ECOLOGY AND ENVIRONMENTAL IMPACT ASSESSMENT: AN ANNOTATED BIBLIOGRAPHY

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This bibliography was prepared as part of a Dalhousie University research project on the ecological basis for environmental impact assessment in Canada. The study was conducted under the guidance of a Project Advisory Committee, the members of which are listed on the opposite page.

The bibliography represents a companion volume to the final report for the study entitled An Ecological Framework for Environmental Impact Assessment in Canada. Both reports are available free of charge from:

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INTRODUCTION

A two-year research project on the ecological basis for environmental impact assessment was undertaken at the Institute for Resource and Environmental Studies, Dalhousie University. The objective of the study was to develop recommendations whereby the principles of ecology can be more effectively applied in environmental assessment studies. The results of the study are documented in a report entitled. An Ecological Framework for Environmental Impact Assessment in Canada, co-authored by Dr. Gordon Beanlands, Principal Investigator of the study, and Peter Duinker, Research Associate. This annotated bibliography represents a companion volume to the study's final report.

The two main information sources for the study were a series of ten technical workshops, held at various locations across Canada during 1981-82, and a review of both the scientific literature and of some thirty environmental impact statements prepared for proposed development projects in Canada. While the final report mentioned above has made extensive use of published information, it was felt that an annotated bibliography of the more pertinent literature items would be a useful complement to the report. The bibliography describes some of the best literature available on various topics related to the application of ecological science in environmental assessment, and each entry should provide sufficient information for the reader to decide whether to obtain a copy of the item.

While our literature search uncovered, from a wide spectrum of sources, well over 400 references on the subject of environmental impact assessment, the bibliography has been limited to about 200 entries which we feel should be of direct interest to those who plan, undertake and review environmental impact studies. Specific topics covered in this document are listed for the convenience of the reader in a Subject Index found at the end of the bibliography. Headings in that index reflect the range of topics discussed at the technical workshops and analysed in the final report.

Whenever possible and appropriate, complete author abstracts (indicated by AUTHOR ABSTRACT) were provided with the literature citations. Occasionally, the author abstracts contained information not germane to this bibliography, in which cases the abstracts were abbreviated (denoted by AUTHOR ABSTRACT (INCOMPLETE)). In cases where no abstract was given, or the author abstract, in the opinion of the reviewer, did not represent the article well for the purposes of this bibliography, the following options were used:

(a) the reviewer prepared an annotation;

(b) a segment of the text was used (indicated by EXTRACTED FROM TEXT);

(c) a publisher's review was quoted (indicated by PUBLISHER REVIEW);

(d) a segment of a "preface" was used (indicated by EXTRACTED FROM PREFACE).

Entries in the biliography are arranged in alphabetical order of first authors,

Adams, S. M. 1980. Coastal zone systems. In Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et *al.*), pp. 239-269. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This chapter first presents a brief description of the physiochemical properties of estuaries, and continues with a short review of the effects of energy production facilities on coastal ecosystems. The remainder of the paper discusses various approaches to ecological effects monitoring of estuaries, including mapping of point source pollution, long-term field surveys, and experimental manipulations.

Adamus, P. R. and G. C. Clough. 1978. Evaluating species for protection in natural areas. Biol. Conserv. *13*:165-178.

AUTHOR ABSTRACT: "As part of a project for identifying which natural features in the state of Maine could and should be protected, systematic criteria, based on thirteen characteristics (the 'suitability' characteristics of site tenacity, seasonal mobility, area size needs, and spatial distribution, and the 'desirability' characteristics of relative scarcity, status changes, endemicity, peripherality, habitat specialization, habitat scarcity, susceptibility to immoderate human presence, other scientific values, and aesthetic amenities —- reviewer's addition) were developed, described and used to evaluate several hundred species. The criteria are applicable to programmes to conserve endangered species, natural areas, and to the broader aspects of environmental impact assessment."

Ames, G. F. 1978. An approach to the determination of significance in the preparation of environmental assessments. *In* Environmental Assessment: Approaching Maturity (S. Bendix and H. R. Graham, eds.), pp. 25-33. Ann Arbor Science Publ. Inc., Ann Arbor, Michigan.

