

STRESS EFFECTS ON NATURAL ECOSYSTEMS^{1, 2}

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Ecologists have long recognized the ecosystem as the basic unit in ecology (Evans 1956). A study of ecosystems requires understanding relationships between structure and function within the system (Odum 1962). In the past, much information was collected regarding ecosystem structure (e.g., population density, species diversity, standing crop biomass, or life history), with only limited information gathered concerning ecosystem function (e.g., resource recycling, ecological energetics, systems development, or regulatory processes operating within the system). In recent years, however, much information has been collected and evaluated in an attempt to understand better total systems dynamics. Both structural and functional parameters must be intensely investigated and analyzed in an integrative approach if systems relationships are to become better understood for prediction and management purposes.

Ecosystems have traditionally been viewed as *natural* systems (largely disregarding the impact of man on ecosystem structure and function). Although man is defined as "man in nature" by most ecologists, ecosystem studies usually focus on a "man outside nature" approach. Man-related compounds (e.g., pesticides, heavy metals, or radioactive materials), however, are now found within most *natural* ecosystems. Further, the influence of man's socio-economic system on ecosystem dynamics can no longer be ignored. For these and other reasons, a recently proposed ecological paradigm (Johnson 1977) defined ecology as that scientific discipline which attempts to understand the structure, function, and behavior of ecological systems (ecosystems), whereas environmental science is defined as an interdisciplinary science that attempts to measure and evaluate the physical and biological environment and the impact of man upon them, as well as to undertake the management of these systems for man's benefit and survival. These definitions are consistent with those recently presented by Barrett and Puchy (1977). Odum (1977) also views ecology in a strict disciplinary context, but points out that ecology needs to integrate, in a holistic approach, with the social sciences regarding efforts such as technological and environmental impact assessment.

Ecology may well maintain its strong biological connotation (Baldwin *et al* 1975) with complementary support from the physical sciences. The ecosystem will also continue to be the basic unit of investigation and integration, whereas environmental science will attempt to balance better biological, physical, and social science concepts and interrelationships. The noösystem might best be defined as the basic unit of study for environmental science. The noösystem definition would include not only a study of the structure and function of ecosystems, but also would include the social, economic, and cultural influences on ecological systems (i.e., man's impact on ecosystem dynamics). In the papers which follow it is important to interpret each author's professional niche in regard to the study and definition of "natural" ecosystems.

As mentioned earlier, the impact of man on ecosystem dynamics has been profound. Although numerous voids remain in our understanding of ecosystem properties, studies which attempt to evaluate various stressors on natural ecosystems must be pursued with great vigor. The area of stress ecology (Barrett *et al* 1976) provides ecologists with a focal point to measure, evaluate, integrate, and predict the effects of perturbations on the structure and function of natural ecological systems. Stress ecology studies will help ecologists to evaluate not only potentially harmful stressors (e.g., pesticides), but also will increase our understanding of ecosystem response to such stressing agents.

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Proper impact (stress) assessment requires studies which: (a) exhibit a valid experimental design (e.g., pre- and post-treatment information collected with control systems maintained throughout the study for comparative purposes), (b) attempt to investigate both state and driving ecosystem variables in a holistic approach, (c) analyze ecosystems ranging from microcosms (e.g., aquaria) to large-scale systems (e.g., biomes), (d) provide for an integrative, predictive model or better understood ecological principles as major end results, and (e) establish valid ecosystem-level environmental indices which permit diverse geographical, community-type, or successional (time) changes to be compared. Guidelines for testing stressors on ecosystems have been recently outlined (Barrett *et al* 1976).

Researchers involved in ecosystem-level stress investigations need to recognize the importance of being a good "team player." For example, one must respect the contrasting array of research methodologies (e.g., the scientific method employed in basic research to refute a null hypothesis in contrast to the problem-solving method often utilized in applied research to forecast alternative solutions), the differences inherent in basic (liberal arts) versus the applied (mission-oriented) educational philosophies, and the necessary utilization of personnel trained in process-oriented (interdisciplinary), problem-oriented (multi-disciplinary), and traditional (disciplinary) academic programs. Thus, specialists in systems ecology, water resources, and botany, to name a few, often must unite for a particular ecosystem-level investigation. In this manner, the goals and objectives, the experimental design, and an ecological lexicon are shared and understood by all.

Long-term team research appears to provide the best approach for the proper evaluation of various natural and man-made stresses on ecosystem dynamics. Large-scale ecosystem studies also provide ample opportunities for the above-mentioned diversity of professionals to interact in a program whereby the duplication of resources such as money, space, and equipment can be greatly reduced. Further, such investigations provide unique research opportunities (e.g., theses, practica, or internships) for undergraduate or graduate students and opportunities for senior staff to get "re-tooled" in new research methodologies.

In summary, the role of ecologists will continue to change and to be challenged in the years ahead as needs for impact assessment, resource management, systems analysis, and more efficient governmental administration develop and intensify. Studies and research programs which attempt to understand better the effects of stressors on ecosystems should contribute to the training of, and an appreciation for, a new breed of ecologists trained in the "new ecology" (Odum 1977) field of study; a new, integrative discipline which is based on holism and dependent upon interorganizational cooperation. Thus, the new ecology is not an interdiscipline (Odum 1977), rather environmental science becomes the new interdiscipline (Watt 1973, Barrett and Puchy 1977). Environmental scientists need not only an understanding of ecosystem dynamics, but also must assume the role of environmental practitioners (Bingham 1975). However, if the ecologist (i.e., the basic researcher) works in close cooperation with the environmental scientist (i.e., the applied researcher), then our understanding of stress effects upon the interacting components of natural ecosystems and the science of managing these components for man's benefit should greatly increase.

The following contributions represent an attempt to define better: (a) how ecologists utilize ecosystem theory for endeavors such as impact assessment or land-use planning, (b) how ecologists design large-scale ecosystem studies in order to monitor the effects of perturbations on large-scale ecosystems (e.g., watershed or biome), and (c) how ecologists view their professional niche in the years ahead. These contributions are the result of a symposium entitled "Stress Effects on Natural Ecosystems" which was sponsored by the Ecology Committee of the Ohio Academy of Science (OAS), Battelle-Columbus Laboratories, the Institute of Environmental Sciences at Miami University, the Environmental Biology Program at Ohio State University, and the Ohio Biological Survey. As Chairman of the Ecology Committee, I want to thank

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