, Terrestrial carbon exchange

337.**Mooney, H., B. Drake, R. Luxmoore, W. Oechel, and L. Pitelka.** 1991. Predicting ecosystem responses to elevated CO2 concentrations. Bioscience 41(2):96-104.

In this article, the authors indicate what can be predicted about the CO_2 response of plants from physiological measurements and what has been learned from field observations. They then show results from direct tests of the CO_2 response of whole ecosystems and indicate the promise and problems of these approaches, discuss the need for new ecosystem-level experiments and identify some of the challenges. The response of plants and ecosystems to rising atmospheric CO_2 have been reviewed previously.

338.**Morgenstern, R., and S. Sessions.** 1988. Weighing environmental risks: EPA's unfinished business. Environment 30(6):14-17, 34-39.

This articles summarizes some of the issues in the Environmental Protection Agency report "Unfinished business: A comparative assessment of environmental problems". It lists obstacles to priority setting, describes in-house improvements regarding priority setting, and compares how the public vs the experts rate the severity of various environmental problems.

339.**Moriarty, F.** 1988. Ecotoxicology. Academic Press, New York.

This book contains chapters on population dynamics, communities, genetics of populations, effects on individual organisms, prediction of ecological effects, and monitoring. Although the book generally focuses on the lower levels of organization, a small section (pages 157-164) covers effects on ecosystems.

340.**Morrison, M.** 1986. Bird populations as indicators of environmental change. Curr. Ornithol. 3:429-451.

341.**Mukhopadhyay, N., R.B. Bendel, N.P. Nikolaidas, and S. Chattopadhyay.** 1992. Efficient sequential sampling strategies for environmental monitoring. Water Resour. Res. 28(9):2245-2256.

Assessments of resources at risk to anthropogenic pollution require extensive environmental monitoring. In addition, such assessments are required to have a long-term monitoring component in order to evaluate not only the status but also the trend of the resources at risk to ecological stresses. There is a need to identify statistical methodologies that would provide effective and cost–saving environmental monitoring designs, since such monitoring surveys are very expensive. In this paper the purely sequential, accelerated sequential, and three–stage procedures are evaluated as effective fixed–precision sampling procedures for environmental monitoring. Current monitoring designs utilize a sampling methodology where each resource is assigned a population inclusion probability, with the intent of describing the distribution of the whole population of resources at risk to anthropogenic environmental stresses. This study assumes that existing designs accurately describe the population distribution. A simultaneous fixed–precision estimation procedure is developed as an efficient method of estimating practically relevant percentiles of the cumulative distribution function, using water quality data from the Eastern Lake Survey as a lake population distribution. Accelerated sequential and three–stage procedures are shown to be better alternatives to the purely sequential procedure, requiring fewer sampling operations without any substantial loss of efficiency. Depending upon the precision required, all procedures showed potential reductions in sample size by as much as 60%. These types of designs for environmental monitoring are expected to be advantageous in national monitoring efforts toward the assessment of the status and trends of various ecological indicators.

342.**Munkittrick, K. R., and D.G. Dixon.** 1989. A holistic approach to ecosystem health assessment using fish population characteristics. Hydrobiologia 188/189:123-135.

The status of a fish population is a reflection of the overall condition of the aquatic environment in which that population resides. As such, fish population characteristics can be used as indicators of environmental health. Simple and inexpensive methods to follow fish population responses to environmental degradation are lacking. This paper outlines a protocol whereby environmental impacts on fish populations are classified by five patterns based on characteristics such as mean age, fecundity, and condition factor. The patterns summarize population changes and describe responses to exploitation, recruitment failure, the presence of multiple stressors, food limitations, and niche shifts. Classification is best based on the selection, and appropriate sampling, of a comparable reference population. Population characteristics can be used to examine ecosystems exposed to stressors for evidence of long-term damage and, when used with biochemical indicators, can be a powerful tool for ecosystem health assessment. The five responses are illustrated by using published data on a number of species challenged by increased predation pressure, acidification, eutrophication, mine waste, and reservoir impoundment. Application of this scheme will aid in directing and focusing research efforts on crucial aspects affected by changing conditions.

Key Words: Ecosystem stress, Fish populations, Growth, Fecundity, Condition factor

343.**Munn, R.** 1988. The design of integrated monitoring systems to provide early indications of environmental/ecological changes. Environ. Monitor. Assess. 11:203-217.

One of the important goals of the next several decades is to achieve and maintain ecologically sustainable development of the biosphere. However, the management of ecological systems is rather difficult, largely because of uncertainties in long-term predictions of environmental and ecological behavior. Thus, one of the objectives for integrated monitoring should be to provide early indications of impending changes so that mitigative actions can be taken.

This paper includes a discussion of the factors to be considered in the design of early-warning monitoring systems, and gives some examples. One approach that appears to be particularly promising is that of identifying, quantifying and monitoring the stresses, feedbacks and component lags in the environmental/ecological system being studied.

344.**Munn, R.** 1992. Towards sustainable development. Atmos. Environ. 26A(15):2725-2731.

Sustainable development is a difficult phrase to define, particularly in the context of human ecosystems. This article examines some of the notions behind sustainability. In rapidly changing environmental and socio-economic situations, policies must be adopted that strengthen resilience and ecosystem integrity. Some suggestions on appropriate indicators of ecosystem integrity are given in this paper but the author states that these need considerable refinement.

Key Words: Sustainable development, Environmental policy, Resilience, Sustainability indicators

345.**Nash, S.** 1991. What price nature? — Future ecological risk assessments may chart the values, and the odds. Bioscience 41(10):677-680.

Ecological risk assessment boils down to a scientific methodology for characterizing health or changes in health in an ecological system. This article provides a background on ecological risk assessment. Subtopics are: Risk assessment as a political concern; Paradigm shifts; Valuation is vexing; How economists value ecosystems; Contingent valuation problems; Science or money criteria and; Valuation projects under consideration.

346.**National Academy of Sciences (NAS).** 1975. Planning for environmental indices: A report to the planning committee on environmental indices. NTIS No. PB 240971 (Available from National Technical Information Service, Springfield, VA.). National Academy of Sciences, Washington, DC.

This study examines the important multidisciplinary considerations related to environmental indices and makes recommendations regarding their development. The report includes examples of indices and a short bibliography.

347.**National Academy of Sciences (NAS).** 1979. Animals as Monitors of Environmental Pollutants. National Academy of Sciences, Washington, DC.

The Symposium on Pathobiology of Environmental Pollutants: Animal Models and Wildlife as Monitors had the following goals: (1) to determine the extent to which environmental pollution can be documented in wildlife, (2) to provide a common forum for pathologists, wildlife biologists, and ecologists, who are studying environmental pollution from different perspectives, (3) to develop an informational and bibliographic resource on this important aspect of animal biology, and (4) to generate information that may be useful for legislators involved in fashioning contemporary policy decisions concerning the control of environmental pollution.

The proceedings are divided into sections on overview methodology, aquatic pollutants, heavy metals, air pollution, and pesticide toxicity.

348.**National Research Council.** 1981. Testing for effects of chemicals on ecosystems. Committee to Review Methods for Ecotoxicology, National Research Council. NTIS No. PB 82127200 (Available from National Technical Information Service, Springfield, VA)National Academy Press, Washington, DC.

The discussion focuses primarily on chemical effects, although other stressors are considered, especially when impacts are similar. This document is an excellent source of references. The authors review chemical toxicity, various testing systems, assessment strategies, vulnerable ecological parameters, and external factors. This book is aimed at identifying characteristics of ecological systems that would indicate hazardous effects of chemicals beyond the single species, establishing criteria for suitable testing schemes, and evaluating the effectiveness of available test systems in assessing effects of chemicals within ecosystems.

(Note: This summary taken from American Management Systems, Inc., 1987)

349.National Research Council. 1990. Managing Troubled Waters: The Role of Marine Environmental Monitoring. National Academy Press, Washington, DC. 125pp.

Although focusing on marine resources, this report contains significant information on general aspects of environmental monitoring. The committee for this report sought to: review the current status of monitoring systems and technology, assess marine environmental monitoring as a component of sound environmental management, and identify needed improvements in monitoring strategies and practices. Chapters include: The role of monitoring in environmental management, Strengthening regional and national monitoring and, Designing and implementing monitoring programs.

350.**National Science Foundation.** 1979. Long-term ecological research — concept statement and measurement needs: Summary of a workshop. June 25-27, 1979, Indianapolis. National Science Foundation, Washington, DC. 27 pp.

351.**National Science Foundation.** 1977. Long-term ecological measurements: Report of a conference. Woods Hole, Massachusetts, March 16-18, 1977. National Science Foundation, Directorate for Biological, Behavioral and Social Sciences, Division of Environmental Biology. Washington, DC.

352.**Needham, R.D., ed. 1992.** Special issue: Breaking the barriers to environmental information. Environ. Monit. Assess. 20(2-3):83-271.

This special issue contains papers from a workshop held March 5-6, 1990 by the Institute for Research on Environment and Economy, University of Ottawa. The themes of the workshop were scientific, technological, political, social, and institutional barriers to information in an era of mounting concern for the health condition of the earth's ecosystems and biotic resources. Some papers briefly touch on the concepts of indicators and environmental assessments while others covered topics ranging from the impact of geographic information systems to making environmental information useful to the public to the connections between environmental science and society.

353.**Newman, J.R.** 1975. Animal Indicators of Air pollution: A Review and Recommendations. Rep. CERL-0006, Corvallis Environmental Research Laboratory. Environmental Protection Agency, Corvallis, OR.

354.**Newman, J.** 1979. Effects of industrial air pollution on wildlife. Biol. Conserv. 15:181-190.

Air pollution is a recognized health hazard for humans and domestic animals. Although industrial air pollutants have been known to cause sickness and death of domestic animals for over 100 years, little attention has been paid to the importance of these contaminants in the decline of wildlife. This paper reviews the existing information on the effects of industrial air pollutants on vertebrate wildlife. Air pollutants have had a worldwide effect on both wild birds and wild mammals, often causing marked decreases in local animal populations. The major effects on industrial air pollution on wildlife include direct mortality, debilitating industrial-related injury and disease, physiological stress, anaemia, and bioaccumulation. Some air pollutants have caused a change in the distribution of certain wildlife species.

355.**Newman, J.R., and K.R. Schreiber.** 1984. Animals as indicators of ecosystem responses to air emissions. Environ. Manage. 8(4):309-324.

With existing and proposed air quality regulations, ecological disasters resulting from air emissions such as those observed at Copperhill, Tennessee, and Sudbury, Ontario, are unlikely. Current air-quality standards, however, may not protect ecosystems from subacute and chronic exposure to air emissions. The encouragement of the use of coal for energy production and the development of the fossil-fuel industries, including oil shales, tar sands, and coal liquification, point to an increase and spread of fossil-fuel emissions and the potential to influence a number of natural ecosystems. This paper reviews the reported responses of ecosystems to airborne pollutants and discusses the use of animals as indicators of ecosystem responses to these pollutants. Animal species and populations can act as important indicators of biotic and abiotic responses of aquatic and terrestrial ecosystems. These responses can indicate long-term trends in ecosystem health and productivity, chemical cycling, genetics, and regulation. For short-term trends, fish and wildlife also serve as monitors of changes in community structure, signaling food-web contamination as well as providing a measure of ecosystem vitality. Information is presented to show not only the importance of animals as indicators of ecosystem responses to air-quality degradation, but also their value as air-pollution indices, that is, as air-quality-related values (AQRV), which are required in current air-pollution regulation.

Key Words: Animals, Indicators, Air pollution, Ecosystem responses

356.**Nielson, N.O.** 1992. Ecosystem health and veterinary medicine. Can. Vet. J. 33:23-26.

Application of the health paradigm to the environment immediately suggests an array of approaches and mechanisms that have proven successful in promoting human, animal, and plant health. It also provides a logical framework in which veterinary medicine's interest in wildlife, toxicology, and epidemiology can be more effective. The article begins by defining "health" and environmental health. Subtopics are: ecosystems and the health paradigm; animals as monitors of ecosystem health; sustainable agriculture, farming systems, and epidemiology; toxicology; and veterinarians and the need for an ecosystem health professional.

357.**Nilsson, J.** 1980. Early warning signals of acidification. Page 344. In: D. Drablos and A. Tollan, eds. Ecological Impact of Acid Precipitation: Proceedings of an International Conference. Sandefjord, Norway, March 11-14, 1980. SNSF Project, Oslo.

358.**Nilsson, J., and E. Cowling.** 1992. A comparison of some national assessments. Pages 463-517. In: T. Schneider, ed. Acidification Research: Evaluation and Policy Applications. Elsevier Science Publishers, Amsterdam.

359.**Norton, B.** 1991. Ecological health and sustainable resource management. Pages 102-117. In: R. Costanza, ed. Ecological Economics: The Science and Management of Sustainability. Columbia University Press, New York.

A contextual approach to environmental management requires a distinction between "resource management," the management of a resource-producing cell such as a field or fishery, and "environmental management," which involves concern for the larger systems which environ those cells. Mainstream natural resource economics defines sustainability mainly by reference to undiminished outputs of economically marketable products and emphasizes productivity criteria in judging management regimes. This approach is appropriate in many cases for guiding "resource management" but, taken alone, it provides no guidance regarding the protection of the larger, environmental context of resource-producing activities.

Aldo Leopold, and most environmentalists following him, have applied a contextual approach in which resource-producing cells are understood as larger, slower-changing (but still dynamic) ecological systems. According to this approach, "resource management" should be limited when resource-producing activities approach a threshold beyond which they alter larger systems and instigate rapid change in environing systems. Metaphorically, this result is referred to as "illness" in the ecological community, but the rules and criteria for describing these limits have never been stated precisely in ecological terms. A definition of "ecosystem health," based on biologically formulated criteria for judging larger ecological systems, will be proposed and integrated into a hierarchical approach to environmental management.

360.**Norton, B.** 1992. In Press. Sustainability, human welfare, and ecosystem health. Environ. Values.

This article discusses the need for environmentalists, scientists, and philosophers to develop, explain, and justify a theory of environmental practice that gives form and specificity to the goal of sustainability. The author sketches two approaches to understanding sustainability. The article is divided into four sections: Sustainability and Human Welfare; A Classification of Risk; Scientific Contextualism; and Health, Integrity, and Sustainability.

361.**Norton, D., D. Muchoney, and E. Slonecker.** 1990. Ecological monitoring using remote sensing supported GIS. In: Technical Papers—1990 ACSM-ASPRS Annual Convention, Volume 4. American Congress on Surveying and Mapping, Falls Church, VA.

362.**Norton, D.J., and E.T. Slonecker.** 1990. Landscape characterization: The ecological geography of EMAP. GeoInfo Syst. 1(0): 32-43.

The U.S. Environmental Protection Agency (EPA) has initiated the Environmental Monitoring and Assessment Program (EMAP), a long-range program to monitor status and trends in the condition of our nation's major ecological resources. EMAP's spatial design borrows from classical geographic thought, past and present, and the program will use geographic information systems (GIS) technology to characterize ecological resources and assess environmental problems. EMAP will collect data using a national, systematic sampling grid and a hierarchical approach of monitoring conditions concurrently at multiple scales of detail. EMAP will apply the concept of landscape characterization to document, at coarse levels, the composition and pattern of land cover, land use, and other attributes of surficial terrain structure. These data will be compiled using multistage remote sensing and will be stored and analyzed in a GIS data base along with a variety of existing spatial data sets. Concurrently, field monitoring groups will measure indicators of ecological condition for wetlands, forests, arid lands, surface waters, near-coastal waters, and agroecosystems.

This article describes EMAP's landscape characterization approach and discusses the growing role of GIS technology in national ecological monitoring.

363.**Norton, D., and E. Slonecker.** 1990. The Environmental Monitoring and Assessment Program's landscape characterization database — New opportunities in spatial analysis. Pages 682-690. In: GIS/LIS '90 - Technical Papers. Geographic Information Systems/Land Information Systems Annual Conference, Anaheim, Ca. American Congress on Surveying and Mapping, Falls Church, VA.

364.**Norton, S., D. Rodier, J. Gentile W. Van der Schalie, W. Wood, and M. Slimak.** 1992. A framework for ecological risk assessment at the EPA. Environ. Toxicol. Chem. 11(12):1663-1672.

Ecological risk assessments evaluate the likelihood of adverse ecological effects caused by stressors related to human activities such as draining of wetlands or release of chemicals. The term stressor is used to describe any chemical, physical, or biological entity that can induce adverse effects on ecological components (i.e., individuals, populations, communities, or ecosystems). In this review article, a historical perspective on ecological risk assessment activities at the U.S. Environmental Protection Agency (EPA) is followed by a discussion of the EPA's "Framework Report", which describes the basic elements for conducting an ecological risk assessment. The "Framework Report" is neither a procedural guide nor a regulatory requirement within the EPA. Rather, it is intended to foster a consistent approach to ecological risk assessments within the agency, identify key issues and define terminology.

365.**Noss, R.F.** 1990. Indicators for monitoring biodiversity—a hierarchical approach. Conserv. Biol. 4(4):355-364.

Biodiversity is currently only a minor consideration in environmental policy. It has been regarded as too broad and vague a concept to be applied to real-world regulatory and management problems. This problem can be corrected if biodiversity is recognized as an end in itself, and if measurable indicators can be selected to assess the status of biodiversity over time. Biodiversity, as currently understood, encompasses multiple levels of biological organization. In this paper, the author expands the three primary attributes of biodiversity recognized by Jerry Franklin - composition, structure, and function - into a nested hierarchy that incorporates elements of each attribute at four levels of organization: regional landscape, community-ecosystem, population-species, and genetic. Indicators of each attribute in terrestrial ecosystems, at the four levels of organization, are identified for environmental monitoring purposes. Projects to monitor biodiversity will benefit from a direct linkage to long-term ecological research and a commitment to test hypotheses relevant to biodiversity conservation. A general guideline is to proceed from the top down, beginning with a coarse-scale inventory of landscape-pattern, vegetation, habitat structure, and species distributions, and overlaying data on stress levels to identify biologically significant areas at high risk of impoverishment. Intensive research and monitoring can be directed to high-risk ecosystems and elements of biodiversity, while less intensive monitoring is directed to the total landscape (or samples thereof). In any monitoring program, particular attention should be paid to specifying the questions that monitoring is intended to answer and validating the relationships between indicators and the components of biodiversity they represent.

366.**Novak, E., D. Porcella, K. Johnson, and E. Herricks.** 1985. Selection of test methods to assess ecological effects of mixed aerosols. Ecotoxicol. Environ. Saf. 10:361-381.

Components of mixed aerosols generated during military training are known to be of toxicological and/or ecological significance. There are few studies, however, that quantify mixed aerosol effects and/or ecological significance. Prompted by the finding that one or more of the compounds in the mixed aerosols commonly encountered in military training areas showed mutagenic effects in several species, a multiyear effort is under way to evaluate the use of ecotoxicity testing methods to assess mixed aerosol ecological impacts. Selection of test methods for ecoepidemiology begins with the identification of the data required to meet defined environmental quality objectives. The data requirements are then matched with appropriate test methods, and testing results are related to important ecological effects resulting from aerosol exposure. The critical element of test system selection is to ensure that toxicity testing results relate to important ecological effects. The procedures developed for identifying test methods to asses mixed aerosols are also applicable to a range of environmental contaminants regulated by air, water, and solid waste regulations.

367.**NSEPB.** 1985. The National Swedish Environmental Monitoring Programme (PMK). Research and Development Department, Environmental Monitoring Section. National Environmental Protection Board, Solna, Sweden.

368.**O'Conner, J.S., and D. Flemer.** 1987. Monitoring, research, and management: Integration for decision making in coastal marine environments. Pages 70-90. In: T. Boyle, ed. New Approaches to Monitoring Aquatic Ecosystems. ASTM STP 940. American Society for Testing and Materials, Philadelphia.