The procedure used by the Washington Suburban Sanitary Commission to assess impact significance is described. Two major steps are involved as the procedure first deals with significance in the immediate context of the project, and then in the regional context. The approach relies on an elaborate questionnaire format which is shown in full.

Andrews, R. N. **L. 1973.** A philosophy of environmental impact assessment. J. Soil and Water Conserv. 28: 197-203.

The initial experiences of U.S. agencies with NEPA are discussed. Three concepts of environmental impact assessment are presented, and a number of principles for improved EIA are described. Some assessment problems are reviewed, and the U.S. Geologic Survey Impact Matrix is criticized.

Andrews, R. N. L., P. Cromwell, G. A. Enk, E. G. Farnworth, J. R. Hibbs and V. L. Sharp. 1977. Substantive Guidance for Environmental Impact Assessment: An Exploratory Study. The Institute of Ecology, Washington, D.C. 79 pp.

This volume is the final report of the Environmental impact Assessment Project of the Institute of Ecology. It discusses the evolution of guidelines for impact assessment, and explores ecological, social and economic perspectives in assessing environmental impacts. A framework for environmental analysis is presented. Finally, the substantive elements of impact assessment are discussed in the context of the administrative process.

Anonymous 1975. Georges Bank Conference: Marine Environmental Assessment Needs on the Georges Bank Related to Petroleum Exploration and Development. Proc., Conf. and Workshop, New England Natural Resources Center, Boston, Massachusetts.

This report contains the proceedings of a conference held to assess the state of knowledge in the Georges Bank area of the North Atlantic Outer Continental Shelf and provide recommendations for baseline and monitorrng research efforts in that area. The report is comprised mainly of working group discussions which included specific recommendations on the needs of an environmental assessment study programme from the perspectives of the disciplines of chemical oceanography, physical oceanography, geological oceanography, and biological oceanography.

Anonymous 1980. Aquatic ecology. In Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et a/.), pp. 179-238. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This paper focusses on the investigation and forecasting of ecological impacts in aquatic systems resulting from the chronic release of toxins. The monitoring of both abiotic and biotic variables is discussed, the latter being separated into structural biotic variables and functional biotic variables. System performance indices and sampling problems are also considered.

Anonymous 1981. Consultation on the Consequences of Offshore Oil Production on Offshore Fish Stocks and Fishing Operations. Canadian Atl. Fish. Sci. Adv. Comm. Research Document 81/8, CAFSAC Marine Environ. and Ecosystems Subcommittee, Bedford Institute Oceanography, Dartmouth, Nova Scotia. 119 pp.

AUTHOR ABSTRACT: "This document records the proceedings of an internal DFO consultation on the probable effects of offshore oil operations on offshore fish stocks and fishing operations. Topics covered included: probable statistics of accidental release of hydrocarbons; the levels of contamination to be expected in water and biota; the observational programs needed to detect the biotic effects; the probability of an effect on fish recruitment; the consequences for offshore fishing; and the effectiveness of various countermeasures."

Anonymous 1982. Can Science deal with environmental uncertainties? Conserv. Found. Letter (January, 1982):1-8.

This paper explores the various limitations and pitfalls of scientific inquiry and its contribution to environmental decision-making and public policy. The text is based largely on papers and proceedings of the 1982 national meeting of the American Association for the Advancement of Science. The need for scientists to distinguish between the results of their research, and their personal speculations and judgements is emphasized.

Auerbach, S.I. 1978. Current perceptions and applicability of ecosystem analysis to impact assessment. Ohio J. Sci. 78: 163-174.

AUTHOR ABSTRACT: "A framework is presented for defining the environmental impact of a project on an ecosystem. The difficulties in assessing impacts at the ecosystem level are illustrated with examples drawn from theoretical considerations and nutrient cycling studies. The need for rigorous, quantitative analysis of ecosystem deviations from homeostasis and the subsequent implications of this deviation over long periods of time is illustrated and discussed in terms of individual and societal value judgements."