A rationale is presented for making research and monitoring interdependent to maximize the contributions of both activities to environmental management. Emphasis is placed on making better choices of temporal and spatial scales of marine assessments, thereby improving managerial guidance from monitoring and research. Although the choice of appropriate scales is a function of particular environmental issues, the most useful scales "in the mean" appear to be long-term (including truly historical) and regional. The likelihood in the near-term of only limited incremental advances in understanding ecosystem processes, with marginal improvements in predictability, leads to an argument for more emphasis on the use of managerially helpful, necessarily simple models. One such model is presented to characterize the geographical prevalence of fin erosion in winter flounder (*Pseudopleuronectes americanus*), relative to sources of probable causes, from Canada to Delaware Bay. Changing emphasis from laboratory bioassays to field population-level effects is an important and essential step toward integrating ecosystem-level knowledge into the managerial and regulatory milieu.

It is now possible to quantify the geographic and, at least recent, temporal associations among human waste sources and some of their biological effects. Further elaboration of the current understanding of source-fate-effects with the help of simple models (for example, indices) is often more useful to managers than is detailed piecemeal quantification of seemingly intractable ecosystem dynamics.

Key Words: Chesapeake Bay, New York region, Monitoring, Waste management, Marine ecosystems, Marine resources, Indices, Environmental quality

369.**Odemerho, F., and B. Chokor.** 1991. An aggregate index of environmental-quality. Appl. Geogr. 11(1):35-58.

In recent times, conflicts have arisen over how the quality of an environment may be appropriately assessed. In particular, the dichotomy between professional and lay assessments of environmental quality has posed a major problem, not only to the interpretation of quality but also to environmental management practices, especially in the third world. This study, therefore, seeks to present a more balanced assessment of quality by combining both professional and lay viewpoints to produce an aggregate index of environmental quality by using the example of Benin City, Nigeria. Data sets reflecting both viewpoints were factor analyzed, and the major dimensions of judgement by each group were weighted and combined into an aggregate index. The findings of the study show a spatial disparity of quality in Benin City between the urban core districts and the suburbs that seems to reflect local environmental problems facing the people of typical third-world cities. It is argued that the neighborhood aggregate index provides a meaningful guide to planners in allocating resources to reflect spatial disparities existing between neighborhoods. Furthermore, real estate businesses and developers, as well as those relocating, may benefit from a more accurate and balanced quality picture of the neighborhoods.

370.**Odum, E.P.** 1981. The effects of stress on the trajectory of ecological succession. Pages 43-47. In: G.W. Barrett and R. Rosenberg, eds. Stress Effects on Natural Ecosystems. John Wiley & Sons, Chichester, England.

It is well known that the response of biotic communities to perturbations varies with the stage in their development (i.e., the stage in ecological succession). For example, Miller and McNaughton found that an application of commercial fertilizer resulted in an increase in net productivity in a 7-year-old-field but not in seventeen-year-old-field, which proved to be resistant to this particular perturbation. Woodwell has reported that the various stages of succession, specifically old fields and forests, differ in their capacity to assimilate treated sewage wastes. Other examples could be cited. The purpose of this article is to suggest a working hypothesis for predicting the response of the sere (i.e., the successional sequence as a whole) to stress.

Subtopics covered in this article include: definitions, a systems approach, optimality, and allogenic vs autogenic causes.

371.**Odum, E.** 1985. Trends expected in stressed ecosystems. Bioscience 35:419-422.

When certain ecosystems are not suffering from unusual external perturbations, we observe certain well-defined developmental trends. Because disturbance tends to arrest, or even reverse, these autogenic developments, we can anticipate some ecosystem responses to stress. Trends expected in stressed ecosystems include changes in energetics, nutrient cycling, and community structure and function.

372.**Odum, E., and J. Cooley.** 1980. Ecosystem profile analysis and performance curves as tools for assessing environmental impact. Pages 94-102. In: Biological Evaluation of Environmental Impacts. Proceedings of a symposium at the 1976 meeting of the Ecological Society of America. Biological Services Program, FWS/OBS-80/26, June 1980. U.S. Department of the Interior, Washington, DC.

The authors suggest that pictorial and graphic models provide the logical procedure intermediary between the piecemeal and holistic assessments of environmental impact. A table showing five general areas of aquatic condition is also presented comparing factor-level measurements (standing states) with ecosystem-level measurements (dynamic states).

373.**Odum, E. P., J.T. Finn, and E.H. Franz.** 1979. Perturbation theory and the subsidy-stress gradient. Bioscience 29(6):349-352.

Human impact on the environment often involves a gradient of subsidy and stress effects, which vary along nutrient, climatic, developmental (successional), and other important ecological gradients. Because performance curves that simulate subsidy-stress responses are unimodal, the zone of optimality can be determined on the basis of relatively few experiments in which specific input factors are of concern. The authors emphasize the importance of assessing the response of the perturbed system at different levels of organization. In practice, at least two levels, the ecosystem and the population (species) level, are necessary for a complete impact evaluation. The authors stress the need for judicious use of terms and the desirability of sticking as closely as possible to basic definitions if one expects to communicate with large numbers of people.

374.**Office of Health and Environmental Research (OHER).** 1988. Terrestrial biosphere response to large-scale environmental change. Proposed initiative, OHER, Ecological Research Division. United States Department of Energy, Washington, DC. October.

375.**Ojima, D., T. Kittel, and T. Rosswall.** 1991. Critical issues for understanding global change effects on terrestrial ecosystems. Ecol. Appl. 1(3):316-325.

Marked alterations in Earth's environment have already been observed, and these presage even greater changes as the impact of human activities (i.e. land use and industrial) increases. Direct and indirect feedbacks link terrestrial ecosystems with global change and include interaction affecting fluxes of water, energy, nutrients, and "greenhouse" gases and ecosystem structure and composition. Community development can affect ecosystem dynamics by altering resource partitioning among biotic components and through changes in structural characteristics, thereby affecting feedbacks to global change. The response of terrestrial ecosystems to the climate-weather system is dependent on the spatial scale of the interactions between these systems and the temporal scale that links the various components.

The International Geosphere-Biosphere Program (IGBP), which was initiated by the International Council of Scientific Unions (ICSU) in 1986, has undertaken to develop a research plan to address a predictive understanding of how terrestrial ecosystems will be affected by global changes in the environment and possible feedbacks. The IGBP science plan, which incorporates established Core Projects and activities related to research on terrestrial ecosystem linkages to global change, includes the International Global Atmospheric Chemistry Project (IGAC); the Biosphere Aspects of the Hydrological Cycle (BAHC); the Global Change and Terrestrial Ecosystems (GCTE); Global Analysis, Integration, and Modelling (GAIM); IGBP Data and Information System (DIS); and IGBP Regional Research Centers (RRC). The coupling of research and policy communities for the purpose of developing mechanisms to adapt to these impending changes urgently needs to be established.

Key Words: Global change, IGBP (International Geosphere-Biosphere Program), Terrestrial ecosystems

376.**Olsen, A.R.**, ed. 1992. The Indicator Development Strategy for the Environmental Monitoring and Assessment Program. EPA/600/3-91/023. U.S. Environmental Protection Agency Environmental Research Laboratory, Corvallis, OR.

This document provides an overview of EMAP, discusses the role of indicators in EMAP, and outlines a strategy for indicator development and evaluation within EMAP. Its objectives are twofold: (1) to present general guidelines, criteria, and procedures for indicator selection and evaluation, and (2) to establish an organizational framework for coordinating and integrating indicator development and use within EMAP. It should serve both to promote internal consistency among EMAP resource groups and to provide a basis for internal and external review of proposed EMAP indicators.

377.**Omernik, J.M., and G.E. Griffith.** 1991. Ecological regions versus hydrologic units: Frameworks for managing water quality. J. Soil Water Conserv. 46(5):334-340.

By using inappropriate spatial frameworks, some assessments may actually do more to obscure the nature and extent of a water quality problem than to clarify it. Spatial frameworks based on ecological regions often can be more useful for assessing the health of aquatic ecosystems than can frameworks based only on hydrologic units, drainage basins, or administrative or political units. Methods of defining the spatial extent of specific water quality problems or components require a similar, although specially tailored, synoptic approach.

This article reviews the background of frameworks, provides a comparison of frameworks (national scale, state/regional scale), and proposes a more logical framework.

378.**O'Neill, R., D. DeAngelis, J. Waide, and T. Allen.** 1986. A Hierarchical Concept of Ecosystems. Princeton University Press, Princeton, NJ. 253 pp.

This book reassesses and critiques current concepts of ecosystems and provides a historical view of how ecologists have viewed ecosystems. Chapters discuss functional vs structural analyses and the application of hierarchy theory to ecological analysis. The book thus provides a discourse on the problems associated with comparing effects on "state variables" (indicators) at lower ecological levels with higher ecological levels.

379.**O'Neill, R., B. Ausmus, D. Jackson, R. Van Hook, P. Van Voris, C. Washburne, and A. Watson.** 1977. Monitoring terrestrial ecosystems by analysis of nutrient export. Water Air Soil Poll. 8:271-277.

Current methodology for environmental impact assessment relies heavily on population parameters to detect ecological effects of perturbation. The authors believe that recent advances in ecosystem analysis permit the identification of monitoring points that reflect changes in the total system. Focusing on mechanisms of ecosystem homeostasis, the authors suggest soil nutrient loss as a sensitive, holistic measure of ecological effects. In three separate studies, attempts were made to detect the effects of toxic substances by monitoring relevant population parameters. In each case, disturbance could be detected in nutrient cycling, but no significant change was evident in the population/community parameters. These results indicate that indices of total ecosystem function may be feasible.

380.**O'Neill, R., R. Gardner, L.W. Barnthouse, G.W. Suter II, S.G. Hildebrand, and C.W. Gehrs.** 1982. Ecosystem risk assessment: A new methodology. Environ. Toxicol. Chem. 1:167-177.

A method is presented for extrapolating laboratory toxicity data to aquatic ecosystem effects such as decreased productivity or reduction in gamefish biomass. The extrapolation requires translating laboratory data into changes in the parameters of an ecosystem model, the Standard Water Column Model (SWACOM). The translation is effected through knowledge of toxicological modes of action. The uncertainties associated with both laboratory measurements and extrapolations are explicitly retained, and risk estimates are given in the form of probabilities that an effect could occur. The approach is illustrated by scenarios in which effects of toxic substances are distributed across different trophic levels. Each scenario affects different population interactions in different ways and alters both the level and the nature of the risks to the ecosystem processes. Particular attention is paid to analyzing the interaction between toxicity and the uncertainties associated with extrapolation.

Key Words: Gamefish Biomass, SWACOM, Aquatic ecosystems, Risk analysis, Organic

381.**O'Neill, R., C. Hunsaker, and D. Levine.** 1992. Monitoring challenges and innovative ideas. Pages 1443-1460. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October. Elsevier, Essex, England.

Monitoring programs are difficult to design even when they focus on specific problems, such as water quality in a particular body of water. Ecosystems are complex, and it is difficult to predetermine what aspects of system structure or dynamics will respond to a particular insult. It is equally difficult to interpret whether a response is a stabilizing compensatory mechanism or a real loss of capacity to maintain the ecosystem. The problems are compounded in broad monitoring programs designed to assess ecosystem "health" at regional and continental scales. It is challenging in the extreme to monitor ecosystem response, at any scale, to past insults, as well as to an unknown future array of impacts.

The challenge can be illustrated by problems in data interpretation. When indicators are remeasured after 5 to 10 years, some values will have changes. Does the change indicate a trend or normal fluctuations? Stochastic fluctuations in weather can account for many short-term changes. A number of ecological phenomena, such as predator-prey cycles, are known to fluctuate normally over 3- to 100-year cycles. Reliable evidence of trends requires monitoring over a long period of time. Likens showed that 20 years of continuous records were needed at Hubbard Brook to determine statistically significant trends in watershed geochemistry. Goldman showed that 15 years of secchi disc readings were needed at Lake Tahoe to establish a statistically significant reduction in transparency. Only these extended data sets allow unambiguous association of a change in an indicator measurement to an ecosystem trend.

However, in spite of the challenge, systematic monitoring is critically needed to balance anecdotal information. Every warm summer, everyone is sure that global warming has started. However, it is clear that we have not been measuring weather long enough to be able to characterize all of the normal trends. Nevertheless, the newspaper and television media jump on every short-term trend as evidence of monotonic change. Systematic monitoring with statistically valid designs is needed to produce reliable indicators of trends.

The present paper will examine some of the fundamental issues and challenges raised by large-scale monitoring efforts. The challenges will serve as a framework and as an excuse to discuss several important topics in more detail. Following the discussion of challenges, the author suggests some basic innovations that could be important across a broad scope of monitoring programs. The innovations include holistic measures, innovative methodology, and creative analysis.

382.**Organization for Economic Cooperation and Development.** 1991. Environmental indicators. Organization for Economic Cooperation and Development, Paris.

This publication provides a preliminary set of environmental indicators by which to measure environmental performance. Twenty-five indicators are described along side statistics and tables. The indicators are: CO_2 emissions, greenhouse gas emissions, SO_X emissions, NO_X emissions, use of water resources, river quality, wastewater treatment, land use changes, protected areas, use of nitrogenous fertilizers, use of forest resources, trade in tropical wood, threatened species, fish catches, waste generation, municipal generation, industrial accidents, public opinion, growth of economic activity, energy intensity, energy supply, industrial production, transport trends, private final consumption, and population.

383.**Orians, G.H.** 1990. Ecological concepts of sustainability. Environment 32(9):10-15 and 34-39.

This paper discusses issues associated with different views of sustainability and includes topics such as limits to sustainable use, valued ecosystem components, old-growth forests as a case study, and policy making for sustainability. Factors affecting sustainability such as predator-prey interactions, mutualistic interactions, species richness, and aesthetic limits are also discussed.

384.**Oriordon, T.** 1991. Towards a vernacular science of environmental change. Pages 149-162. In: L. Roberts and A. Weale, eds. Innovation and Environmental Risk. Belhaven Press, London.

385.**Ott, W.** 1978. Environmental Indices: Theory and Practice. Ann Arbor Science Publishers, Ann Arbor, MI.

In the 1960s and 1970s, many indices and statistical approaches for interpreting and presenting information on the state of the environment have been developed. The author has attempted to bring together, in a systematic fashion, all existing environmental index systems, along with principles for their design, application, and structure. Chapter I introduces the reader to environmental data, presenting simple communicative approaches such as environmental quality profiles. The language and role of indices are also discussed. Chapter II presents a framework that is designed to embrace nearly all existing environmental indices, allowing the behavior of different index structures to be compared and probed in detail. Additional chapters cover air and water pollution indices. The final section is devoted to conceptual approaches to quality-of-life indices and also discusses other indices involving noise, total environment, and species diversity.

386.**Oviatt, C., M. Pilson, and S. Nixon.** 1984. Recovery of a polluted estuarine system: A mesocosm experiment. Mar. Ecol. Prog. Ser. 16:203-217.

387.Paoletti, M., M. Favretto, B. Stinner, and F. Purrington. 1991. Invertebrates as bioindicators of soil use. Agric. Ecosyst. Environ. 34: 341-362.

We face an increasing demand from administrative, technical, and environmental authorities to use bioindicators—animals, plants, and community patterns that register quantitative and qualitative environmental changes. Such monitoring can range from simple chemical and physical sampling to quantifying the patterns of animal and plant communities. These techniques for analyzing soil communities were first developed for aquatic systems. Protozoans, earthworms, woodlice, myriapods, Acari, springtails, and other groups of invertebrates seem to respond to chemical residues and other environmental stresses in many different ways. Although a rich literature on interactions is available, only limited information exists on community-level responses and little is known of the food-chain level responses in the soil. Research is needed to find appropriate patterns that could model different situations.

388.Parker, J. 1991. Environmental assessment—2 conferences on environmental indicators and indexes. Environment 33(5):41-43.

This article briefly describes EMAP, and explains the need for environmental indicators and assessments of the "state of the environment." The majority of the article provides brief descriptions of the types of papers presented at two conferences: the 1st International Symposium on Ecological Indicators (Ft. Lauderdale, October, 1990), and the Workshop on Indicators and Indices for Environmental Impact Assessment and Risk Analysis (Ispra, Italy, May, 1990). The difference between an indicator and an index is also noted.

389.Parker, J., and C. Hope. 1992. The state of the environment: A survey of reports from around the world. Environment 34(1):18-20,39-45.

This article presents a preliminary list of the current State of the Environment Reports (SERs) from around the world. SERs are comprehensive sets of statistics on the quality of a country's environment. The article also discusses SERs and the public, the U.N. Conference on Environment and Development, and difficulties with SERs.

390.Parr, J., R. Papendick, S. Hornick, and R. Meyer. 1992. Soil quality: Attributes and relationship to alternative and sustainable agriculture. Am. J. Altern. Agric. 7(1-2):5-11.

Different chemical, physical, and biological properties of a soil interact in complex ways that determine its potential fitness or capacity to produce healthy and nutritious crops. The integration of these properties and the resulting level of productivity often is referred to as "soil quality." Soil quality should not be limited to soil productivity, but should encompass environmental quality, human and animal health, and food safety and quality. There is inadequate reliable information on how changes in soil quality directly affect food quality, or indirectly affect human and animal health. In characterizing soil quality, biological properties have received less emphasis than chemical and physical properties, because their effects are difficult to measure, predict, or quantify. Improved soil quality often is indicated by increased infiltration, aeration, macropores, aggregate size, aggregate stability, and soil organic matter, and by decreased bulk density, soil resistance, erosion, and nutrient runoff. These are useful, but future research should seek to identify and quantify reliable and meaningful biological/ecological indicators of soil quality, such as total species diversity or genetic diversity of beneficial soil microorganisms, insects, and animals. Because these biological/ecological indexes of soil are dynamic, they will require effective monitoring and assessment programs to develop appropriate databases for research and technology transfer. We need to know how such indexes are affected by management inputs, whether they can serve as early warning indicators of soil degradation, and how they relate to the sustainability of agricultural systems.

Key Words: *Global change, Soil erosion, Soil degradation*

391.Parzyck, D., R. Brocksen, and W. Emanuel. 1980. Regional analysis and environmental impact assessment. Pages 114-121. In: Biological Evaluation of Environmental Impacts. Proceedings of a symposium at the 1976 meeting of the Ecological Society of America. FWS/OBS-80/26. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

This paper presents a number of techniques that can be used to assess environmental impacts on a regional scale. Regional methodologies have been developed that examine impacts on aquatic and terrestrial biota in regions through consideration of changes in land use, land cover, air quality, water resource use, and water quality. Techniques used to assess long-range atmospheric transport, water resources, effects on sensitive forest and animal species, and impacts on humans are presented in this paper, along with an optimization approach that serves to integrate the analytical techniques in an overall assessment framework.

This paper on assessment techniques is meant to provide a brief review of the research approach and certain modeling techniques used within one regional studies program. Although it is not an all-inclusive report on regional analyses, it does illustrate the types of analyses that can be performed on a regional scale.

392.**Paul, J., F. Holland, K. Scott, D. Flemer, and E. Meier.** 1989. An ecological status and trends program: EPA's approach to monitoring the condition of the nation's ecosystems. Pages 579-664. In: Oceans '89. Vol. 2. Proceedings of a conference held September 18-21, 1989 in Seattle, WA. IEEE Pub. No. 89CH 2780-5. Ocean Engineering Society of the Institute of Electric and Electronic Engineers.

The U.S. Environmental Protection Agency (EPA) is initiating an Environmental Monitoring and Assessment Program (EMAP) to monitor the status and trends of the nation's near-coastal waters, forests, freshwater wetlands, surface waters, and agroecosystems. This program is also intended to evaluate the effectiveness of Agency policies at protecting ecological resources in these systems. Monitoring data collected for all ecosystems will be integrated for national status and trends evaluations.

The near-coastal component of EMAP will consist of four ecosystem categories: estuaries, wetlands, coastal waters, and Great Lakes. Near-coastal ecosystems will be regionalized and classified, an integrated sampling strategy designed, and quality assurance/quality control procedures and data base management procedures implemented. A pilot study will be conducted in one region of the country, followed by a full-scale national implementation.

393.**Paul, J.F., A.F. Holland, J.K. Summers, S.C. Schimmel, and K.J. Scott.** 1991. EPA's Environmental Assessment and Monitoring Program: An ecological status and trends program. Pages 80-99. In: D. Chapman, F. Bishay, E. Power, K. Hall, L. Harding, D. McLeay, M. Nassichuck, and W. Knapp, eds. Proceedings of the Seventeenth Annual Aquatic Toxicity Workshop. Held November 5-7, 1990, Vancouver, BC. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1774.

394.**Peichl, L., and D. Reiml.** 1990. Bioprobes: Biological–effect test systems for the early recognition of unexpected environmental changes. Environ. Monitor. Assess. 15:1-12.

Pre-marketing assessments of chemicals regarding their potential environmental impacts contain numerous sources of error and uncertainties. Practices and methods for the evaluation of environmental risks posed by individual pre-selected agents seem unsuitable for detecting unexpected trends in the environment. This is particularly so in view of the multitude of anthropogenic assaults on the environment and their complex interactions. Therefore, requirements for symptom-oriented biological effect-test systems, 'bioprobes', capable of reacting sensitively to environmental changes of unknown origin were conceived. Bioprobes designed to detect biological effects should respond to a broad spectrum of anthropogenic chemicals. They are environmental quality measuring devices consisting of cultivated organisms, cells, organelles or biomolecules in combination with recording units. In contrast to traditional biotests for chemical testing, bioprobes are deliberately exposed to selected segments of the environment for certain periods of time. During and after such exposures, changes of defined biological states or process rates - "observation elements" - are registered.

395.**Perkins, R.** 1974. Stress and its relation to the ecosystem. Int. J. Ecol. Environ. Sci. 1:119-127.

Quantification of environmental stress by using species diversity indices has had only limited success. By using a definition of stress that is compatible with ecology and by incorporating ecosystem function into an environmental stress index, a new measure of environmental stress is proposed. Comparison of eight ecosystems, representing a gradient from harsh to mild environments, demonstrates the validity of an index based on ecosystem parameters rather than on population parameters. A stress index may be a useful component in ecosystem models and in evaluation of resource management practices.

396.**Perry, D., and J. Borchers.** 1990. Climate change and ecosystem responses. Northwest Environ. J. 6(2):293-313.

In this paper the authors briefly review current knowledge concerning the possible consequences of a changing climate for terrestrial ecosystems. Forests and grasslands of western North America figure prominently in the discussion, but the intent of the authors is to consider general principles rather than specific communities. Nevertheless, these principles are applicable to the fate and management of old-growth forests. First, the authors review the current climate-change scenarios and their implications for plant growth and physiology. Next, they consider the severity and frequency of disturbances such as fire, insect outbreaks, and windstorms. The authors then turn to the possible net effect of climate change on ecosystems, an effect that emerges from numerous interactions and feedback processes and is greatly affected by the speed with which species migrate. Finally, they discuss some approaches for mitigating possible impacts and for easing transitions from one community type to another.

397.**Perry, J., D. Schaeffer, and E. Herricks.** 1987. Innovative designs for water quality monitoring: Are we asking the right questions before the data are collected? Pages 28-39. In: T. Boyle, ed. New Approaches to Monitoring Aquatic Ecosystems. American Society for Testing and Materials, Philadelphia.

Water quality management consists of decisions about the environment; those decisions are usually based on data from monitoring programs. Such data are usually collected following a design that is governed by "bureaucratic risk," that is, the perceived risk of ire by a superior. The authors propose the application of a systematic process called the Environmental Audit as a tool for guiding management decision making and for designing monitoring programs. Application of the audit is shown to produce data that leads directly to real environmental information (in contrast to pure data). Such information is translated into management decisions that incorporate all elements of the broad definition of environmental risk.

Key Words: Data management, Environmental audit, Environmental risk, Monitoring, Water quality management

398.**Perry, J.A., N. Troelstrup, Jr., M. Newsom, and B. Shelley.** 1987. Whole ecosystem manipulation experiments: The search for generality. Water Sci. Technol. 19(11):55-71.

The objective of this paper is to summarize population and community-level responses observed during two recent whole-ecosystem manipulations and then to examine those results in light of the literature. The authors address the question: "Are there generalities in the ways that structure and/or function respond to experimentally imposed stresses?"

Based on these ideas, the authors hypothesized that there should be some degree of generality in the ways that ecosystems respond to stress and that the degree of generality should be quantifiable. Specifically, they hypothesized that (1) community structure variables should be less resistant to a given stress than should community function variables and (2) a given property or process should respond with the same quality (direction of change) and the same relative quantity (order of magnitude) of response when a similar level of stress is applied to diverse ecosystem types (e.g., organic matter processing in lakes vs. streams, subjected to different stresses).

399.**Peters, R.** 1980. Useful concepts for predictive ecology. Synthese 43:257-269.

Scientists deal with two classes of ideas. The first class consists of theories, predictive or falsifiable statements about the universe. The second class consists of concepts which, by definition, are unfalsifiable. Both types of ideas are necessary for a scientist, but only theories comprise a science. Nevertheless, in ecology, concept and theory are confused to the point that nonpredictive ideas impede scientific advancement. In this essay, the author distinguishes between the roles of theory and concept, indicating the very real shortcomings of a science that is too rooted in concept. The author suggests that we set aside the bulk of our ecological concepts in order concentrate on theory building and modification and I describe some small steps towards a predictive ecology.

400.**Petersen, R.C., Jr.** 1992. The RCE: A riparian, channel, and environmental inventory for small streams in the agricultural landscape. Freshwater Biol. 27:295-306.

The Riparian, Channel, and Environmental (RCE) Inventory has been developed to assess the biological and physical condition of small streams in the lowland, agricultural landscape. It consists of sixteen characteristics that define the structure of the riparian zone, stream channel morphology, and the biological condition in both habitats. The inventory is based on the view that in landscapes where non–point–source pollution and agriculture dominate, the environmental condition of small streams can be assessed by appraising the physical condition of the riparian zone and stream channel. It is assumed that disturbance of this physical structure is a major cause for reduction of stream biological function. This assumption is supported by a case study using fifteen Italian stream locations in which the RCE was found to be positively correlated to the benthic macroinvertebrate community as measured by the Extended Biotic Index ($r = 0.80$, $P < 0.001$) and Shannon Diversity Index ($r = 0.73$, $P < 0.001$).

The inventory is designed for quick use to cover a large number of streams in a short period. It generates a numerical score that can be used to compare the physical and biological condition of different streams within a region. the numerical score is divided into five, color-code classes to facilitate use in stream monitoring programs and to allow comparison with biological indices.

401.**Phillips, D.** 1980. Quantitative Aquatic Biological Indicators. Applied Science Publishers, Ltd., London.

402.**Phillips, D.** 1986. Use of bio-indicators in monitoring conservative contaminants: Programme design imperatives. Mar. Pollut. Bull. 17:10-17.

The general acceptance of the advantages inherent in the use of bioindicators to monitor aquatic pollution has given rise to the establishment of national and international programs employing such indicator species in many parts of the world over the last decade. The authors review the overall design of such programs. Some deficiencies in the studies to date are noted, and suggestions for improvement in future monitoring programs are presented.

403.**Pickett, S., J. Kolasa, J. Armesto, and S. Collins.** 1989. The ecological concept of disturbance and its expression at various hierarchical levels. Oikos 54:129-136.

Current definitions of disturbance are intuitive, narrow, and only implicitly based on system structure. This is because the concepts are based on experience at particular levels of organization or on systems whose structure is well known. The definitions are thus inadequate for the development of a general theory of ecological disturbance. A universally applicable definition would: (1) identify the object disturbed (2) distinguish between change in the object that is disturbance and change that is not and (3) distinguish between direct and indirect consequences of disturbance. To meet these requirements, the authors formally link the hierarchical organization of ecological objects and the concept of disturbance. Any persistent ecological object will have a minimal structure, or system of lower-level entities that permit its persistence. Disturbance is a change in the minimal structure of an object caused by a factor external to the level of interest. Using these definitions, disturbance can be unequivocally identified and associated with various specific ecological levels of organization. Because of the dependence of the concept of disturbance on recognizing the minimal structure of ecological systems, application of the concept will advance as refined models of the hierarchical structure of ecological systems are elaborated.

404.**Piekarz, D.** 1990. Editorial. Environ. Monitor. Assess. 15:iii-v.

This editorial gives introductory remarks about this particular issue's topic, environmental indicators, and the conference on the State of the Environment reporting for Canada. It discusses in general fashion the identification of ecological indicators and the collection of the requisite monitoring data that would ideally serve to diagnose the "health" of ecosystems.

405.**Piekarz, D.** 1990. Rapporteur's report of workgroup: Indicators and assessment of agricultural sustainability. Environ. Monitor. Assess. 15:307-308.

This article summarizes the response of the conference workgroup in answering two issues: (1) Identification of the most important variables to measure to ensure sustainable agriculture ecology and (2) Identification of indicators of the resilience of soil ecosystems.

406.**Pikul, R.** 1974. Development of environmental indices. Pages 103-121. In: J. Pratt, ed. Statistical and Mathematical Aspects of Pollution Problems. Marcel Dekker, New York.

The author has suggested there are over 100 factors, which he ranked and grouped into 14 categories, for which indices of environmental quality could be constructed. These categories are: water pollution, hazardous substances (radioactivity levels, pesticide residues, etc.), land management (wetlands, erosion potential, dam siltage, urban green, etc.) solid waste disposal, recycling, resources (timber, agriculture, fish catch, minerals, etc.), natural phenomena (climate, solar radiation, floods, runoff, etc.), social-aesthetic conditions (rat infestation, outdoor recreation, housing, noise, urban sprawl, traffic congestion, odor, etc.), population, human health, biological health and ecological balance (endangered species, fish kills, algal blooms, etc.), economic loss, and pollution control measures.

407.**Posthumus, A.** 1991. Effects of air pollution on plants and vegetations. Pages 191-198. In: J. Rozema and J. Verkleij, eds. Ecological Responses to Environmental Stresses. [Series: Tasks for vegetation science 22 (1991)]. Kluwer Academic Publishers, Dordrecht, The Netherlands.

408.**Powell, G., and A. Powell.** 1986. Reproduction by Great White Herons in Florida Bay USA as an indicator of habitat quality. Biol. Conserv. 36(2):101-114.

Reproduction parameters of great white herons were used to evaluate the habitat quality of eastern Florida Bay. Clutch size and productivity of the herons during three breeding seasons were compared with similar data from 1923 that predated suspected human alteration of the Florida Bay ecosystem. In addition, because about 15% of the great white herons nesting in eastern Florida Bay supplemented their diet with food obtained from people, it was possible to evaluate the impact of food availability on reproduction. Herons that fed naturally in Florida Bay (unsupplemented) had significantly smaller clutches and produced significantly fewer fledglings than those of 1923. Herons that received supplemental food had reproductive parameters similar to those of 1923. The authors interpret these data as indicating that habitat quality is currently reduced from 1923 levels. These results support the prediction that wading bird reproduction can be sensitive to habitat quality and that these species should be useful as biological indicators of habitat quality.

409.**Pratt, J.R., and N.J. Bowers.** 1992. Variability in community metrics: Detecting changes in structure and function. Environ. Toxicol. Chem. 11:451-457.

Increased environmental realism in toxicity testing has been advocated to better predict ecological effects of toxic chemicals, and several aquatic microcosm bioassays have been developed that use both natural and synthetic organism assemblages. Additionally, greater emphasis is being placed on community changes as evidence of adverse effects on aquatic ecosystems. The ability to infer structural or functional changes in stressed vs unstressed communities is linked to statistical power that arises from the combination of experimental design and the underlying variability in chosen metrics.

The authors evaluated several community response variables (metrics) in aquatic laboratory microcosm experiments and field studies to estimate metric variability. Variability of community metrics under laboratory conditions was similar to that observed in the field. Power curves were constructed to estimate the detectability of significant responses with different experimental designs. Using the median C.V. for each measured response, the authors estimated the minimum detectable distance for power of 0.8 (beta = 0.2) and alpha= 0.05 for each response. Community metrics with C.V.s < 30% allow detection of differences between means of 20 to 60%, using as few as three replicates. Structural metrics such as species richness and standing crop are expected to prove more useful in detecting community and ecosystem changes. Process rates are affected by material supplies that may not change under stress.

Key Words: Microcosms, Variability, Community metrics

410.**Price, P., and T. Reeves.** 1992. What we have concluded: Research and development priorities and issues for indicators. Pages 75-82. In: A. Hamblin, ed. Environmental Indicators for Sustainable Agriculture. Bureau of Rural Resources, Dept. of Primary Industry and Energy, Queen Victoria Terra, Australia.

411.Proceedings of Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems. 1980. Forest Service Pacific SW Forest Experiment Station General Technical Report PSW-43. U.S. Department of Agriculture, Berkeley, Ca.

This document contains papers in five categories: Natural influences of forests on local and regional air quality; Effects of chronic exposures to gaseous pollutants on primary production processes; Secondary and interactive effects of chronic gaseous pollutants exposure of producers, consumers, and decomposers; Chronic effects of acidic precipitation and heavy metals on forest ecosystems and; Simulation modeling of the effects of chronic pollutant stress on plant processes and plant community dynamics. The last category contains a paper addressing the topic of response of plant communities to air pollution.

412.**Randall, A.** 1991. The value of biodiversity. Ambio 20(2):64-68.

Given the current threat to biodiversity worldwide, the article considers various philosophical approaches to the value of biodiversity. A clear case can be made, on instrumentalist and utilitarian grounds, that humans have good reason to place a high value on preserving biodiversity. Many conservationists and philosophers find such reasoning to be unsatisfactory, perhaps because it would leave biodiversity unprotected in the event that people develop technologies that substitute for naturally occurring genetic material or find substitutes for the amenity value of natural environments. The author considers nonconsequentialist philosophical approaches that define right action as that which respects moral duties or, alternatively, rights. Like the utilitarian alternative, these theories provide no assurance that biodiversity will prevail over other valid concerns unless one asserts at the outset that preservation of biodiversity is a first principle that trumps all others. Without according first-principle status or preeminent value to biodiversity, it is still possible to develop appealing philosophical theories in which biodiversity counts. It is reasonable to argue, starting from either moral or utilitarian principles, that, in the absence of overriding constraints, policy may be decided on the basis of benefits and costs. However, it is reasonable also to insist that a safe minimum standard of protection of biodiversity is an appropriate constraint to place on the policy-decision process. The author concludes with cautious optimism that benefit cost analysis can be applied successfully to biodiversity issues.

413.**Rajagopal, R., U. Natarajan, and J. Wacker.** 1992. Information integration for environmental monitoring and assessment. Environ. Prof. 14:151-177.

Annual federal and state investments in the collection, storage, and maintenance of resource and environmental data are enormous (estimated in the range of a few to tens of billions of dollars). Despite these investments, the use of information from these data bases for societal endpoints has been limited. Further research to evaluate the usefulness of large environmental data bases in the analysis of selected scientific and regulatory questions, therefore, would be timely.

The primary purpose of this paper is to provide an annotated review of selected literature on the topic of information integration in the context of environmental monitoring and assessment. Significant scholarly contributions to this field have been identified that fall into four categories: institutional, resource/ecological, design, and technological. The publications reviewed are grouped, indexed, associated with keywords and organized under these four major categories. Within the four first-tier categories, the authors have identified several second-tier keywords to define more precisely the content of the title being classified. The collection, accumulated over 2 years, is comprehensive, although not exhaustive. As the authors accumulate additional literature, the classification system will evolve to reflect the content of the new titles.

414.**Rapport**, D.J. 1983. The stress-response environmental statistical system and its applicability to the Laurentian Lower Great Lakes. Stat. J. United Nations ECE 1:377-405.

415.**Rapport**, D.J. 1984. State of ecosystem medicine. Pages 315-324. In: V. Cairns, P. Hodson, and J. Nriagu, eds. Contaminant Effects on Fisheries. John Wiley & Sons, New York.

This essay explores an analogy between medicine and the study of the environment and indicates how concepts derived from the former might provide the means to perceive a more integrated view of ecosystem behavior under stress. Topics covered include: symptoms of ecosystem distress, diagnosis of ecosystem health, and treatment protocols for rehabilitation.

416.**Rapport**, D.J. 1989. Symptoms of pathology in the Gulf of Bothnia (Baltic Sea): Ecosystem response to stress from human activity. Biol. J. Linnean Soc. 37:33-49.

An extensive review of the data now accumulated on the response of the Gulf of Bothnia ecosystem to stress from human activity provides abundant evidence for incipient ecosystem pathology. Signs of "ecosystem distress" appear at local, coastal, and basin-wide scales. Symptoms include early signs of eutrophication in local and coastal waters, formation of local abiotic zones, reduced species diversity, reduced genetic diversity (particularly in salmonids), reduced size of biota, increased dominance by opportunistic species, increased disease prevalence and bioaccumulation of toxic substances (e.g., PCBs and DDT). Pathology may propagate between local, coastal, and basinwide regions by several different pathways. Despite reductions in loadings of some toxic substances in recent years (e.g., PCBs and DDT), stress from human activities on the Gulf of Bothnia continues to impact the ecosystem at all spatial scales.
Key Words: Baltic Sea, Gulf of Bothnia, Ecosystem degradation, Ecosystem behavior under stress, State of environment, Ecosystem pathology

417.**Rapport**, D.J. 1990a. What constitutes ecosystem health? Perspect. Biol. Med. 33(1):120-132.

What constitutes the health of Nature (i.e., What are the suitable concepts and conventions to assess the condition of the environment?) is a question now being raised for the earth's major ecosystems (forests, lakes, seas, etc.) and indeed the entire biosphere. Ultimately, a healthy environment is essential for a healthy human population. It does not follow, however, that the appropriate standards for the health of nature need be based solely on criteria for human health. Ecosystems have lives of their own with or without human components, and it is this life that is receiving more attention as situations come to light in which ecosystems have become severely damaged. Topics covered include: what are ecosystems, measures of ecosystem health, and the role of social values.

418.**Rapport**, D.J. 1990b. Challenges in the detection and diagnosis of pathological change in aquatic ecosystems. J. Great Lakes Res. 16(4):609-618.

There are a number of challenges in developing better tools for the detection and diagnosis of pathological change in ecosystems. The use of indicators can be improved by adopting a pluralistic approach rather than relying on any one type of measure of ecosystem health. This approach would best fulfill three functions that indicators should serve in the context of ecosystem health: (1) utility in diagnosis of pathological changes in ecosystem; (2) utility as an early warning indicator of ecosystem breakdown and; (3) utility in reflecting ecosystem integrity. Understanding ecosystem breakdown and rehabilitation processes is enhanced by correlating, over space and time, the appearance of symptoms of pathological change with changes in stress loadings. Such analyses, as illustrated by a case study of Kyronjoki estuary (Baltic Sea), are complex because of both discontinuities in the response of ecosystems to stress and lags between the onset of stress and ecosystem response. As the practice of "ecosystem medicine" evolves, much is to be gained by shifting the emphasis from "curative" to "preventative" aspects. Here, a "salutogenic" approach, one that is focused on understanding the origins of health and mechanisms that promote "healthiness," might find ready applications. Such an approach would suggest bolstering ecosystem-coping responses to stress, thereby promoting greater immunity to the negative aspects of cultural disturbance.