Ayensu, E. S. 1980. Evaluating impacts on endangered and threatened flora. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp.129- 132. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

This paper reviews the status of endangered species protection in the U.S., and summarizes the activities of the Endangered Flora Project of the Smithsonian Institution. Modes of anthropogenic disturbance to plants are briefly described and specialized habitats of threatened plants are listed. Means of incorporating the concept of endangered species protection in environmental impact assessment, and the reasons for doing so, are presented.

Baker, J. M. 1976. Biological monitoring: principles, methods and difficulties. *In* Marine Ecology and Oil Pollution (J. M. Baker, ed.), pp. 4 l-53. John Wiley and Sons, Inc., New York.

AUTHOR ABSTRACT: "Biological monitoring is defined as the use of living organisms to determine the presence, amounts, changes in and effects of physical, chemical and biotic factors in the environment.

"Different approaches and methods for monitoring estuarine and coastal areas are covered: these include a discussion of different types of indicator organism; and a description of the shore transect technique used in several monitoring programmes. An outline monitoring programme for a typical estuary is given."

Barnthouse, L. W. and W. VanWinkle. 1980. Modeling tools for ecological impact evaluation. *In* Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et al.), pp. 27 l-31 3. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The authors present a review of modelling considerations for environmental impact assessment. Problems, limitations and guidelines associated with ecological models are outlined, and then four classes of models (namely, dose-response models, population models, ecosystem models, and diversity indices) are discussed with examples. Finally, generalized advice is given for the use of models in the design and implementation phases of impact assessment.

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

Ecology and environmental science are contrasted in the manner in which they relate to studies of ecosystem-level stress. A set of ideal characteristics of impact assessment studies is given.

Barrett, G. W., G. M. VanDyne and E. P. Odum. 1976. Stress ecology. Bioscience 26: 192- 194.

This paper presents a set of ten guidelines for undertaking stress/response study programmes at the ecosystem level. Five of the guidelines deal with issues of study design, three deal with study programme management, and two are concerned with higher education.

Baxter, R. M. 1977. Environmental effects of dams and impoundments. Ann. Rev. Ecol. Syst. 8:255-283.

This review discusses (a) the morphology and limnology of man-made lakes, (b) some general ecological principles for prediction of reservoir ecosystem development, (c) the development of benthic, planktonic, littoral and vertebrate communities within reservoirs, and (d) the downstream effects of impoundment.

Baxter, R. M. and P. Glaude. 1980. Environmental effects of dams and impoundments in Canada: experience and prospects. Can. Bull. Fish. Aquat. Sci. 205. 34 pp.

AUTHOR ABSTRACT: "Although dams and reservoirs have contributed immeasurably to the well-being of Canadians, they may have side effects which may be detrimental to the environmental and to human welfare. In this Bulletin, the authors survey the environmental consequences that have ensued from dam construction and the impoundment of water in Canada in the past, and attempt to alert environmentalists and engineers to the types of problems that may be associated with such activities in the future.

"Some of these effects are immediate, direct, and obvious, such as the loss of resources by flooding, interference with the passage of fish, and environmental damage and pollution as a result of construction activities. Others may manifest themselves only over a period of time, such as changes in water chemistry and modification of the new shoreline. This last is likely to be of particular importance in reservoirs on permafrost. Large impoundments may influence the climate in their vicinities and sometimes induce earthquakes. Still other consequences follow from the mode of operation of the reservoir. Low-level discharge through turbines may radically alter the temperature regime in the stream below. The induction of an unnatural seasonal

pattern of water level fluctuation may lead to the formation of a virtually barren drawdown zone around the reservoir, and induce geographical and ecological changes downstream, sometimes at great distances.

"Many of these effects act in various and sometimes opposing ways on the living organisms in the reservoir and the stream so that the ultimate biological consequences often cannot be confidently predicted."

"It is sometimes difficult to reconcile the interests of those who stand to benefit from a given project and the interests of others who are likely to suffer a loss from it. This conflict is particularly acute when the project affects communities of native peoples following a traditional way of life. Such fragile societies are likely to be gravely disrupted unless particular care is taken."