Key Words: Fish management, Aquatic ecosystems, Ecological indicators, Ecosystem health

419.**Rapport**, D.J. 1990c. Workgroup issue paper: Criteria for ecological indicators. Environ. Monitor. Assess. 15:273-275.

This article briefly discusses the criteria for good environmental indicators and other issues associated with them, such as early warning potential, diagnostic capability, and baseline data.

420.**Rapport**, D.J. 1992a. What is clinical ecology? In: R. Costanza, B. Norton, and B. Haskell, eds. Ecosystem Health: New Goals for Environmental Management. Island Press, Covelo, California.

Over the past decade and a half, interest in diagnosing the causes of ecosystem breakdown and in coming to grips with strategies for rehabilitation of damaged ecosystem has been steadily growing. A decade ago, papers on the topic "ecosystem medicine" sparked debate about the aptness of medical metaphors, while today International Societies for the Promotion of "ecosystem health" attest to the growing acceptance of the approach.

It is fitting therefore, to take stock of the development of this fledgling field, which is here termed "clinical ecology." To do so, the concept of "health" from an ecosystem perspective is elaborated, and then some promising approaches to gauging the health status of whole ecosystems are examined. Curative approaches are contrasted with preventive approaches in the treatment of ecosystems under stress. Finally, areas of clinical ecology are suggested that remain undeveloped and need more rigorous definition to advance the practice of clinical ecology.

421.**Rapport**, D.J. 1992b. Evolution of indicators of ecosystem health. Pages 121-134. In: D. McKenzie, D.E. Hyatt, and J. McDonald. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Observations on the health of Nature and the use of "indicators" to denote changes are as old as human culture. Historical references to degradation of agricultural lands and forests can be found in the writings of Plato and even earlier. Yet many centuries later, we are far from consensus regarding the identity of a minimal but sufficient set of indicators by which to measure changes in the state of Nature. Such indicators ideally would satisfy these criteria: (1) provide "early warning" for some incipient transformation; (2) be sensitive to a variety of stresses; (3) be "diagnostic," that is, reflective of the integrity of some suitably defined complex system. These properties do not go well together, and indicators that are suitable for one aspect are often the least suitable for another.

Two approaches to indicators of the state of the environment are broadly discernable: one focuses on the stress side and provides measures of loadings of various types, be they contaminants or physical disturbances; the other looks at the response side. Neither are entirely satisfactory - both have strengths and weaknesses with regard to the capability to assess and monitor changes in regional environments. In this paper the evolution of both stress and response indicators is traced and the challenges of integration of these two approaches are addressed.

422.**Rapport**, D.J. 1992c. Evaluating ecosystem health. J. Aquat. Ecosys. Health 1(1):15-24.

In the past decade, metaphors drawn from human health are finding increasing application in environmental assessment at ecosystem levels. If ecosystem medicine is to come of age, it must cope with three fundamental dilemmas. The first stems from the recognition that there are no strictly objective criteria for judging health. Assessments of health, as in humans, inevitably are based on some combination of established norms and desirable attributes. The second stems from the irregular pulse of nature which either precludes the early recognition of substantive changes or gives rise to false alarms. The third is posed by the quest for indicators that have the attributes of being holistic, early warning, and diagnostic. Indicators that excel in one of these aspects often fail in another.

Advances in ecosystem medicine are likely to come from closer collaborations with medical colleagues in both clinical and epidemiological areas. In particular the time appears ripe for a more systematic effort to characterize ecosystem maladies, to validate treatments and to develop more sophisticated diagnostic protocols. These aspects are illustrated with comparisons drawn from studies of environmental transformation in the Laurentian Great Lakes, the Baltic Sea and Canadian terrestrial ecosystems.

423.**Rapport, D.J., and A. Friend.** 1979. Towards a comprehensive framework for environmental statistics: A stress-response approach. Occasional papers. Catalog 11-510. Statistics Canada, Ottawa.

This document consists of three parts: the need for environmental information; ecological perspective and the design of environmental information systems; and frameworks for environmental statistics - recent experience of Statistics Canada. Among many other topics and ideas covered within the document are: measurement of the state of the natural ecosystem; data required to describe ecosystem response to stress; mapping, modelling, and monitoring; environmental quality indices; and ecological indicators.

424.**Rapport, D.J., and H.A. Regier.** 1980. An ecological approach to environmental information. Ambio 9(1):22-27.

The authors' ecological perspective implies three major interdependent sets of data. To begin with, we should classify terrestrial and aquatic systems according to ecological similarity, such as watersheds, ecosystems, communities, and biomes (ecological transformations considered in terms of both plants and animals in the area concerned). Second, we need to classify, quantify and geocode those aspects of human activity that potentially alter the state of nature. Third, we must identify a series of indicators, some specific to particular types of ecosystems, which diagnose transformations in nature.

425.**Rapport, D.J., and H. Regier.** 1992. Disturbance and stress effects on ecological systems. In: B. Patten and S. Jorgensen, eds. Complex Ecology: The Part-Whole Relation in Ecosystems. Prentice Hall, Englewood Cliffs, NJ.

426.**Rapport, D.J., H. Regier, and T. Hutchinson.** 1985. Ecosystem behavior under stress. Am. Nat. 125:617-640.

Drawing from representative empirical studies about the impacts of various stresses on the structure and function of aquatic and terrestrial systems, the authors identify common symptoms of ecosystem distress and the major phases of ecosystem response to stress. The authors find that Selye's model serves to provide a unifying framework for the description of ecosystem behavior under stress.

427.**Rapport, D.J., H. Regier, and C. Thorpe.** 1981. Diagnosis, prognosis, and treatment of ecosystems under stress. Pages 269-280. In: G. Barrett and R. Rosenberg, eds. Stress Effects on Natural Ecosystems. John Wiley & Sons, Chichester, England.

In this paper the authors explore the application of concepts and the practice of human medicine to the development of new directions in stress ecology. Their purpose is not merely heuristic. The authors believe that the application of the experience of medical practice to stress ecology will provide a more rigorous approach to the questions of diagnosis and treatment of degraded ecosystems and that the analogy suggests novel and worthwhile research questions that will increase our understanding of ecosystem breakdown and recovery processes.

428.**Rapport, D.J., C. Thorpe, and H.A. Regier.** 1979. Ecosystem medicine. Bull. Ecol. Soc. Am. 60(4):180-182.

This article develops an analogy between human and ecosystem medicine. It proposes to raise questions to be subjected to the critical, skeptical tests of science. It notes some intriguing commonalities in the practice of human and ecosystem medicine and suggests that perhaps each may derive benefits from the transfer of ideas.

429.**Reams, M.A., S.R. Coffee, A.R. Machen, and K.J. Poche.** 1992. Use of environmental indicators in evaluating effectiveness of state environmental regulatory programs. Pages 1245-1275. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

The Environmental Protection Agency (EPA) has recommended that measures of environmental quality can be used as benchmarks to measure the effectiveness of environmental regulatory programs. This paper attempts to characterize efforts of state regulatory officials in evaluating their environmental programs. Specifically, it describes the extent to which program performance indicators are based on environmental parameters. Also, an attempt is made to identify those factors that explain variation in the use of environmentally based performance indicators.

430.**Regier, H., rapporteur.** 1986. Report of working group on technical information. Pages 235-237. In: B. Haug, L. Bandurski, and A. Hamilton, eds. Towards a Transboundary Monitoring Network: A Continuing Binational Exploration. International Joint Commission, Ottawa.

431.**Regier, H.** 1990. Workgroup issue paper: Indicators and assessment of the state of fisheries. Environ. Monitor. Assess. 15:289-294.

This article addresses the research process behind assessment, gives criteria for environmental indicators, and discusses the role of management.

432.**Regier, H.A.** 1992. Indicators of ecosystem integrity. Pages 183-200. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

The political reform movement in the late 1960s and early 1970s led, in the U.S.A., to the separate incorporation of two concepts—ecosystem and integrity—into federal legislation. These concepts came together in the statement of purpose of the 1978 Canada–U.S.A. Great Lakes Water Quality Agreement. Progress under that Agreement and its several amending protocols involves progressive clarification of the notion of ecosystem integrity (e.g., in the form of indicators and objectives). Indicators of ecosystem integrity are under development at three spatial/temporal scales: local, as in Remedial Action Plans for degraded Areas of Concern; subregional, as in Lakewide Management Plans; and basin, as in proposed policies to cope with periodic fluctuations in water levels and flows. The author attempts to explain the scientific aspects of this process of specification and clarification. The author also suggests that emphasis on ecosystem integrity and its indicators may serve political needs in the second wave of environmental/political reform, which is now expected for the 1990s.

433.**Regier, H., and E. Cowell.** 1972. Applications of ecosystem theory, succession, diversity, stability, stress, and conservation. Biol. Conserv. 4(2):83-88.

Processes at the ecosystem level of organization are examined as they are affected by conventional regimes of fishery exploitation and pollution, the latter including both nutrient and toxic materials. Exploitation and pollution are treated as stresses that deform and transform community structure and

reverse the usual sequence of ecological succession with respect to dominance of various taxa, diversity, stability, and production. Broad economic implications of such processes are outlined.

434.**Regier, H., and D.J. Rapport.** 1983. Ecological information services for the Great Lakes. In: Proceedings of the International Conference on Renewable Resources Inventories for Monitoring Changes and Trends. Corvallis, OR.

435.**Regier, H.A., and D.J. Rapport.** 1980. Ecology's family coming of age in a changing world. Pages 49-63. In: Biological Evaluation of Environmental Impacts. Proceedings of a symposium at the 1976 meeting of The Ecological Society of America. FWS/OBS-80/26. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

This article discusses a plethora of issues regarding the nature and development of ecology and relates these to environmental impact assessment. Short sections of the article, however, deal with issues related to EMAP, including levels of organization, ecological factors or stresses, and stimulus-response interactions.

436.**Reichholf, J.** 1982. Water birds as indicators of the ecological state of aquatic ecosystems. (In German, summary in German, English). Dech. Beih. 26:138-144.

Biological indicators have to fulfill certain criteria before they may be used for an "early-warning system" that leads to actual controls. Water birds are considered useful because they have world-wide distribution; are easy to determine and count; have different trophic positions between the full range of primary and end consumers; are capable of independent respiration of water; can yield measurements that can be integrated across space and time; sufficiently precise reaction in distribution and numbers to the trophic state of the water; have a reflection of important structural parts of the aquatic ecosystem; are indicators of medium and long-term changes (i.e., the diversion of an aquatic ecosystem from its basic state); and are suitable for making testable predictions on trends.

437.**Reid, W.V., J.A. McNeely, D.B. Tunstall, D.A. Bryant, and M. Winograd.** 1992. Developing Indicators of Biodiversity Conservation. 31 pp. World Resources Institute, Washington, DC.

438.**Reilly, W.** 1989. Measuring for environmental results. EPA J. May/June:2-4.

This article by the former head of the U.S. Environmental Protection Agency briefly describes the new approach that the EPA is undertaking to assess the success of its environmental protection efforts. It is a strategic, "big-picture approach" to the collection and use of environmental data.

439.**Reimold, R. J., D.M. Kent, J.M. Kelly, and C.E. Tammi.** 1992. Coupling wetlands structure and function: Developing a condition index for wetlands monitoring. Pages 557-568. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

Based on a review of published wetlands monitoring efforts conducted in support of delineation and mitigation activities in estuarine and freshwater wetlands throughout the United States, the authors present an approach to integrate functional and structural wetland measurements for development of a family of wetlands functional indices and a Wetlands Integrated Monitoring Condition Index (WIMCI). WIMCI, with values ranging from 0 to 1, represents the overall functional condition of the monitored wetland. WIMCI averages individual functional values, is compensatory in nature, and does not result in any one function being a limiting factor for wetlands characterization. WIMCI is flexible, wetland functions can be added or deleted, depending on specific wetlands, or weighted where it has been determined that the functions ascribed to a wetland are not equal in significance. The family of functional indices and WIMCI can be easily field-verified in relation to ongoing wetlands monitoring efforts associated with local, state, and federal permit activities requiring mitigation. Based on these functional indices and WIMCI, cost-effective and scientifically responsive, generic monitoring approaches can be readily incorporated into future wetland monitoring permits.

440.**Reiners, W.** 1983. Disturbance and basic properties of ecosystem energetics. Pages 83-98. In: H.A. Mooney and M. Godron, eds. Disturbance and Ecosystems: Components of Response. Springer-Verlag, New York.

The thrust of comparison in this paper is not between undisturbed and disturbed ecosystems, but between natural and human-engendered disturbances and their consequent effects. What, if anything, is different about the nature of human-caused disturbances and what, if any, difference in ecosystem behavior can be expected? The article is divided into the following sections: (1) Biomass and Energy Flow in Infrequently Disturbed Ecosystems — (a) Net Primary Production and Energy Flow Pathways, (b) Biomass and Detritus Accumulation, (c) Net Ecosystem Production, (d) Variation in Infrequent Disturbance Events; (2) Biomass and Energy Flow in Multiple Disturbance Ecosystems — (a) Constant Species Composition and Site Quality, (b) Changing Ecosystem Structure with Disturbance Frequency; and (3) Conclusions: Integration.

441.**Richardson, D., ed.** 1987. Biological Indicators of Pollution. Royal Irish Academy, Dublin.

442.**Riitters, K., and J. Barnard.** 1990. Criteria for evaluating indicators of forest health. Pages 443-452. In: H. Lund and G. Preto, eds. Global Natural Resources Monitoring and Assessments: Preparing for the 21st Century. American Society for Photogrammetry and Remote Sensing, Bethesda, MD.

The criteria to evaluate forest health indicators must be agreed so that a global forest health monitoring system can be established. The criteria must be formulated within a framework for analyzing data that takes into account:

1. Strategic value—Monitoring should be a part of a broader plan for identifying and assessing changes in forest health.
2. Tactical value—The indicators should give useful information for different types of assessments of health.
3. Scientific basis—The indicators should be chosen from biological models that lend realism and that are interpretable.

Once forest health is defined, monitoring gives information on the emergence of new problems and the development of known problems. Indicators of forest health for global monitoring can be either very general or very specific, according to the intended assessment. A modeling framework is suggested such that global comparability for assessments may not require that indicators to be monitored be globally uniform.

443.**Riitters, K., B. Law, R.C. Kucera, A. Gallant, R.L. DeVelice, and C.J. Palmer.** 1992. A selection of forest condition indicators for monitoring. Environ. Monitor. Assess. 20:21-33.

Regional monitoring and assessments of the health of forested ecosystems require indicators of forest conditions and environmental stresses. Indicator selections depend on objectives and the strategy for data collection and analysis. This paper recommends a set of indicators to signal changes in forest ecosystem distribution, productivity, and disturbance. Additional measurements are recommended to help ascribe those changes to climate variation, atmospheric deposition, and land use patterns. The rationale for these indicators is discussed in the context of a sequential monitoring and research strategy.

444.**Risser, P.G.** 1985. Toward a holistic management perspective. Bioscience 35(7):414-418.

Today, there are several approaches to studying ecosystems under stress, and it remains to be seen which, if any, will produce powerful problem-solving results. Some of the most significant questions about stressed ecosystems relate to the temporal and spatial occurrence of stress symptoms: Which characteristics are the best indicators of stress? and Which of the ecosystem properties are able to resist or recover from extreme stress? We must manage stressed ecosystems in ways that recognize the holistic nature of the system. This and the other papers in this issue present several current approaches to these challenges. The author begins by discussing agroecosystems, ecological-

economic interactions, landscape ecology, models and predictions, and short- and long-term ecological horizons.

445.**Robarge, G.M., and J. Benforado.** 1992. Reducing agricultural impacts on the environment. J. Sustain. Agric. 2(3):123-140.

Successful adaptation of sustainable agricultural practices in the United States will hinge on identifying the potential benefits of the practices and demonstrating their feasibility within the context of agricultural economic conditions. The U.S. Environmental Protection Agency has a number of ongoing research efforts that relate to sustainable agriculture. However, these efforts have not been designed as, and do not constitute, an organized environmental/agricultural research program. New research initiatives, such as the Environmental Monitoring and Assessment Program, are evolving towards a more integrated approach for solving environmental/agricultural problems. These efforts provide a foundation for an integrated program in sustainable agricultural research. One of the major challenges will be to work effectively with the U.S. Department of Agriculture, taking advantage of the research capabilities and strengths of each agency.

446.**Roberts, K.A.** 1991. Field monitoring: Confessions of an addict. Pages 179-211. In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

The author suspects that most monitoring is thoughtless, so this chapter starts with some thoughts on the nature of monitoring. Monitoring is not as simple as collecting "the facts"; nor do the facts "speak for themselves", and never are interpretations "not open to serious question", as one hopeful author wrote.

The second part of the chapter consists of some personal monitoring tales. These derive from the author's work as a nature reserve warden, from expeditions abroad, from research to support the Lee Valley Conservation Group, and from studies with his students of the University of London's Certificate in Ecology and Conservation. The author found the practical experiences invaluable at the time because they demonstrated a lot of strange things about monitoring.

447.**Roberts, L.** 1990. Counting on science at EPA. Science 249:616-618.

This news and comment feature describes the environmental risk ranking process undertaken by the EPA. The task was an attempt to focus the agency's resources on the environmental problems that pose the biggest risks rather than those that have attracted the most political attention.

448.**Robinson, G.R., R.D. Holt, M.S. Gains, S.P. Hamburg, M.L. Johnson, H.S. Fitch, and E.A. Martinko.** 1992. Diverse and contrasting effects of habitat fragmentation. Science 257:524-526.

Diverse components of an ecosystem can respond in very different ways to habitat fragmentation. AN archipelago of patches, representing different levels of fragmentation, was arrayed within a successional field and studied over a period of 6 years. Ecosystem processes (soil mineralization and plant succession) did not vary with the degree of subdivision, nor did most measures of plant and animal community diversity. However, fragmentation affected vertebrate population dynamics and distributional patterns as well as the population persistence of clonal plant species. The results highlight the dangers of relying on broad community measures in lieu of detailed population analyses in studies of fragmented habitats.

449.**Roughgarden, J.** 1989. Viewpoint: The United States needs an ecological survey. Bioscience 39(1):5.

In this commentary, the author proposes to create a U.S. Ecological Survey that would describe the biological component of the environment and identify processes that shape it.

450.**Rose, K., and E. Smith.** 1992. Experimental design: The neglected aspect of environmental monitoring. Environ. Manage.

Environmental monitoring is increasing due to regulatory mandates and public concerns over the health of the environment. Much of the data appear to be being collected without explicit statement of hypotheses and with little regard for principles of experimental design. Mismatches between the monitoring design and the hypotheses of interest arise when inappropriate designs are used, hypotheses are poorly stated or change over time, and when data collected for one purpose are used for other purposes (i.e., data are used to evaluate hypotheses which the data were never intended to address). Two long–term time series on historical changes in dissolved oxygen (DO) in Chesapeake Bay are analyzed to illustrate how a mismatch between monitoring design and the hypotheses of interest can lead to analyses of low power and even contradictory conclusions. Neither time series was collected to evaluate long–term trends in DO; regression analysis results in one time series showing a downward trend in DO, whereas the other time series shows no temporal trends. The importance of experimental design considerations will increase in the future as monitoring is used to not only identify and define environmental problems but also to quantify the effectiveness of management and remedial actions taken in response to identified problems. To ensure the usefulness of the large amounts of environmental monitoring data accumulating, we need to ask more questions that relate how data are collected (the experimental design) to why data are collected (the hypotheses of interest).