Baysinger, E. B. 1980. Evaluating impacts upon endangered or threatened species. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 123- 128. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

The author presents a review of the legal and procedural aspects of endangered species protection in the U.S., and comments on the resulting implications for federal agencies.

Bella, D. A. and W. S. Overton. 1972. Environmental planning and ecological possibilities. J. San. Eng. Div., Am. Soc. Civ. Eng. *98*:579-592.

Based on the notion that man faces an environmental predicament in that his ability to modify the natural environment is increasing faster than his ability to foresee the effects of doing so, this paper calls for an environmental strategy (policy) of preserving environmental diversity. It is reasoned that such a strategy has the potential of reducing the chances of unanticipated environmental catastrophes.

Birchard, E. C., S. A. M. Conover, G. Green and A. S. Telford. 1978. Assessment of the ecological effects of an oil spill in an offshore subarctic environment. *In* Proc., Conf. on Assessment of Ecological Impacts of Oil Spills, pp. 835-855. Amer. Inst. Biol. Sci., Arlington, Virginia.

AUTHOR ABSTRACT: "The waters of the eastern Canadian arctic and subarctic, Baffin Bay, Davis Strait, and Labrador Sea hold the potential for large, as yet undiscovered oil and gas formations. Since 1976 a program of field studies and investigations have been undertaken in the Davis Strait region that is intended to gather data to assist in designing the technology of a drilling system and which will be used to assess the ecological implications of drilling in the area. Utilizing this data, and based on oil spill scenarios developed for various hypothetical oil spill situations, an assessment was prepared as part of the development of an environmental impact statement (EIS)."

Boesch, D. F. 1980. Evaluating impacts on continental shelf environments: concepts and prospects. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 159- 169. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

An outline is given of the nature and extent of activities that potentially impact upon continental shelf ecosystems. Past experiences and ongoing programs concerning impact evaluation for U.S. continental shelves are reviewed. Various features of continental shelf ecosystems which should influence study design are noted, and finally a conceptual framework for future environmental impact investigations is developed.

Botkin, D. B. and M. J. Sobel. 1976. Stability in ecosystems: semantics, models, and reality. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 239-250. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "An evaluation of damage to an ecosystem should be based on a clear idea of what is "normal" in an unmanipulated ecosystem. All ecosystems vary with time although the semantics used by conservationists and ecologists promote the misconception that an unmanipulated ecosystem would be static. This article addresses the issue: how do you evaluate the significance of an unnatural change in a system which is itself naturally changing? Firstly, we discuss the history of fire and of tree species in the Boundary Waters Canoe Area (Minnesota). Even in this relatively undisturbed ecosystem, both of these factors have varied over time. Secondly, we present several concepts of stability which are useful for gauging the severity of ecosystem damage. These concepts are given general definitions and then applied to the Boundary Waters Canoe Area."

Boyce, S. G. 1979. Ecosystem dynamics for multiple-use management. *In* Symp. Proc., Multiple-Use Management of Forest Resources, pp. 34-47. Clemson University, Clemson, South Carolina.

This paper shows the essential differences between ecosystem dynamics and organism dynamics, and proceeds to explain how a knowledge of ecosystem dynamics can be used for decision-making in forest multiple-use management.

Brew, D. A. 1976. Environmental impact analysis: the example of the proposed trans-Alaska pipeline. *In* Focus on Environmental Geology (R. W. Tank, ed.), pp. 378-402. Oxford University Press, New York.

This paper begins by discussing various reasons for undertaking environmental impact analysis. The general methodology for analyzing environmental impacts is described, and the application of this methodology to the proposed trans-Alaska pipeline is outlined. The paper continues with a description of the main types of impacts predicted in the analysis, and an examination of some alternatives to the proposed pipeline. The author concludes with

his viewpoints on the degree to which environmental considerations influenced decision-making in the case of the pipeline environmental assessment.

Brink, C. H. 1978. Preparing and reviewing environmental statements and related documents. Wildl. Soc. Bull. 6: 246-248.