451.**Rozema, J., and J. Verkleij, eds.** 1991. Ecological Responses to Environmental Stresses. [Series: Tasks for Vegetation Science 22 (1991)]. Kluwer Academic Publishers, Dordrecht, The Netherlands.

452.**Rump, P. and N. Hillary.** 1987. Monitoring for Change: Workshop Proceedings. Canada Land Use Monitoring Program. Land Use in Canada Series Number 28. Lands Directorate, Environment Canada, Ottawa.

These proceeding consist of the edited papers and workshop summaries from the Monitoring for Change Workshop held in Ottawa in late 1985. The overall objective of the workshop was to encourage dialogue, information exchange, and cooperation to strengthen and enhance the land monitoring contribution to the prevention and resolution of land use conflicts. Summaries are placed into three themes: Issues and Role; Methods and Techniques and; Strategies for Cooperation. A common thread throughout the proceedings is the contribution of land use change and land degradation information towards improved land and natural resource management.

453.**Ryder, R.** 1990. Ecosystem health, a human perception—definition, detection, and the dichotomous key. J. Great Lakes Res. 16(4):619-624.

This article presents a background to the concept of ecosystem health and provides some definitions. It also covers detection of ecosystem malaise and uses the Great Lakes ecosystem as an example; it discusses the use of the "dichotomous key" (a computerized expert system) as a tool to assess ecosystem health.

454.**Ryder, R., and C. Edwards, eds.** 1985. A Conceptual approach for the Application of Biological Indicators of Ecosystem Quality in the Great Lakes Basin. Great Lakes Regional Office. International Joint Commission, Windsor, Ontario.

455.**Salanki, J., and H. Salama.** 1987. Signalization, monitoring, and evaluation of environmental pollution using biological indicators. Acta Biol. Hung. 38(1):5-11.

This essay gives an overview of biological indicators, their advantages, and the role of laboratory and field studies.

456.**Saunders, D., R. Hobbs, and C. Margules.** 1991. Biological consequences of ecosystem fragmentation—A review. Conserv. Biol. 5(1):18-32.

Research on fragmented ecosystems has focused mostly on the biogeographic consequences of the creation of habitat "islands" of different sizes and has provided little of practical value to managers. However, ecosystem fragmentation causes large changes in the physical environment as well as biogeographic changes. Fragmentation generally results in a landscape that consists of remnant areas of native vegetation surrounded by a matrix of agricultural or other developed land. As a result, fluxes of radiation momentum (i.e., wind), water, and nutrients across the landscape are altered significantly. These in turn can have important influences on the biota within remnant areas, especially at or near the edge between the remnant and the surrounding matrix. The isolation of remnant areas by clearing also has important consequences for the biota. These consequences vary with the time since isolation, distance from other remnants, and degree of connectivity with other remnants. The influences of physical and biogeographic changes are modified by the size, shape, and position in the landscape of individual remnants, with larger remnants being less adversely affected by the fragmentation process. The dynamics of remnant areas are predominantly driven by factors arising in the surrounding landscape. Management of, and research on, fragmented ecosystems should be directed at understanding and controlling these external influences as much as at the biota of the remnants themselves. There is a strong need to develop an integrated approach to landscape management that places conservation reserves in the context of the overall landscape. .

457.**Schaeffer, D.J.** 1991. A toxicological perspective on ecosystem characteristics to track sustainable development: VII. Ecosystem health. Ecotoxicol. Environ. Saf. 22:225-239.

The goal of "ecosystem health," an emerging science paralleling human and veterinary medicine, is the systematic diagnosis and treatment of stressed ecosystems. Ecosystems are stressed by physical factors such as boat traffic, biological factors such as introduction of exotic species, and chemical factors such as pH change. Even if these classes of stressors affect the same trophic levels, the resulting disease ecosystem states have different etiologies because the stress is introduced and propagated by different mechanisms. This paper presents a toxicological perspective on ecosystem sustainability, and discusses how classical toxicological concepts have to be modified when the experimental unit is an ecosystem. When exposures are high, effects are acute and are often measurable (e.g., fish kill). However, when exposures are low and chronic, effects are often hard to separate from background. Ecosystem "threshold criteria" are established to ensure ecosystem sustainability; high risk to sustainability is evident when these criteria are exceeded.

458.**Schaeffer, D. and D. Cox**. 1992. Approaches to establish ecosystem threshold criteria. VIII. Ecosystem health. In: R. Costanza, B. Norton, and B. Haskell, eds. Ecosystem Health: New Goals for Environmental Management. Island Press, Covelo, CA.

The authors' preliminary definition of an ecosystem threshold criterion is: "Any condition (internal or external to the system) which, when exceeded, increases the adverse risk to maintenance of the ecological system." Systematic development of ecosystem threshold criteria is a significant, new research area that integrates legal, political, social, and economic disciplines with biological and physical sciences.

To adequately address the complex problems associated with development of threshold criteria, the initial focus needs to be on a comprehensive synthesis and integration rather than on narrowly defined topics. Four major initial research objectives are to (1) examine the functionality of the proposed definition of an "ecological threshold criterion"; (2) determine the extent to which ecological system threshold criteria already exist and characterize the properties and measurements used in each criterion; (3) learn whether meaningful criteria have been developed through the legal, political, social, and economic disciplines and evaluate how well these criteria perform when compared with criteria developed from the physical and biological sciences; and (4) determine the extent to which ecosystem-condition references can be established.

The legal, political, social, and economic disciplines need to be examined to determine whether sound criteria can be developed in the absence of good scientific data. The nature and measures of threshold criteria proposed by biological and physical scientists should be determined based on review of the literature. A variety of approaches for developing threshold criteria, ranging from court-imposed criteria to consensus criteria and from measurements of ecological system properties and processes to mathematical models of system connectedness and multispecies risk, need to be considered.

459.Schaeffer, D., D. Cox, and R. Deem. 1987. Variability of test systems used to assess ecological effects of chemicals. Water Sci. Technol. 19(11):39-45.

Numerous chemicals may produce toxicological effects that are ecologically important. Assessment of risk to ecological systems from chemical exposures includes the use of biological test systems to evaluate toxicity. Most biological test systems are oriented to the laboratory and have no clear environmental relevance. To help focus the selection of test systems, the authors developed a series of descriptions of test system characteristics and suggested some criteria for selecting test systems to determine ecological effect. Another step in the selection process is evaluation of the variability of aquatic test systems by using published data. Using the relative standard deviation v, the authors classify variability as low ($v < 10\%$), medium ($10\% < v < 20\%$), high ($20\% < v < 30\%$), and very high ($>30\%$).

Key Words: Bioassays, Toxicity testing, Bioassessment, Coefficient of variation

460.Schaeffer, D.J., E.E. Herricks, and H.W. Kerster. 1988. Ecosystem health: I. Measuring ecosystem health. Environ. Manage. 12:445-455.

Ecosystem analysis has been advanced by an improved understanding of how ecosystems are structured and how they function. Ecology has advanced from an emphasis on natural history to consideration of energetics, the relationships and connection between species, hierarchies, and systems theory. Still, we consider ecosystems as entities with a distinctive character and individual characteristics.

Ecosystem maintenance and preservation are the object of impact analysis, hazard evaluation, and other management or regulation activities. In this article the authors explore an approach to ecosystem analysis that identifies and quantifies factors that define the condition or state of an ecosystem in terms of health criteria. They relate ecosystem health to human/nonhuman animal health and explore the difficulties of defining ecosystem health; they suggest criteria that provide a functional definition of state and condition. The authors suggest that, as has been found in human/nonhuman animal health studies, disease states can be recognized before disease is of clinical magnitude. Example disease states for ecosystems are functionally defined and discussed, together with test systems for their early detection.

461.Schaeffer, D., and E. Novak. 1988. Integrating epidemiology and epizootiology information in ecotoxicology studies: III. Ecosystem health. Ecotoxicol. Environ. Saf. 16:232-241.

Epidemiology is the study of the disease incidence rates in humans and epizootiology is the nonhuman equivalent. There have been few attempts to integrate epidemiological epizootiological data from human and nonhuman animal populations coexisting in the same environment. The authors propose that epizootiological research be conducted on chemical pollutants by using the framework of the natural environment as a laboratory. These kinds of studies are termed "epizootiologic ecotoxicology." It is suggested that guilds, defined as a group of human individuals or a group of nonhuman species that use their environment in a similar way, be used as experimental probes to assess the effects of chemicals on ecosystems and humans. Improved data would increase the likelihood that effects in exposed populations will attain statistical significance so that high-risk populations can be detected even though the number of affected individuals is low. Epizootiological information, the product of this research, must be treated as an important component of a unified health evaluation system.

462.Scherer, E. 1992. Behavioural responses as indicators of environmental alterations: Approaches, results, development. J. Appl. Icthyol. 8:122-131.

Over the past 15 to 20 years, growing awareness of anthropogenic alterations of aquatic environments has led to a search for sensitive and ecologically relevant indicators and meaningful early warning signals at various levels of biological integration from subcellular biophysics and biochemistry to ecosystem function. Besides playing its role in basic ecology, the integrative whole–organism behavioral response has long been used in mammalian toxicology and pharmacology. For its use in

assessing effects of physical and chemical changes of the environment on fish, however, broader **ecology–oriented** concepts and new quantitative methods were needed, and are now being developed. **Published** data are relatively numerous in the areas of unconditioned preference–avoidance responses (**relating** to habitat selection and maintenance), and changes of locomotor activity. More complex **effects** on intra– and interspecific interactions have recently attracted increased attention. Recent **technical** and methodological advances include instantaneous response digitization and computerized **video** image analysis. Apparent strengths and weaknesses of present behavioral testing are presented, and some research needs and current developments are pointed out.

463.**Schindler, D.W.** 1987. Detecting ecosystem responses to anthropogenic stress. Can. J. Fish. Aquat. Sci., Suppl.1 44:6-25.

Recent ecological work on aquatic populations, communities, and ecosystems is reviewed for advances that show promise as early indicators of anthropogenic stress in aquatic ecosystems. Work at the Experimental Lakes Area (ELA) in northwestern Ontario indicates that among the earliest of responses to stress are (1) changes in species composition of small, rapidly reproducing species with wide dispersal powers such as phytoplankton and (2) the disappearance of sensitive organisms from aquatic communities. Work elsewhere illustrates that the incidence of morphological abnormalities in benthic invertebrates is also highly sensitive to pollution stress. For several categories of pollutants, this sensitivity of benthic organisms may be the result of greater concentrations of pollutants in sediments than in the water column. Variables reflecting ecosystem functions, such as primary production, nutrient cycling, and respiration, were not altered by eutrophication, acidification, or cadmium addition at ELA and are relatively poor indicators of early stress. Mesocosm experiments appear to be fruitful for addressing chemical- or plankton-related problems but are less useful for addressing community- or ecosystem-level questions. Among population-level approaches, life-table population studies of invertebrates appear to be the most-sensitive early indicators of stress on ecosystems.

Relative sensitivities of freshwater and forested terrestrial ecosystems exposed to airborne pollutants are compared. Primary production seems to be reduced at a much earlier stage of air pollution stress in terrestrial ecosystems than in aquatic systems. Soils, like lake sediments, tend to be sinks for pollutants. This may protect the pelagic regions of lakes from influxes of toxins that would occur if watersheds and sediments were unreactive but may cause additional stresses to the fauna and flora of soils and sediments. In extreme cases, high concentrations of toxins may inhibit the replacement of terrestrial producers.

The importance of long-term monitoring in distinguishing natural from anthropogenic stress is discussed. It is suggested that paleoecological techniques be rapidly developed and calibrated with whole-ecosystem experiments to resolve certain adequacies of past monitoring records.

464.**Schindler, D.W.** 1990. Experimental perturbations of whole lakes as tests of hypotheses concerning ecosystem structure and function. Oikos 57:25-41.

Production, respiration, nutrient concentrations, and changes in biological communities were monitored for several years in two experimentally eutrophied and two experimentally acidified lakes in the Experimental Lakes Area, Canada. Results were examined to detect changes in ecosystem structure and function that might be sensitive indicators of ecosystem stress.

Phytoplankton production in eutrophied lakes was higher than in reference lakes. It decreased quickly to background values when fertilization was terminated. Winter respiration was unchanged, and P/R ratios were constant under constant N/P fertilization, but decreased for three years after the N/P ratio in fertilizer was decreased from 14:1 to 5:1 by weight.

Phytoplankton production was not affected by acidification to a pH of 5.0. Winter respiration declined at pH values of 5.1 and below, causing P/R to be highest at the lowest pH values. Respiration returned to normal when the pH of the lake was increased to 5.4. Gross periphyton production and respiration both increased with acidification, but P/R ratios declined at pH values below 6.2. Nitrification in both acidified lakes ceased at pH values of 5.4 to 5.7. It recovered when pH was allowed to increase, but with a lag time of 1 year. No other nutrient cycles appeared to be disrupted.

Both eutrophication and acidification caused declines in species diversity among several taxonomic groups. Among phytoplankton, both stresses caused an increase in size of organisms in summer. Among higher taxa, there was not a consistent tendency for either small or large organisms to be favored.

Periphyton metabolism was the most sensitive indicator of acidification, followed by taxonomic changes in several groups. Ecosystem-level production and respiration were the most resistant properties to acid stress.

The earliest serious changes in ecosystems and food webs occurred when acidification eliminated acid-sensitive organisms that were also the sole occupants of key ecological niches. Such situations occur frequently in northern lakes.

465.**Schindler, D.W., and K. Mills.** 1985. Long-term ecosystem stress: The effects of eight years of acidification on a small lake. Science 1:1395-1401.

Experimental acidification of a small lake from an original pH value of 6.8 to 5.0 over an 8-year period caused a number of dramatic changes in the lake's food web. Changes in phytoplankton species, cessation of fish reproduction, disappearance of the benthic crustaceans, and appearance of filamentous algae in the littoral zone were consistent with deductions from synoptic surveys of lakes in regions of high acid deposition. Contrary to what had been expected from synoptic surveys, acidification of Lake 223 did not cause decreases in primary production, rates of decomposition, or nutrient concentrations. Key organisms in the food web leading to lake trout, including *Mysis relicta* and *Pimephales promelas*, were eliminated from the lake at pH values as high as 5.8, an indication that irreversible stresses on aquatic ecosystems occur earlier in the acidification process than was heretofore believed. These changes are caused by hydrogen ion alone and not by the secondary effect of aluminum toxicity. Because no species of fish reproduced at pH values below 5.4, the lake would become fishless within about a decade on the basis of the natural mortalities of the most long-lived species.

466.**Schneider, E.D.** 1992. Monitoring for ecological integrity: The state of the art. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

467.**Schroeder, R.L., and M.E. Keller.** 1992. Setting objectives — A prerequisite of ecosystem management. Pages 1-4. In: R.S. Mitchell, C.J. Sheviak, and D.J. Leopold, eds. Ecosystem management: Rare Species and Significant Habitats. Proceedings of the 15th Annual Natural Areas Conference. New York State Museum, Albany, NY.

Management implies movement toward desired end results. Therefore, primary prerequisites of ecosystem management are : clear definition of the components of the system to be managed and establishment of the desired end conditions for those components. Several steps are recommended in setting ecosystem management objectives: (1) objectives should be set early in the planning stages of the project; (2) managers should decide exactly what resources are of concern and focus the objectives on these specific resources; (3) objectives should be set within a "top-down" framework to force the consideration of larger scale constraints and needs; (4) objective statements should be made clear and concise, and stated in such a manner that progress in meeting those objectives can be measured; (5) the process of setting objectives is dynamic and should be kept flexible to respond to new information. It may be difficult to set clear objectives, due to imperfect knowledge or a lack of adequate data on the resources of concern. A great deal of additional research is needed to quantify and explain important population, community, and ecosystem level processes in order to make such decisions. In the interim, however, resource managers should make the best use of available information and conduct their management efforts within the framework of well-understood, measurable objectives.

Key Words: Ecosystem management, Rare species and significant habitats

468.**Schroevers, P.J.** 1983. The need of an ecological quality concept. Environ. Monitor. Assess. 3:219-226.

An indicator is something which makes visible, audible, or perceptible something which in itself is not visible, audible, or perceptible. Many times indicators concern rather concrete matters that might be experienced also in a more direct way. Acidity can be tasted, but a pH meter is a better instrument. If such an instrument is not available, the presence of *Sphagnum cuspidatum* indicates that the pH cannot be higher than 6.5. When the accumulation of mercury in certain tissues of fish constitutes a good reflection of mercury content of water, the observation will be far easier. With this description, the concept of quality is introduced. Quality is something which is not visible, perceptible, or audible, but which can be made such by our indicators. We experience how behind the perceived reality, another reality is hidden, an abstract reality, not of matters but of principles. Is "quality" such a principle? Are we able, by looking at the things around us (e.g., plants, animals, communities, tissues, oxygen concentrations) to tell something about the difficult phenomenon of "quality"?

469.**Schubert, R.** 1992. Possibilities and limitations in bioindication on landscape monitoring scales. Pages 817-828. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

470.**Scott, K.J., J.F. Paul, A.F. Holland, S.B. Weisberg, J.K. Summers, and A. Robertson.** 1992. In Press. The estuarine component of the U.S. EPA's Environmental Monitoring and Assessment Program. Chem. Ecol.

471.**Segar, D., D. Phillips, and E. Stamman.** 1987. Strategies for long-term pollution monitoring of the coastal oceans. Pages 12-27. In: T. Boyle, ed. New Approaches to Monitoring Aquatic Ecosystems. ASTM STP 940. American Society for Testing and Materials, Philadelphia.

Monitoring of long-term effects of marine pollution on regional marine ecosystems can be most useful to managers if based primarily on the use of bioindicators to monitor temporal changes in the mean background abundance of bioavailable contaminants in the region. Design of successful long-term, regional bioindicator monitoring program requires that specific quantitative objectives be defined and expressed as null hypotheses. An optimum sampling and analysis plan designed to test these hypotheses must select the age, size range, and number of individuals per sample, the number of samples per site, the number of replicate analyses per sample, and other factors based on the known sources of variance in the environment, sampled population, and analysis procedure. Sampling sites must be systematically selected to be affected as little as possible by contaminant inputs that vary temporally on short time scales. Many suitable sites will require the transplantation of bioindicators, and the optimum program will probably require the exclusive use of transplanted populations.

Key Words: Bioindicators, Monitoring, Marine pollution, Sampling, Statistical design, Strategy

472.**Seidl, P. and P. Murray, eds.** 1991. A Proposed Framework for Developing Indicators of Ecosystem Health for the Great Lakes Region. Council of Great Lakes Resource Managers, International Joint Commission, Windsor, Ontario.

This report is a summary of the current knowledge about indicators. It also is a cursory attempt to show the linkages between socio-economic and biogeochemical variables. The report is divided into five parts: Introduction; Relating indicator development to management goals for the Great Lakes Basin; Framework for developing a monitoring program; Evaluating available indicators (physicochemical, biological, and socio-economic) and; Conclusions and recommendations. A reference list containing 170 citations is provided.

473.**Seitz, A., and H. Ratte.** 1991. Aquatic ecotoxicology: On the problems of extrapolation from laboratory experiments with individuals and populations to community effects in the field. Comp. Biochem. Physiol. 100C(1/2):301-304.

1. Ecotoxicology is defined as the study of the effect of toxicants on structure and function of ecosystems.
2. Properties of individuals and populations in laboratory experiments differ from those in the field with respect to distribution in space and time as well as to genetic structure.
3. Studies of community response can only be extrapolated to other systems if they include the analysis of the causal chain.
4. Causal explanations require a system analysis at different trophic levels as well as a modelling of the system and an analysis of sensitivity.
5. A research project is presented that deals with most of the suggested problems.

474.**Severinghaus, W.** 1981. Guild theory development as a mechanism for assessing environmental impact. Environ. Manage. 5:187-190.

The following proposed procedures are designed, through the use of guild theory, to allow relatively accurate, quantifiable predictions of environmental impact that can be aimed at both quantitative (biomass) and qualitative (diversity) aspects of the flora and fauna of the proposed area of impact. Examination of impact on plant and animal guilds should allow determination of the cause-effect relationships between the perturbation and the environment, thus giving insight into potential mitigating procedures. The author proposes that guilds designed from an applied perspective can be used as an analytical and predictive tool in environmental management.

Key Words: Guild theory, Impact predictions

475.**Sheehan, P.** 1984. Effects on community and ecosystem structure and dynamics. Pages 51-99. In: P. Sheehan, D. Miller, C. Butler, and P. Bourdeau, eds. Effects of Pollutants at the Ecosystem Level. SCOPE 22. John Wiley & Sons, New York.

This chapter covers effects on ecosystems in the following areas: abundance and biomass, reduction in population size and extinction, community composition and species dominance, species diversity and similarity indices, spatial structure, stability, and succession and recovery.

476.**Sheehan, P.J.** 1984. Functional changes in the ecosystem. Pages 101-146 In: P.J. Sheehan, D.R. Miller, and G.C. Butler, eds. Effects of Pollutants at the Ecosystem Level. SCOPE 22. John Wiley & Sons, New York.

This chapter covers effects in the following areas: material and energy movement, decomposition and element cycles, productivity and respiration, food-web and functional regulation, and energy flow and nutrient cycling.

477.**Sheehy, G.** 1989. Environmental indicator research: A literature review for state of the environment (SOE) reporting. (Draft) Technical Report Series No. 7. Strategies and Scientific Methods, SOE Reporting Branch, Canadian Wildlife Service. Environment Canada, Ottawa.

The development of a set of environmental indicators which represents the total array of desirable and available data for state of the environment (SOE) reporting is a long–term goal of Environment Canada's SOE Reporting program. The concept of indicators is well–established, but rarely has the literature been reviewed from the standpoint of information needs in SOE reporting. This study was therefore commissioned as an initial stage in the development of an appropriate set of environmental indicators for agencies which will be involved in SOE data collection and analysis. The review provides a documented assessment of the state of the art of indicator research and application, with a particular focus on North America, Europe and by international organizations. Research documents judged to be most useful are included in an annotated bibliography of 56 references.

478.Shelfer, I.C. 1990. NOAA environmental digest: Selected environmental indicators of the United States and the global environment - final report. NTIS No. PB91-108696/HDM. National Oceanic and Atmospheric Administration, Office of the Chief Scientist, Washington, DC. September. 110 pp.

The National Oceanic and Atmospheric Administration (NOAA) is the Nation's earth systems agency. NOAA has the responsibility and capability to monitor the United States and the global environment. NOAA currently monitors a number of environmental parameters on a regional and global scale. The paper describes a NOAA report of these atmospheric, oceanic, and biological indicators monitored by NOAA, the offices collecting and synthesizing the data, and the dissemination products.

479.Short, H.L. 1992. Use of the Habitat Linear Classification System to inventory and monitor the structure of ecosystems. Pages 961-974. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October, 1990. Elsevier, Essex, England.

The Environmental Monitoring and Assessment Program (EMAP) of the Environmental Protection Agency can be used to describe habitat conditions and trends for the nation's wildlife community and to determine land-use changes attributable to landscape fragmentation, pressure of urbanization, impacts of desertification, etc., within the coterminous United States. The Habitat Linear Classification System (HLCS) may be a suitable indicator that, if applied similarly across all ecosystems, could allow EPA to achieve these important monitoring and assessment goals. The HLCS is a simple way to translate map-overlay data and on-site survey data into a graphic or numeric presentation that can be compared between sample areas or between time periods for a single sample area. HLCS provides detailed information for all terrestrial ecosystems that have emergent vegetative structures.

The HLCS is analogous to the linear classification systems used by animal scientists to appraise heritable traits of animals to represent those appraisals in an easily understood manner and to satisfy a management goal by selecting desirable sires for herd improvement programs. The HLCS evaluates important structural traits of landscapes and arrays trait information so that a manager can visualize or understand a condition, so that management strategies to achieve some goal can be developed.

A structural trait is a variable such as broadleaf deciduous woody vegetation in the understory layer. The HLCS is based on point intercept measures of structural traits collected within a family of subplots at an evaluation site. The HLCS provides three values when arraying trait information - density, quantity, and clumpiness. Density pertains to the percent of intercept points within subplots that encounter the trait; quantity is the percentage of the population of subplots that contain the trait at a prescribe density; and clumpiness is the way that the quantity of subplots with the trait are arranged within an evaluation site-clumped together or dispersed. The HLCS can represent data from aerial photography or on-site measurements from field sites.

The manuscript reports results from an intensive field assessment of a variety of wildlife habitats in southcentral Colorado. The point intercept data used in the HLCS analysis were of structural traits measured from the surface through the understory, midstory, and overstory within 12 evaluation sites, representing a variety of vegetational communities. The HLCS analysis of these data described differences in traits associated with vegetational communities and the effects of timber management practices on vegetation structure. The HLCS analysis associated bird species with structural traits within layers of habitat and associated the presence of small mammal species with structural traits at the surface and within the understory layer of habitat.

Future efforts with the HLCS will emphasize its use in interpreting aerial photography and its potential application to national assessments.

480.Shriner, D.S., C.R. Richmond, and S.E. Lindberg. 1980. Atmospheric Sulfur Deposition: Environmental Impact and Health Effects. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Among the different topics that are covered include: process level effects, ecosystem level effects on agroecosystems, forest and grassland ecosystems, and regional scale studies.

481.**Shubert, L.** 1984. Algae as Ecological Indicators. Academic Press, London. 434 pp.

The current volume considers the recent advances and current deficiencies in the use of algae as indicators of ecological change. The text contains 14 papers, which are divided into 6 sections. Sections include such subjects as freshwater, marine, and terrestrial ecosystems. Other sections consider toxic substances, the industrial application of algae indicators, and biological models. Tables, graphs, and a subject index supplement the text.

482.**Shugart, L.R., J. McCarthy, and R.S. Halbrook.** 1992. Biological markers of environmental and ecological contamination — An overview. Risk Anal. 12(3):353-359.

An approach, using biomarkers (biological responses) for assessing the biological and ecological significance of contaminants present in the environment is described. Living organisms integrate exposure to contaminants in their environment and respond in some measurable and predictable way. Responses are observed at several levels of biological organization from the biomolecular level, where pollutants can cause damage to critical cellular macromolecules and elicit defensive strategies such as detoxification and repair mechanisms, to the organismal level, where severe disturbances are manifested as impairment in growth, reproduction, developmental abnormalities, or decreased survival. Biomarkers can provide not only evidence of exposure to a broad spectrum of anthropogenic chemicals, but also a temporally integrated measure of bioavailable contaminant levels. A suite of biomarkers are evaluated over time to determine the magnitude of the problem and possible consequences. Relationships between biomarker response and adverse ecological effects are determined from estimates of animal health and population structure.

Key Words: Biomarker, Environmental contamination, Environmental assessment, Ecological significance

483.**Simpson, J.W.** 1989. Landscape medicine: A timely treatment. J. Soil Water Conserv. 44:577-579.

The concept of health is applied to the landscape in this commentary. The author believes opportunities in environmental management would improve if land planners and managers became widely perceived as the landscape's doctors. The medical analogy is employed as the author promotes diagnosis of ecosystem ills via symptoms (indicators) such as soil erosion, water quality, reduction in biomass, or changes in microclimate.

484.**Sindermann, C.** 1988. Biological indicators and biological effects of estuarine/coastal pollution. Water Res. Bull. 24(5):931-939.

Sustained interest in and concern about the health status of the aquatic environment have resulted in extensive research focused on (1) effects of pollution on survival, growth, and reproduction of resource species at all life stages; (2) diseases of fish and shellfish, that may be related to pollution and that serve as indicators of environmental stress; and (3) contaminant body burdens in fish and shellfish and the effects of contaminants on the aquatic animals and their potential effect on humans. Effects, lethal and sublethal, of pollutants on life-history stages of fish and shellfish have been documented, as have impacts on local stocks in badly degraded habitats, but as yet there has been no adequate quantitative demonstration of effects on entire aquatic species. This failure is probably attributable to the difficulty in sorting out relative effects of the many environmental factors that influence abundance. Sublethal effects, especially those that result in disease, have been examined intensively, and some diseases and disease syndromes have been associated statistically with pollution. Other pollution indicators (biochemical- physiological, genetic, behavioral, and ecological) have also received some attention, as have body burdens of contaminants in aquatic animals. Research, especially that conducted during the past decade, has done much to clarify the many pathways and toxic effects of contaminants on aquatic animals, and has also helped to identify mechanisms for survival of fish and shellfish in the presence of environmental changes caused by human activities.

Key Words: Pathology, pollution-associated; Biochemistry, pollution-associated; Chromosomes; Abnormalities; Indicators, biological; Lesions, liver; Skeletal abnormalities; Fin erosion; Fish; Ulcers, fish; Mixed function oxygenases, metallothioneins; Stress, pollution-related; Pollution, biological effects

485.**Slobodkin, L., and D. Dykhuizen.** 1989. The two roles of ecotoxicology. In: Present Situation, Problem, Prospect and Practical Implementation Program of Education and Research for Efficient Utilization and Conservation of Inland Waters. Education and Research for Higher Agricultural Productivity, Conserving Nature and Agroecosystem in Asia and Pacific Countries Series 3. Asia and the Pacific Program of Educational Innovation for Development. University of Tsukuba, Japan.

There is still debate and uncertainty about how to use ecotoxicology to asses whether or not and to what extent damage has been done to an ecological community. The usual procedure is to use organisms or microorganisms as surrogates either for other organisms or for entire ecological systems. The authors suggest that this is an error. The ecological role of particular types of organisms should be independent of their role in monitoring toxicity. The use of organisms chosen for convenience as chemical concentration monitors, rather than as surrogates for ecological communities would facilitate both legal and managerial aspects of applied ecology.

486.**Slocombe, D.S.** 1992. Environmental monitoring for protected areas: Review and prospect. Environ. Monit. Assess. 21:49-78.

Monitoring activities in protected areas have a long history. Early internal planning and management needs led to ecological inventories. More recently, the increasing number and awareness of external threats to parks has led to a variety of monitoring programs. Efforts to use protected areas, especially biosphere reserves, as ecological baselines have reinforced this trend. As protected areas are increasingly recognized to be islands with complex internal and regional interactions, holistic, systems approaches to inventory, monitoring, and assessment of their state are being developed. This paper begins with a review of the threats to parks and the origins and importance of inventory and monitoring activities and is followed by a review of resource survey methods. Ecosystem science and environmental monitoring are introduced as a basis for considering several newer approaches to monitoring and assessing natural environments. These newer approaches are stress/response frameworks, landscape ecology, ecosystem integrity, and state of the environment reporting. A final section presents some principles for monitoring the state of protected areas. Examples are drawn from experience with Canadian National Parks.

487.**Smith, W.** 1984. Ecosystem pathology: A new perspective for phytopathology. For. Ecol. Manage. 9:193-219.

Evaluations of ecosystem health are substantially different from evaluations of individual plant health. The significance of regional air pollutants (e.g., ozone, acid deposition, and trace metals) must be evaluated in terms of ecosystem health. All ecosystems have common components organized in structural patterns and united by functional processes. The most important ecosystem components affected by regional air pollutants include the producers and decomposers. These influences can alter the processes of energy flow (production) and biogeochemical cycling. This alteration, in turn, can change the production of biomass and/or the pattern of succession of the ecosystem. Forest ecosystem interaction with three air pollutants is reviewed to illustrate ecosystem pathology.

488.**Smith, W.** 1980. Air pollution—A 20th century allogenic influence on forest ecosystems. Pages 79-87. In: Proceedings of Symposium on Effects of Air Pollutants on Mediterranean and Temperate Forest Ecosystems. U.S.D.A. Forest Service Pacific SW Forest Experiment Station General Technical Report PSW-43. U.S. Department of Agriculture, Berkeley, CA.

Chronic doses of ozone, sulfur dioxide, nitrogen oxides, hydrogen fluoride, and other primary or secondary gaseous air contaminants may cause subtle effects on forest ecosystems. Air pollutants may influence reproduction, nutrient cycling, photosynthesis, predisposition to entomological or pathological stress, or quantity of healthy foliar tissue. Forest ecosystem response to chronic air pollution may include alterations in growth rates and successional patterns. The establishment of

comprehensive field and laboratory investigations to systematically examine chronic air pollution stress on forest ecosystems in those parts of the world subject to atmospheric contamination is concluded to be of top priority. In the United States, forest ecosystems judged to be at particular risk and in need of more intensive investigation include the Northern Hardwood forest, Central Hardwood forest, and Western Montane forest.

489.**Smith, W.H.** 1990. The health of North American forests: Stress and risk assessment. What is the condition of temperate forests? J. For. 88(1):32-35.

Making generalizations about the health of North American forests is difficult because of the extraordinary diversity of forests, management regimes, and stress factors. Thus, this overview article will summarize forest health fundamentals, significant health risks, and priorities in future forest health management for temperate forests of the United States.

490.**Smol, J.P.** 1992. Paleolimnology: An important tool for effective ecosystem management. J. Aquat. Ecosyst. Health 1(1):49-58.

Effective management of aquatic resources requires long–term environmental data. However, because long–term observations are rarely available, indirect proxy methods must be used to substitute for these missing historical data sets. Major advances have been made in paleolimnology over the past decade, and many of these advances can be applied directly to integrated and cost–effective assessments of aquatic ecosystem health. This commentary uses the analogy of human health to argue that paleolimnological data provide information crucial to the decision–making process of ecosystem managers.

Key Words: Lake management, Ecosystem Health, Long–term monitoring, Indicators, Acidification

491.**Spellerberg, I.F.** 1991. Monitoring Ecological Change. Cambridge University Press, Cambridge, England.

This book is an introductory survey on the topic of ecological monitoring. The author assesses how changes in biological communities, ecosystems, and populations have been monitored. He also assesses the role of single organisms in monitoring environmental change. The emphasis in this book is not necessarily on pollution or even the effects of physical disturbances brought about by man's exploitation of nature and natural resources. The emphasis throughout the book is on the assessment of biological and ecological monitoring programs, particularly with regard to conservation.

Chapters are: The science and art of monitoring; World programs and monitoring organizations; Biological monitoring in the United States and Europe; Elements of ecology and ecological methods; Biological indicators; Diversity; Similarity; Environmental and biotic indices; Biological variables, processes, and ecosystems; Planning the monitoring; Monitoring bird populations; Freshwater biological monitoring; Insularization and nature conservation; Monitoring land use and landscapes; Environmental impact assessments and monitoring; and Species monitoring and conservation.

492.**Stakeholder Group on Environmental Reporting.** 1987. A study of environmental reporting in Canada. Environment Canada, Ottawa.

493.**Stebbing, A.** 1981. Stress, health, and homeostasis. Mar. Poll. Bull. 12:326-329.

In recent times the concept of stress has been applied to physiological studies of marine vertebrates, but often its use is followed by requests for definition or qualification. The author attempts to identify the causes of confusion, to discuss the concept of stress in a context that may help clarify some of the sources of difficulty, and to develop these ideas in the framework of toxicology.

494.**Steedman, R., and H. Regier.** 1987. Ecosystem science for the Great Lakes: Perspectives on degradative and rehabilitative transformations. Can. J. Fish. Aquat. Sci., Suppl. 2. 44:95-103.

Conventional approaches to ecological management presuppose the preeminence of normal natural processes in quasi-equilibrium state, in the presence of one or a few cultural stresses of light to moderate intensities. They also presuppose that the abiotic and biotic structural form of the ecosystem is relatively unaffected. In some parts of the Great Lakes, normal natural ecosystem processes have been overwhelmed by numerous intense cultural factors. Rehabilitation of such areas requires information and understanding of a type that is not central to conventional fisheries biology. The authors review and extend existing scientific approaches that contribute to an effective and relevant "ecosystem science," according to the criteria that they (1) incorporate spatial and structural models appropriate to an ecosystem perspective of the Great Lakes basin, (2) incorporate functional attributes actually observed in stressed and culturally degraded aquatic ecosystems, and (3) provide information directly relevant to effective, informal, broadly based mechanisms of ecosystem rehabilitation and husbandry.

Subtopics covered in this article are (1) approaches to the study of structure in aquatic ecosystems; (2) ecosystem response to stress; and (3) rehabilitation of degraded systems.

495.**Steedman, R.J., and H.A. Regier.** 1990. Ecological bases for an understanding of ecosystem integrity in the Great Lakes Basin. Pages 257-270. In: C.J. Edwards and H.A. Regier, eds. An Ecosystem Approach to the Integrity of the Great Lakes in Turbulent Times. Great Lakes Fishery Commission Special Publication 90-4. Great Lakes Fishery Commission, Ann Arbor, MI.

Use of the word integrity, when applied to natural ecosystems as affected by human cultural activities, may connote health as sketched by Neess (1974) in which the ecosystem

1. is energetic, in that natural ecosystemic processes are strong and nor severely constrained;

2. is self-organizing, in an emerging, evolving way;

3. is self-defending, against invasions by exotic organisms;

4. has biotic capabilities in reserve, to survive and recover from occasional severe crises;

5. is attractive, at least to informed humans; and

6. is productive in terms of goods and opportunities valued by humans.

Of these six features, the first four need not relate directly to human interests, as do the last two. Thus, the first four may be treated objectively in the sense that subjective cultural interests are absent. The term integrality might be used to refer to the systemic state of a healthy ecosystem, which can be characterized fully by the objective methods of natural science.

To make operational a concept of ecological integrity (or integrality), ecological phenomena may be related to ideas in system theory and to empiric generalizations about ecosystems. In particular, we should know how ecological integrity develops, how it responds to turbulent or surprising external influences or stresses, how it may be measured, and how it may be managed. Each of these topics is addressed briefly in this chapter.

496.**Steinhart, C.E., L. Schierow, and W.C. Sonzogi.** 1982. An environmental quality index for the Great Lakes. Water Res. Bull. 18(6):1025-1031.

To facilitate communication on the environmental quality of lakes, particularly among policymakers and the general public, a new index for summarizing technical information is presented. The index is designed for the nearshore waters of the North American Great lakes, but the concept is applicable to other temperate lakes with relatively good water quality. The index is based on nine physical (P), chemical (C), biological (B), and toxic substance (T) variables. Raw data are converted to subindex values by mathematically defined functions based on national or international objectives. Subindex values are multiplied by weighting factors and are added together to yield a final score ranging from 0, worst quality, to 100, highest quality. Subscripted letters following the index score indicate the types and numbers of variables whose values are equal to or worse than the objective (e.g., 70 C_1P_1 indicates that one chemical and one physical variable exceeded the objective). For eighteen nearshore locations in the Great Lakes, index scores ranged from 98 at two stations in Lake Superior to 30 $C_2P_1B_2T_3$ off Point Mouillee, off Lake Erie. If properly utilized, the index should be a useful tool to help managers evaluate the response of the Great Lakes to the multibillion dollar cleanup efforts conducted during the 1970s.

Key Words: Water quality, Index, Great Lakes, Toxic substances, Pollution control

497.**Stohlgren, T.J., and J.F. Quinn.** 1992. An assessment of biotic inventories in the western United States national parks. Natur. Areas J. 12(3):145-153.