Practical but general guidance to wildlife biologists for conducting baseline studies for environmental impact assessment and for writing and reviewing environmental impact statements is given.

Buffington, J. D., R. K. Sharma and J. T. McFadden. 1980. Assessment of ecological damage: concensus. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 25-32. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

This paper represents a summary of discussions at the Workshop on Biological significance of Environmental Impacts, held June, 1975, at Ann Arbor, Michigan. Topics reviewed include data gathering, hypothesis testing, temporal and spatial constraints, the utility of species lists and diversity indices, study methodology and modelling, assimilative capacity and compensatory responses with ecosystems, and elements of impact significance. On this last point, it was considered essential to separate the concepts of impact significance and impact acceptability. The definition for significance put forward by the workshop group reads as follows:

> "An impact is significant if it results in a change that is measurable in a well designed sampling program, and if it persists or is expected to persist more than several years. ''

Cairns, J., Jr. 1975. Critical species, including man, within the biosphere. Naturwissenschaften 62: 193-199.

AUTHOR ABSTRACT: "The protection of critical ecosystems appears to be a sounder management strategy than the protection of critical species. Environmental quality-control systems designed to protect ecosystems are described. These quality-control systems will make it possible to optimize the ability of ecosystems to assimilate and transform wastes and protect them from degradation."

Cairns, J., Jr. 1976. Estimating the assimilative capacity of water ecosystems. In Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 173-189. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Any material entering a water ecosystem is a potential pollutant that may adversely affect the system's structure and function. The ability of a particular ecosystem to resist displacement of structure and function by pollutants is probably dependent upon the presence of the following characteristics: (1) indigenous organisms accustomed to highly variable environmental conditions; (2) high ecosystem structural and functional redundancy; (3) stream order, flow dependability, turbulent diffusivity, and flushing capacity; (4) hard, well-buffered water antagonistic to toxic substances; (5) nearness to a major ecological transitional threshold: and (6) presence of a drainage basin management group with a water quality monitoring program. The intensity of use of an ecosystem should depend not only on its assimilative capacity but also upon its elasticity or ability to snap back once displaced in either structure or function. Elasticity depends upon: (1) existence of nearby epicenters to supply appropriate reinvading organisms; (2) transportability or mobility of dissemules; (3) general condition of the habitat following pollutional stress; (4) presence of residual toxicants following pollutional stress; (5) chemical-physical environmental quality following pollutional stress; and (6) management or organizational capabilities for immediate and direct control of damaged area. It is also important to determine the resiliency (the number of times an ecosystem can snap back after displacement)."

Cairns, J., Jr. 1980. Estimating hazard. Bioscience 30: 101-107.

This paper discusses the various activities employed in estimating hazard of chemical pollutants to living organisms. These activities include determination of the environmental pathways of chemicals, and evaluation of the inherent toxic properties of the chemicals.

Cairns, J., Jr. and K. L. Dickson. 1980. Risk analysis for aquatic ecosystems. In Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 73-83. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

Several reasons are put forth for the reluctance of ecologists to develop means of estimating risk for ecosystems. Four ecosystem characteristics — namely (1) vulnerability to irreversible damage, (2) elasticity (ability to recover from damage), (3) inertia (ability to resist displacement), and (4) resilience (the number of times a system can "snap back" after displacement) — are described in concept and application. The monitoring of biota is shown to be necessary in ecosystem risk assessment.

Cairns, J., Jr., G. P. Patil, and W. E. Water (eds.). 1979. Environmental Biomonitoring, Assessment, Prediction, and Management: Certain Case Studies and Related Quantitative Issues. Intern. Co-op. Publ. House, Fairland, Maryland. 438 pp.

This recent volume contains both papers describing specific case studies in environmental problems and papers on broad topics of environmental assessment and management.

Cantilli, E. J., M. Hair, J. M. Cassin and J. C. Falcocchio. 1978. An energy approach to ecological impact assessment. J. Environ. Systems 7:243-256.