The authors evaluated existing natural resources data from 40 national parks and monuments in the U.S. National Park Service's Western Region, which includes Arizona, California, Hawaii, Nevada, and several Pacific Trust Territories. Better information on species occurrence was available for vascular plants, mammals, and birds than for other taxa (reptiles, amphibians, fish, terrestrial invertebrates, aquatic invertebrates, and non-vascular plants). Although most parks had compiled species lists for at least some taxa, the majority of the lists were reported to be less than complete in their species, geographic, and ecologic (community type) coverage. None of the species lists resulted from systematic parkwide surveys. About half of the parks reported essentially no research on invertebrates or non-vascular plants — major components of biological diversity. The actual status of natural resources information is difficult to assess because of (1) a lack of catalogued and readily accessible information on past studies of resources, (2) essentially no standardization in recording procedures, (3) missing or poorly maintained voucher specimens, and (4) disproportionate attention to "popular" taxa. Large parks tended to have more information about their natural resources than smaller parks that historically have received less funding for research and resource management activities. If parks are to serve as baselines against which to measure environmental change, there is an urgent need to rank inventorying and monitoring needs, standardize recording techniques, test model inventory and monitoring systems, substantially improve the natural resource awareness of al National Park Service staff, and develop a hierarchical framework of methods to collect and synthesize biological resource data over large spatial and long temporal scales. The authors present suggestions for strengthening biological inventory programs in the U.S. National Park system.

498.**Stokes, P., M. Havas, and T. Brydges.** 1990. Public participation and volunteer help in monitoring programs: An assessment. Environ. Monitor. Assess. 15:225-229.

A number of opportunities exist for involving the public in environmental monitoring. This paper outlines some examples in which this has been done, evaluates these examples, and then summarizes some of the benefits as well as the disadvantages of this approach.

499.**Stokes, P., and Piekarz, D., eds.** 1987. Ecological indicators of the state of the environment. Environmental Interpretation Division. Environment Canada, Ottawa.

500.**Stolte, K.W., D.M. Duriscoe, E.R. Cook, and S.P. Cline.** 1992. Methods of assessing responses of trees, stands, and ecosystems to air pollution. Pages 259-330. In: R.K. Olsen, D. Binkley, and M. Bohn, eds. Response of Western Forests to Air Pollution. Springer-Verlag, New York.

501.**Stork, N., and P. Eggleton.** 1992. Invertebrates as determinants and indicators of soil quality. Am. J. Altern. Agric. 7(1-2):38-47.

Invertebrates are an integral part of soils and are important in determining the suitability of soils for the sustainable production of healthy crops or trees. The authors discuss the importance of the soil invertebrate fauna in relation to terrestrial and global biodiversity. The authors describe the role of the main invertebrate groups in soils, including earthworms, termites, springtails, and nematodes, and how they determine soil quality. Practical problems in dealing with the invertebrate fauna include sampling, taxonomy and availability of biological information on species. Various measures are available that use invertebrates to assess soil quality, each with its advantages and disadvantages. They include abundance, biomass, density, species richness, trophic/guild structure, food web structure, keystone species and ecosystem engineers. The authors propose the three most useful and practical of these as suitable to be combined with other biological (microbial) and non–biological (hydrological, physical, chemical) criteria into a single index of soil quality that might be used on a regional, if not international basis.

Key Words: Biodiversity, Soil invertebrates, Species richness, Keystone species, Earthworms, Springtails, Nematodes, Termites

502.**Study Group on Environmental Monitoring.** 1977. Environmental Monitoring. Report to the U.S. Environmental Protection Agency. National Research Council. National Academy of Sciences, Washington, DC.

This report is divided into four sections: An overview of current environmental monitoring programs, purposes of monitoring, EPA's management of scientific data, and toward more effective national environmental monitoring. A brief discussion is provided on ecological effects monitoring and the use of indicators.

503.**Stumpp, J., and W. Mucke.** 1991. Environmental monitoring with biological indicators—A program for recording the impact of pollutants on terrestrial ecosystems. (In German, abstract in German, English). Staub Reinhalt. Luft 51(9):295-299.

Biological indicators are used in environmental monitoring programs. Besides chemical and physical measurements, biomonitoring methods are part of ecological monitoring programs. According to the ranges of application, a minimum program for terrestrial ecosystems is presented. Based on proved and standardized methods it involves (1) long-term monitoring of natural ecosystems: control of changes in vegetation and chemical analysis; (2) wide-spread monitoring networks: lichen-vegetation, indicators of photochemical oxidants, moss and spruce; and (3) local and regional monitoring: lichen-exposure, indicators of photochemical oxidants, standardized grass-culture, and borecole.

504.**Suter II, G.W.** 1989. Ecological endpoints. Pages 2-1 – 2-28. In: W. Warren-Hicks, B.R. Parkhurst, and S.S. Baker, Jr., eds. Ecological assessment of hazardous waste sites: A field and laboratory reference. EPA/600/3-89/013. U.S. Environmental Protection Agency, Corvallis, OR.

The purpose of ecological assessment of hazardous waste sites is to provide input to the decision-making processes associated with a broad range of applications, including site prioritization, waste characterization, site characterization, cleanup or remediation assessment, and site monitoring. The results of the ecological assessment that constitute the input to the decision making processes are descriptions of the relationship of pollutants to ecological endpoints. If the ecological endpoints are not compelling, they will not contribute to the decision. This chapter describes two different types of endpoints, presents criteria for judging endpoints, presents classes of endpoints that are potentially useful in assessments of waste sites, judges them by the criteria, and discusses how the nature of the assessment problem affects endpoint choice.

505.**Suter II, G.W.** 1990. Endpoints for regional ecological risk assessments. Environ. Manage. 14(1):9-23.
Ecological risk assessments must have clearly defined endpoints that are socially and biologically relevant, accessible to prediction and measurement, and susceptible to the hazard being assessed. Most ecological assessments do not have such endpoints, in part because the endpoints of toxicity tests or other measurements of effects are used as assessment endpoints. This article distinguishes assessment and measurement endpoints in terms of their roles in risk assessments and explains how the criteria for their selection differ. It then presents critical discussions of possible assessment and measurement endpoints for regional ecological risk assessments. Finally, the article explains how endpoint selection is affected by the goal of assessment. Generic goals for regional risk assessment include explanation of observed regional effects, evaluation of an action with regional implications, and evaluation of the state of a region. Currently, population level assessment endpoints such as

abundance and range are the most generally useful. For higher levels (ecosystems and regions) data are generally not available and the validity of models has not been demonstrated, and for lower level effects (physiological and organismal), data are not relevant. However, landscape descriptors, material export, and other regional-scale measurement endpoints show promise for regional assessments.

Key Words: Endpoints, Risk, Assessment, Regional, Landscape

506.**Suter II, G.W.** 1993. In Press. A critique of ecosystem health concepts and indices. Environ. Toxicol. Chem. 12.

Because people wish to preserve their health and wish to do something equivalent for ecosystems, the metaphor of ecosystem health springs to mind. This paper presents the argument that it is a mistake for environmental scientists to treat this metaphor as reality. First, the metaphor fails because it misrepresents both ecology and health science. Ecosystems are not organisms, so they do not behave like organisms and do not have the properties of organisms such as health. Also, health is not an operational concept for physicians or health risk assessors because they must predict, diagnose, and treat specific states called diseases or injuries; they do not calculate indices of health. Second, attempts to operationally define ecosystem health result in the creation of indices of heterogeneous variables. Such indices have no meaning, they cannot be predicted so they are not applicable to most regulatory problems, they have no diagnostic power, effects on one component are "eclipsed" by responses of other components, and the reason for a high or low index value is unknown. Their only virtue is that they reduce the complex array of responses of various ecosystems to various disturbances to one number with a reassuring name. A better alternative is to assess the real array of ecosystem responses so that causes can be diagnosed, future states can be predicted, and benefits of treatments can be compared.

Key Words: Endpoint, Ecosystem health, Environmental health, Index, Indices, IBI

507.**Szaro, R.** 1986. Guild management: An evaluation of avian guilds as a predictive tool. Environ. Manage. 10:681-688.

The use and applicability of the guild concept to management is evaluated and questioned. Ecological problems are never as simple as implied in using one or two guild axes. A close examination of bird communities in a ponderosa pine forest reveals little relationship between guilds or guild blocks and the responses exhibited by individual bird species or bird species groups. Response guilds changed from year to year without any obvious changes in vegetation. A 3 year composite analysis shows a clearer picture of the responses of ponderosa pine forest birds to the overall interactions between structure, weather, competition, and so on than does guild analysis. The six response groups in the composite analysis are species that (1) were absent in 1973 on most or all study plots and showed no preference for any forested site; (2) had their highest densities on the medium-cut and light-cut plots; (3) were absent in 1973 on most or all study plots and had their highest densities on the medium-cut and light-cut plots; (4) had their highest densities on the untested, light-cut and medium-cut plots; (5) had their highest densities on the untreated and light-cut plots and were either absent or had greatly reduced densities on all other plots; (6) were present only on the clearcut, except for the Rock Wren which was also on the medium-cut and heavy-cut plots. The overall correlation between species density and guild density was significantly higher for response guilds (alpha < 0.05) than for any of the structural or functional guilds. The whole concept of guild management must be further researched and developed before it can be recommended as a management tool.

508.**Szaro, R., and R. Balda.** 1982. Selection and monitoring of avian indicator species: An example from a ponderosa pine forest in the southwest. General Technical Report RM-89. U.S.D.A. Forest Service.

509.**Taub, F.** 1987. Indicators of change in natural and human-impacted ecosystems: Status. Pages 115-144. In: S. Draggan, J. Cohrssen, and R. Morrison, eds. Preserving Ecological Systems: The Agenda for Long-term Research and Development. Praeger, New York.

Even if an ecological change is associated with human impacts, it is often a major problem to identify a specific cause from among the myriad of changes that simultaneously impact a developed area. It is still a greater problem to decide when a change represents an unacceptable or dangerous alteration in an ecosystem. Some contend that only changes involving human health or economic concerns are important. Others see value in documenting ecological changes even if the biological significance of these indices are currently unknown. When is there enough confidence in our ecological indicators to implement policies that have major economic impacts such as power production, chemical use and disposal? Is a modest change in an ecological index an early warning of a serious problem or merely a short-term alteration in a highly variable, complex, and self-regulating variable? This paper is restricted to reviewing indicators of change, their inadequacies, and new research that might improve the situation.

510.**Taylor, G., and D. Shriner.** 1981. Indicators of air pollution stress in terrestrial ecosystems. (abstract only). Bull. Ecol. Soc. Am. 62(2):90.

Throughout regions of the eastern United States, various components of terrestrial ecosystems are exposed to differing degrees of elevated levels of gaseous and particulate atmospheric pollutants. Although the deposition of such pollutants under conditions of high pollutant loading is recognized to cause significant alterations of ecosystem structure and/or function, ecosystem level-responses to low and intermediate levels of pollutant exposure are difficult to assess. To estimate the significance of subtle air pollution stress on a regional basis, sensitive indicators of chronic exposure to low levels of pollutant loading are required. Parameters capable of direct measurement for representative ecosystem components are suggested (e.g., suppressed photosynthesis, enhanced respiration and growth). These parameters can be related to altered system function (e.g., reduced productivity or vigor), combinations of chemical fate, and mobility of pollutants impacting producer, consumer, or decomposer populations.

511.**Thomas, J., D. McKenzie, and L. Eberhardt.** 1981. Some limitations of biological monitoring. Environ. Int. 5:3-10.

Biological monitoring data are obtained to document changes in population abundance for resource management, to verify compliance with regulatory directives, and to assess cause and effect for research purposes. Particular statistical analyses are often not appropriate because suitable field designs are either not available or not matched a priori to the monitoring objectives. When monitoring to detect normal changes in population numbers, quantitative problems may not be as difficult as they are in detecting and assigning causation induced by a natural or man-made pollutant. Changes in biotic abundance can be caused or influenced by compensation, indirect effects, direct mortality, and interactions among environmental variables. Even though data from baseline monitoring programs usually should be only used to detect change in biotic abundance, they sometimes can be used to draw inferences about cause by correlation or to test laboratory results against a long-term historical record. Available quantitative methodologies useful in evaluating monitoring data are limited and interpretations about cause and effect are difficult.

512.**Thomas, W.** 1972. Indicators of Environmental Quality. Plenum Press, New York.

This book contains an overview of indicators and environmental (and social) indices. Chapters discuss: Why environmental quality indices, uses of indices in policy formulation, the obligations of scientists to explain environment to the public, indicators of environmental quality of urban life, establishing priorities among environmental stresses, aquatic communities as indices of pollution, plants as indicators of air quality, biochemical indicators of pollution, and plants as indicators in ecology. Other chapters focus on recreation, radioactivity, soil quality, and environmental noise.

513.**Train, R.** 1972. The quest for environmental indices. Science 178:121.

This editorial briefly discusses environmental indices: the need for them, what makes a good index, and obstacles to developing a good index.

514.**Treshow, M.** 1978. Terrestrial plants and plant communities. Pages 223-237. In: G.C. Butler, ed. Principles of Ecotoxicology. John Wiley & Sons, Chichester, England.

This chapter is divided into the following sections and subsections: Introduction; Toxicant Uptake; Responses of Communities to Perturbation — (i) Physiological responses, (ii) Responses of organisms, (iii) Responses of plant communities, (iv) Agricultural systems; Diagnosing Community Dysfunction — (i) Diagnosing changes, (ii) Predicting changes; and Conclusions.

515.**Tyson, J., and M. House.** 1989. The application of a water quality index to river management. Pages 175-186. In: Urban Discharges and Receiving Water Quality Impacts. (Series: Advances in Water Pollution Control). Pergamon Press, Ltd., Oxford.

516.**Ulanowicz, R. E.** 1978. Modeling environmental stress. Pages 1-18. In: J. Thorp and J. Gibbons, eds. Energy and Environmental Stress in Aquatic Systems. Department of Energy Symposium Series CONF 771114. Department of Energy, Technical Information Service, Oak Ridge, TN.

The word "stress" when applied to ecosystems is ambiguous. Stress may be low-level, with accompanying near-linear strain, or it may be of finite magnitude, with nonlinear response and possible disintegration of the system. Because there are no widely accepted definitions of ecosystem strain, classification of models of stressed systems is tenuous. Despite appearances, most ecosystem models seem to fall into the low-level linear response category. Although they sometimes simulate system behavior well, they do not provide necessary and sufficient information about sudden structural changes nor structure after transition. Dynamic models of finite-amplitude response to stress are rare because of analytical difficulties. Some idea about future transition states can be obtained by regarding the behavior of unperturbed functions under limiting strain conditions. Preliminary work shows that, because community variables do respond in a coherent manner to stress, macroscopic analyses of stressed ecosystems offer possible alternatives to compartmental models.

517.**Ulanowicz, R.E.** 1986. A phenomenological perspective of ecological development. Pages 73-81. In: T.M. Poston and R. Purdy, eds. Aquatic Toxicology and Environmental Fate: Ninth Volume. ASTM STP 921. American Society for Testing and Materials, Philadelphia, Pa.

The most direct and realistic approach to quantifying ecosystems is to measure their supporting networks of flows of materials and energy. The growth and development of such networks may be quantified by applying information theory to the data on flows. Once development has been formalized, other heretofore subjective notions, such as "eutrophication" and "ecosystem health," take on more precise, quantitative significance.

Key Words: Aquatic toxicology, Ecosystem theory, Food webs, Information theory, Thermodynamics, Self-organization, Eutrophication, Ecosystem health, Networks

518.**Ulanowicz, R.E.** 1986. Growth and Development: Ecosystems Phenomenology. Springer-Verlag, New York. 286 pp.

519.**Ulrich, B.** 1983. An ecosystem oriented hypothesis on the effect of air pollution on forest ecosystems. Pages 221-231. In: Ecological Effects of Acid Precipitation. Rep. PM 1636. National Swedish Environment Protection Board.

520.**Underwood, A.** 1989. The analysis of stress in natural populations. Biol. J. Linnean Soc. 37:51-78.

Populations usually persist despite environmental variations. Experimental analysis of responses to stress must include distinction between potential stresses (environmental perturbations that might not cause stress) and actual stress (phenomena that cause a response by the population). This is made difficult by large temporal fluctuations in the abundance data of many organisms. Monitoring can measure this variability but is insufficient to predict the potential impact of most stresses. Experimental analyses of stresses are also made difficult by differences in population inertia (lack of response to perturbation), resilience (magnitude of stresses from which a population can recover), and stability (rate of recovery following a stress). These attributes of population cause a range of responses to intermittent, temporary, and acute (or "pulse") stresses and to long-term chronic ("press") disturbances. The timing, magnitude, and order of stresses can cause different responses by populations. Synergisms between simultaneous or successive stresses can also have unpredictable effects on populations and cause complexity in interpretation of patterns of competition and predation. Experimental manipulations are needed to understand the likely effect of environmental disturbance on populations. The appropriate experiments are those designed to measure the effects of different types, magnitudes, and frequencies of simulated stresses. These will be more revealing than the more common experimental analyses used to determine why and how observed changes in abundances of populations are caused by existing stresses.

Key Words: Stress, Perturbation, Inertia, Resilience, Stability, Experimental design, Prediction

521.**Underwood, A.** 1991. Beyond baci — Experimental designs for detecting human environmental impacts on temporal variations in natural populations. Aust. J. Mar. Freshwater Res. 42(5):569-587.

Biological effects of environmental impacts are usually defined simplistically in terms of changes in the mean of some biological variable. Many types of impacts do not necessarily change long-run mean abundances. Here, designs for detection of environmental impact are reviewed and some shortcomings noted. New sampling designs to detect impacts that cause changes in temporal variance in abundance of populations, rather than in the means, are described. These designs are effective at distinguishing pulse and press episodes of disturbance and could be used for other variables of interest (size, reproductive state, rate of growth, number of species, etc.) for monitoring. The designs require sampling different time-scales before and after a proposed development that might cause impact. Cases are discussed in which there is a single control location. This approach is inadequate for management of impacts that cause temporal change rather than alterations of the mean abundance of population.

522.**United States House of Representatives.** 1984. "Environmental Monitoring and Improvement Act": Hearings before the Subcommittee on Natural Resources, Agricultural Research, and the Environment of the Committee on Science and Technology. March 28, 1984. U.S. Government Printing Office, Washington, DC.

523.**Usher, M.B.** 1991. Scientific requirements of a monitoring programme. Pages 16-32. In: B. Goldsmith, ed. Monitoring for Conservation and Ecology. Chapman and Hall, London.

In planning a monitoring program, five basic questions need to be answered. Each question is important and should be answered before any monitoring begins; these questions essentially form a sequential set because a satisfactory answer to any individual question cannot be given until all questions higher on the list have been answered. The questions are:

1. Purpose: What is the aim of monitoring?
2. Method: How can this aim be achieved?
3. Analysis: How are the data, which will be collected periodically, to be handled?
4. Interpretation: What might the data mean?
5. Fulfillment: When will the aim have been achieved?

The aim of this chapter is to follow these questions through, discussing aspects of each that relate to the data being collected and the interpretations likely to be placed on them. Many of the subsequent chapters address specific issues raised by these five broader questions.

524.**van Straalen, N.N., and R.G.M. de Goede.** 1987. Productivity as a population performance index in life-cycle toxicity tests. Water Sci. Technol. 19(11):13-20.

Toxicity at the population level is often measured by the intrinsic rate of population increase (r_m). In this paper, the biomass turnover ratio (P/B) of a population is introduced as another measure of population performance under toxic stress. An expression is derived by which the intrinsic P/B ratio may be calculated from life-table data. Unlike r_m, P/B depends also on the individual growth curve. The theory is exemplified by experimental data on the effect of cadmium on *Orchesella cincta* (Collembola) from forest soil. The results are compared with seasonal fluctuations of productivity in an unstressed field population. Toxic effects of cadmium appear at a much lower exposure level than would be deduced from the P/B ratio. Some mechanism of compensation seems to be present in that the high natural mortality (by predation) obscures the sublethal effects on growth. This may explain why Collembola can inhabit forest soils that are contaminated to levels far above the no-effect level for individual growth.