AUTHOR ABSTRACT: "This paper was prepared to educate the transportation planner/engineer in some of the rudiments of ecology and with the hope of systematizing

current approaches to ecological assessment. Considerations of energy, or bio-energetics, have been found to be singularly applicable to transportation impact assessment. This method of evaluating the effects of environmental impacting factors on environmental elements is outlined herein. The method can be applied to the analysis of the ecological impact of all types of activities and with particular pertinence to transportation.

"The energy theory is based on analysis of the amount of energy which is required by plants or animals or ecosystems, to permit their growth or stability to continue. The numerical calculations involved permit quantification of impact effects of transportation facilities."

Carpenter, R. 1976. The scientific basis of NEPA -- is it adequate? Environ. Law Reporter *6*:500 14-500 19.

The author maintains that the success of the U. S. National Environmental Policy Act (NEPA) depends to a large degree on complete and timely scientific information, The procedural mechanisms for NEPA are far more advanced than its ecological underpinnings. The paper discusses this fundamental problem, and makes several recommendations towards a solution, including (a) increased ecological research and training for environmental impact assessment, and (b) more explicit predictive analyses so that the limitations are appreciated by the decision-makers.

Carpenter, R. A. 1980. Using ecological knowledge for development planning. Environ. Mgmt. 4: 13-20.

AUTHOR ABSTRACT: "Since October, 1977, the East-West Environment and Policy Institute in Honolulu has been conducting a multi-national collaborative project to enhance the preparation and utilization of natural systems assessments in developing countries. This paper presents some of the findings to date: 1. Channels are developing rapidly for transferring ecological knowledge into political and administrative decision-making. 2. The systematic approach of ecology is replacing 'environmental quality' as the organizing concept for information about natural resources and the environment. 3. Benefit-cost analysis is a promising method for integrating ecological knowledge into economic development decision making. 4. The lack of baseline information, inventories, and predictive capability will not be remedied soon or easily; thus priorities for ecological research are essential."

Christensen, S. W., W. VanWinkle and J. S. Mattice. 1976. Defining and determining the significance of impacts: concepts and methods. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 19 l-2 19. NR-CONF-002, Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "The term 'impact' is conceptually and mathematically defined to be the difference in the state or value of an ecosystem with versus without the source of impact. Some resulting problems associated with the measurement of impacts based on comparisons of baseline and operational data are discussed briefly. The concept of a 'significant' adverse impact on a biological system is operationally defined in terms of an adverse impact which, according to a proposed 'decision-tree', justifies rejection of a project or a change in its site, design, or mode of operation.

"A gradient of increasing difficulty in the prediction of impact exists as the scope of the assessment is expanded to consider long-term, far-field impacts with respect to higher levels of biological organization (e.g., communities or ecosystems). The analytical methods available for predicting short-term, near-field impacts are discussed. Finally, the role of simulation modeling as an aid to professional judgement in predicting the long-term, far-field consequences of impacts is considered, and illustrated with an example."

Clark, W. C. 1978. Managing the Unknown: An Ecological View of Risk Assessment. Working Paper W-26. Inst. of Resource Ecology, University of British Columbia, Vancouver, B.C. 74 pp.

The focus of this paper is on viewing hazard as the inability to cope with stress and to deal with error. The prediction of environmental hazard is considered largely unsuccessful, and the need for adaptive management is stressed. Ecosystem resilience is described under the general themes of Bounded Stability (entailing limits within which a system is considered stable and outside of which a system enters a new stability regime, with accompanying changes in structure and/or function), Selective Coupling (involving the restoration of perturbed parts of a system, using resources from unperturbed parts), and Hierarchical Embedding (implying mutual independence of parts of a system which can perform the same function). Finally, hazard management is discussed in light of the implications of these ecological concepts.

Cooper, W. E. 1976. Ecological effects. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 73-87. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Society is currently attempting to anticipate the environmental effects of human activities associated with the design and management of synthetic ecosystems. Part of this analysis involves the utilization of ecological theories and technologies to determine the biological significance of change. The baseline that is often used as a reference point for the determination of significance is based on steady-state, ecological-systems theories that are valid only in an evolutionary space-time perspective. One must carefully articulate and rigorously investigate the structure and critical assumptions of the proposed paradigm before accepting its general use as a decision-making tool."