Key Words: Cadmium, *Orchesella cincta*, Collembola, Soil pollution, Productivity, Toxicity

525.**Vass, R.** 1982. Surveillance monitoring versus system investigation. Pages 23-39. In: B. Hart, ed. Water Quality Management: Monitoring Programs and Diffuse Runoff. Water Studies Centre. Chisolm Institute of Technology and Australian Society for Limnology, Melbourne, Australia.

526.**Vighi, M.** 1991. Environmental decision-making—The ecotoxicological contribution. Pages 211-216. In: J.B. Opschoor and D.W. Pearce, eds. Persistent Pollutants: Economics and Policy. Kluwer Academic Publishers, Dordrecht, The Netherlands.

This article provides two case studies as good examples of the kind of information ecotoxicology can produce for the management of environmental problems. Ecotoxicological approaches for the study of marine pollution and the environmental impact of pesticides are provided.

527.**Vinogradov, B.** 1990. Remote sensing of biosphere state and ecosystem dynamics. Pages 693-704. In: H. Lund and G. Preto, eds. Global Natural Resource Monitoring and Assessments: Preparing for the 21st Century. American Society for Photogrammetry and Remote Sensing, Bethesda, MD.

At the present time the development of a reliable system for ecological data collection is a main problem of both a synthetical and analytical global approach to biosphere studies. On the one hand, the global synthesis of ecological data is provided with complete and regular space surveys at small scales. On the other
hand, the local analysis of these data is obtained from selective and permanent ecological observations on the set of the ground truth stations covering a wide range of the different ecoregions. This is a main area of involvement of IGBP "Global Change", no less important than the formation of the satellite world-wide data survey, collection, and analysis systems. This set of ground truth stations which provides the satellite systems with information and includes forest and agricultural experiment stations, ecological observation sites, biosphere reserves, natural reserves,
undersatellite ecological test sites, and others.

528.**Visser, S., and D. Parkinson.** Soil biological criteria as indicators of soil quality: Soil microorganisms. Am. J. Altern. Agric. 7(1-2):33-37.

Diverse soil microbiological studies have attempted to assess deterioration or improvement in soil quality. These studies have been done on three levels: population level studies of the dynamics of species that are presumed to be important or sensitive; community level studies of microbial community structure, such as species diversity and frequency of occurrence of species; and ecosystem level studies of a range of soil processes. The authors suggest that ecosystem level approaches offer the best possibilities for rapidly assessing changes in soil quality. Data from such studies will allow researchers to decide whether to proceed with population or community level studies.

Key Words: Soil bacteria, Soil fungi, Total microbial biomass, Carbon cycling, Nitrogen cycling, Nutrient leaching, Soil enzymes

529.**Vitousek, P.** 1990. Biological invasions and ecosystem processes: Towards an integration of population biology and ecosystem studies. Oikos 57:7-13.

Biological invasions by exotic species clearly alter the composition and community structure of invaded areas. There is increasing evidence that they can also alter properties of whole ecosystems, including productivity, nutrient cycling, and hydrology. For example, the exotic actinorrhizal nitrogen-fixer *Myrica faya* alters primary successional ecosystems in Hawaii Volcanoes National Park by quadrupling inputs of nitrogen , the nutrient limiting to plant growth. A few other examples of ecosystem-level changes have been documented. Biological invaders change ecosystems by differing from native species in resource acquisition and/or resource use efficiency, by altering the trophic structure of the area invaded, or by altering disturbance frequency and/or intensity. Where exotic species clearly affect ecosystem-level properties, they provide the raw material for integrating the methods and approaches of ecosystem ecology.

530.**Vonk, J.W.** 1983. Problems in characterizing the ecological quality of soil in relation to human activities. Environ. Monitor. Assess. 3(3/4):289-296.

The soil ecosystem is composed of various groups of organisms which have complex relations. The physical structure and chemical characteristics of the soil provide the boundary conditions. In view of various deteriorating human activities, it is important to find soil quality characteristics with respect to its most important function: the ecological function. An enumeration has been given of chemical, physical, and biological soil parameters which are more or less important for soil quality. Several of these parameters are discussed. For use as indicators of deterioration, for a given site, the optimum values of the soil parameters have to be established, as well as acceptable deviations from the optimum, taking into account natural fluctuation. It is concluded that, due to lack of data, such an approach is not possible at this moment. However, it might be possible to identify those soil parameters which should be taken into consideration when evaluating human activities.

531.**Vos, J.B., J.F. Feenstra, J. de Boer, L.C. Braat, and J. van Baalen.** 1985. Indicators for the State of the Environment. Institute for Environmental Studies, Free University, Amsterdam.

532.**Walker, B.H.** 1992. Biodiversity and ecological redundancy. Conserv. Biol. 6:18-23.

This paper addresses the problem of which biota to choose to best satisfy the conservation goals for a particular region in the face of inadequate resources. Biodiversity is taken to be the integration of biological variability across all scales, from the genetic, through species and ecosystems, to landscapes. Conserving biodiversity is a daunting task, and the paper asserts that focusing on species is not the best approach. The best way to minimize species loss is to maintain the integrity of ecosystem function. The important questions therefore concern the kinds of biodiversity that are significant to ecosystem functioning. To best focus our efforts we need to establish how much (or how little) redundancy there is in the biological composition of ecosystem. An approach is suggested, based on the use of functional groups of organisms defined according to ecosystem processes. Functional groups with little or no redundancy warrant priority conservation effort. Complementary species–based approaches for maximizing the inclusion of biodiversity within a set of conservation areas are compared to the functional;l group approach.

533.**Walker, J., and B. Jones.** 1992. What is meant by indicators and the decisions behind those chosen for the Environmental Monitoring and Assessment Program of the U.S. EPA. Pages 44-49. In:A. Hamblin, ed. Environmental Indicators for Sustainable Agriculture. Bureau of Rural Resources, Dept. of Primary Industry and Energy, Queen Victoria Terra, Australia.

534.**Walters, C.** 1986. Adaptive Management of Renewable Resources. MacMillan, New York.

This book discusses ways of dealing with uncertainty in the management of renewable resources, such as fisheries and wildlife. The basic theme is that management should be viewed as an adaptive process. The potentials of natural populations to sustain harvesting mainly through experience with management itselr, rather than through basic research or the development of general ecological theory are discussed. The book includes sections on model building, problem bounding, and uncertainty in environmental analysis.

535.**Walters, C.J., and C. Holling.** 1990. Large-scale management experiments and learning by doing. Ecology 71(6):2060-2068.

Even unmanaged ecosystems are characterized by combinations of stability and instability and by unexpected shifts in behavior from both internal and external causes. This is even more true of ecosystems managed for the production of food or fiber. Data are sparse, knowledge of processes is limited, and the act of management changes the system being managed. Surprise and change are inevitable. The authors review methods to develop, screen, and evaluate alternatives in a process in which management itself becomes partner with the science by designing probes that produce updated understanding as well as economic product.

536.**Ward, R.C.** 1992. Indicator selection: A key element in monitoring system design. Pages 147-158. In: D. McKenzie, D.E. Hyatt, and J. McDonald, eds. Ecological Indicators. Proceedings of the International Symposium on Ecological Indicators held in Fort Lauderdale, FL, 16-19 October 1990. Elsevier, Essex, England.

537.**Waring, R.** 1991. Ecosystem stress and disturbance. In: J. Cole et al., eds. Comparative Analysis of Ecosystems: Patterns, Mechanisms, and Theories. Springer-Verlag, New York.

538.**Waring, R.H., J.D. Aber, J.M. Melillo, and B. Moore III.** 1991. Precursors of change in terrestrial ecosystems. Bioscience 36(7):433-438.

In this article, the authors describe some ecosystem variables that are precursors of change and indicate the potential of using remote sensing to assess these variables. Topics covered are changes in net photosynthesis and transpiration, patterns of carbon allocation, plant maintenance respiration, and organic matter turnover.

539.**Weber, F.R.** 1990. Preliminary indicators for monitoring changes in the natural resource base. AID Program Design and Evaluation Methodology-14; AID-PN-AAX-233. NTIS No. PB90-262056/HDM. Agency for International Development, Center for Development Information and Evaluation, Washington, DC. 43 pp.

The paper describes ten simple, practical indicators of the natural resource base and suggests ways in which they can assist the Agency for International Development (AID) field personnel to monitor both the negative and positive impacts of project interventions on natural resources—soils, water, natural vegetation, and wildlife. It also discusses methods for collecting and using the indicators, stressing reliance on locally available information and simple techniques. Furthermore, the paper contains a brief discussion on indicators for measuring impacts on areas of historical, religious, cultural, and scientific significance. Although the main thrust of the paper deals with identifying impacts at project-output and objective levels, it also touches on how indicators can eventually be used to measure longer range impacts of USAID Mission programs, particularly in dealing with agricultural and rural development.

540.**Weinert, E.** 1991. Biomonitoring of environmental change using plant distribution patterns. Pages 179-190. In: D.W. Jeffrey and B. Madden, eds. Bioindicators and Environmental Management. Academic Press, London.

Plant distribution depends on autoecological requirements of and behavior of species and on the environmental situation, which is characterized by a complex interaction of biotic and abiotic factors. Biomonitoring of environmental change may be accomplished by recording changes in the regional and local distribution of indicator plants as individuals, populations, and communities.

Distribution patterns of sensitive indicator plants are used to illustrate the range and intensity of human impact (air, soil, and water pollution) that has led to environmental change in central European landscapes.

Key Words: Phytoindicator, Distribution pattern, Extinction, Expansion, Recession, Pollution, Environmental change, Central Germany

541.**Weinstein, D.A., and E.M. Birk.** 1989. The effects of chemicals on the structure of terrestrial ecosystems: Mechanisms and patterns of change. Pages 181-209. In: S. Levin, M. Harwell, J. Kelly, and K. Kimball, eds. Ecotoxicology: Problems and Approaches. Columbia University Press, New York.

This chapter is divided into the following sections: mechanisms of chemical exposure, effects of disturbance on organisms, consequences of organism injury to alterations in ecosystem structure, and chronic exposures. The authors conclude that severe cases of physically and chemically induced stresses in ecosystems have similar consequences with regard to retarding the development of ecosystem biomass and composition. Chronic levels of chemical exposure create a very different perturbation than physical disturbance. As a consequence, the mechanisms that operate following these perturbations differ, as do the changes in structural properties that result from those mechanisms.

542.**Westman, W.** 1978. Measuring the inertia and resilience of ecosystems. Bioscience 28:705-710.

The resilience of natural ecosystems is a property of keen interest to both theoretical and applied ecologists. Resilience, in this context, refers to the degree, manner, and pace of restoration of initial structure and function in an ecosystem after disturbance. It is an important ecological characteristic, reflecting ultimately the nature and complexity of homeostatic processes in an ecosystem. A property distinct from this is the ability of a system to resist displacement in structure or function when subjected to a disturbing force. This property is referred to as "inertia." Notions of inertia and resilience in ecosystems are of considerable interest to applied ecologists, environmental managers, and planners.

543.**White, D., A.J. Kimerling, and W.S. Overton.** 1992. Cartographic and geometric components of a global sampling design for environmental monitoring. Cartogr. Geogr. Inform. Syst. 19(1):5-22.

A comprehensive environmental monitoring program based on a sound statistical design is necessary to provide estimates of the status of, and changes or trends in, the condition of ecological resources. A sampling design based upon a systematic grid can adequately assess the condition of many types of resources and retain flexibility for addressing new issues as they arise. The randomization of this grid requires that it be regular and retain equal-area cells when projected on the surface of the earth. After review of existing approaches to constructing regular subdivisions of the earth's surface, the authors propose the development of the sampling on the Lambert azimuthal equal area map projection of the earth's surface to the face of a truncated icosahedron fit to the globe. This geometric model has less deviation in area when subdivided as a spherical tessellation than any of the spherical Platonic solids, and less distortion in shape over the extent of a face when used for a projection surface by the Lambert azimuthal projection. A hexagon face of the truncated icosahedron covers the entire conterminous United States, and can be decomposed into a triangular grid at an appropriate density for sampling. The geometry of the triangular grid provides for varying the density, and points on the grid can be addressed in several ways.

Key Words: Global sampling design, Sampling grid, Map projections, Polyhedral tessellation, Truncated icosahedron, Hierarchical grid geometry

544.**White, G., et al.** 1990. The use of forest ecosystem process measurements in an integrated environmental monitoring program in the Wind River Range. In: Proceedings-Symposium on Whitebark Pine Ecosystems. General Technical Report INT-270. U.S. Department of Agriculture Forest Service, Intermountain Research Station.

545.**Whittier, T.R., and S.G. Paulsen.** In Press. 1993. The surface water component of the Environmental Monitoring and Assessment Program: An overview. J. Aquat. Ecosyst. Health.

546.**Wiersma, G.B.** 1985. Recommended integrated monitoring system for pollutants on U.S. National Parks. Informal report, EGG-PBS-6721. EG&G Idaho, Inc., Idaho Falls.

547.**Williams, B., and M. Marcot.** 1991. Use of biodiversity indicators for analyzing and managing forested landscapes. Pages 613-627. In: R. McCabe, ed. Transactions of the 56th North American Wildlife and Natural Resources Conference. Wildlife Management Institute, Washington, DC.

This paper presents: (1) an overview of biodiversity of Klamath National Forest (KNF) and Klamath Physiographic Province; (2) examples of how past land management trends have affected biodiversity in the U.S Pacific Northwest; (3) a generalized approach to planning for biodiversity in National Forest Land Management Plans and; (4) a set of indicators of biodiversity being used on KNF to evaluate the effects of management alternatives on biodiversity and some preliminary data reflecting current conditions on KNF relating to the indicators.

548.**Woodley, S., and J. Theberge.** 1992. Monitoring for ecosystem integrity in Canadian National Parks. Pages 369-377. In: J.H.M. Willison, S. Bondrup–Nielsen, C. Drysdale, T.B. Herman, N.W.P. Munro, and T.L. Pollack, eds. Science and the Management of Protected Areas. (Series: Developments in Landscape Management and Urban Planning 7). Elsevier Science Publishers, Amsterdam.

549.**Woodward, F., and A. Diament.** 1991. Functional approaches to predicting the ecological effects of global change. Funct. Ecol. 5(2):202-212.

This paper is concerned with the potential of physiological ecology to investigate and predict the effects of global environmental change on communities, ecosystems, or vegetation. The aim is to incorporate the mechanistic approach of physiological ecology with the large-scale approach of ecosystem ecology, both in time and space, to provide a scaling-down approach to ecological investigation and prediction. This paper describes modelled examples of approaches for investigating physiological ecology at larger scales. They attempt to avoid the problems of scaling-up and exploit the benefits of scaling-down, as an approach to understanding function and the connections between function and structure.

Key Words: Climate change, Fire, Forest, Grassland, Microwave backscatter, Saline soils, Scaling, Soil water, Sound, Transpiration

550.**Woodward, F., G. Thompson, and I. McKee.** 1991. The effects of elevated concentrations of carbon dioxide on individual plants, populations, communities and ecosystems. Ann. Bot. 67: 23-38.

Changes in atmospheric concentrations of CO_2, over periods of millennia, are positively correlated with the temperature of the world. It is expected that this positive correlation will be manifested in the future, warmer "greenhouse world" that will have higher concentrations of atmospheric CO_2. The predicted changes in temperature and precipitation are expected to cause significant changes in the distribution patterns of the world's terrestrial vegetation.

In addition to this indirect effect, CO_2 influences plants directly; an increase in the concentration of CO_2 may increase the rate of photosynthesis in plants with the C_3 pathway of fixation. Experimental observations often differ in the degree and length of this stimulation, reflecting the stronger impact of other photosynthetic limitations. Where photosynthetic stimulation does occur, there is a general decrease in leaf protein, which may stimulate rates of leaf herbivory. The well-established and associated increase in the C/N ratio of individual leaves should reduce rates of leaf decomposition. However, the few community experiments at elevated CO_2 suggest little change in the rate of nutrient cycling in communities.

Stomatal opening is generally reduced as CO_2 concentration increases. This feature scale-up through to the community level, however, it appears that the total volume of water used by a community is unlikely to alter with CO_2 alone because plants tend to develop leafier canopies. This change, plus enhanced rates of root development, indicate a greater potential for carbon sequestration by terrestrial ecosystems. Monthly observations of atmospheric CO_2 concentration above the tundra over the last 14 years indicate these expected increases in the rates of CO_2 drawdown by the northern ecosystems of the tundra and the boreal and temperate deciduous forests. However, some of this change may be the result of interactions with the warmer climate of the 1980s and perhaps an increased aerial supply of pollutant nitrogen.

Key Words: CO_2, Plant ecophysiology, Population biology, Ecosystem function and structure

551.**Woodwell, G.** 1970. Effects of pollution on the structure and physiology of ecosystems. Science 168:429-433.

This article summarizes the effects of chronic irradiation of a late successional oak-pine forest at Brookhaven National Laboratory, Long Island, New York. In addition it discusses the general pattern of ecosystem response to pollution.

552.**Woodwell, G.** 1975. Threshold problems in ecosystems. Pages 9-21. In: S. Levin, ed. Ecosystem Analysis and Prediction. Society for Industrial and Applied Mathematics (SIAM), Philadelphia.

This article outline some of the issues surrounding the question "Is it reasonable to assume that thresholds for effects of disturbance exist in natural ecosystems, or are all disturbances effective, cumulative, and detrimental to the normal functioning of natural ecosystems?" It covers such factors as distinguishing short-term or acute disturbances from chronic, long-term change and addresses the question of what to measure when we seek thresholds for changes in ecosystems that normally change more or less continuously.

553.**Yasuno, M., and B. Whitlon, eds.** 1988. Proceedings of the International Symposium on Biomonitoring of the State of the Environment. Tohai University Press, Tokyo.

554.**Zachariassen, K., T. Aunass, J. Borseth, and S. Einerson.** 1991. Physiological parameters in ecotoxicology. Comp. Biochem. Physiol. 100C(1/2):77-79.

1. Regulated physiological parameters are normally maintained at a constant level by regulatory mechanisms. Acute toxic effects develop whenever a pollutant causes a regulated parameter to be displaced beyond tolerated limits, and thus, regulated parameters may be convenient toxicity parameters. The presented study indicates that delta u_{Na+} across the adductor muscle membrane of *Mytilus edulis* is a regulated parameter and that injuries develop whenever this parameter drops below -7000 J/mole.
2. Regulatory physiological parameters may display quick and substantial changes when regulatory mechanisms are activated to counteract variations in the regulated parameters. Thus, regulatory parameters may be used as sensitive alarm parameters in environmental monitoring. Results indicate that the phosphate index $[(ATP \times P\text{-arginine})/P_i)^2]$, metabolic rate, and strombine may be used as alarm parameters.
3. The combined response of all parameters may provide a pollutant-specific fingerprint in environmental monitoring.

555.**Zhou, J.H., S.J. Ma, and C.M. Chen.** 1991. An index of ecosystem diversity. Ecol. Modell. 59(3-4):151-163.

An information entropy index is presented to measure ecosystem diversity based on the numbers of components and the strengths of interactions between them.

Key Words: Species diversity, Stability, Communities, Complexity

556.**Zonneveld, I.** 1983. Principles of bio-indication. Environ. Monitor. Assess. 3:207-217.

One can apply "indication" with two different incentives:

- in order to gain more knowledge on the indicated item in a purely scientific sense or
- to be able to judge the quality of the indicated item (applied research).

The latter goes further than the former because it requires a presumption of good and evil and a consideration of society. In this paper the authors restrict discussion to the indication as such.