Cooper, W. E. 1978. Systems prediction: the integration of descriptive, experimental and theoretical approaches. Ohio J. Sci. 78: 186- 189.

This paper examines the relationship between the concepts of change and stress, and explores the difficulties in establishing meaningful baselines or reference points of means and variances of ecological phenomena. For community and ecosystem effects, hypothesis testing and experimentation are needed, especially in relation to cumulative stresses.

Cooper, W. E. 1980. Scientific logic and the environmental review process. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 12-19. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

Concepts in environmental impact assessment are discussed in the context of the experiences of the Michigan Environmental Review Board. The EIS is described as a predictive model, and various aspects of its quality, such as content, format and style, are analyzed.

Cooper, C. F. and P. H. Zedler. 1980. Ecological assessment for regional development. J. Environ. Mgmt. *10*: 285-296.

AUTHOR ABSTRACT: "A system is proposed in which regional planning is facilitated by organized presentation of current ecological information. All development projects should be analyzed in a regional setting rather than as isolated cases. A regional perspective is enhanced by a synthesis of ecological and environmental data which provide a generally accepted analysis of the relative sensitivity to perturbation of the ecosystems in the region. Sensitivity is defined by three components: (a) significnace of the ecosystem, regionally and globally; (b) rarity or abundance; (c) ecosystem resilience. Quantitative measures of sensitivity are not derived, but rank ordering of the sensitivity of land units can be achieved. This scheme appears to have contributed to effective decision making in the design of a power transmission system in California. The resulting selection avoided all areas of greatest ecological sensitivity and passed only peripherally through areas of the next lower sensitivity ranking. There is, however, a lack of mechanisms whereby regional environmental studies can be impartially reviewed and certified as a basis for the planning of multiple projects in the same region. A major dilemma is how to induce planners and developers to use an officially sanctioned ecological sensitivity analysis without coercion that would either politicize it excessively or lead to narrow legal arguments over wording."

Cowell, **E. B. 1978.** Ecological monitoring as a management tool in industry. Ocean Management *4*:273-285.

AUTHOR ABSTRACT: "This paper examines the objectives and advantages to industry of biological monitoring in the context of responsible management. It attempts to define the differing roles of the industrial ecologist and those working for regulatory agencies or academic organizations.

"The main objectives of industrial ecological monitoring are illustrated by examples taken from the international programmes conducted by a major oil company. The type of environmental questions posed by management are listed.

"The paper discusses the importance of baseline data and reference sampling sites from which natural and man-induced changes can be distinguished. There is a brief discussion on the development of appropriate data handling techniques. In conclusion the advantages to industry from operating ecological monitoring schemes are outlined."

Cowell, E. B. and D. C. Monk. 1979. Problems in ecological monitoring in Port Valdez, Alaska. *In* Proc., 1979 Oil Spill Conference, pp. 7 13-717. Publ. No. 4308, American Petroleum Institute, Washington, D.C.

AUTHOR ABSTRACT: "The technical and scientific problems of ecological monitoring of Port Valdez, Alaska are discussed. Particular attention is given to the lack of understanding of the processes of the Alaskan Rocky Shore ecosystem and the paucity of data on the natural stresses controlling temporal and spatial variation in populations. In addition, taxonomic difficulties, particulary in the littoral macro-algae, further compound survey problems.

"The paper suggests some possible approaches that could be applied and is illustrated by data taken on baseline surveys made in 1977. Particular attention is given to unexpected age size distributions in the limpet *Collisella pelta*."

Cowell, E. B. and W. J. Syratt. 1979. A technique for assessing ecological damage to the intertidal zone of rocky shores for which no previous baseline data is available. In Proc., Ecological Damage Assessment Conference, pp. 29-39. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "Damage, either man-made or natural, often occurs in areas for which no pre-event baseline is available. This makes damage assessment, and subsequent recovery studies, difficult to interpret.

"This paper describes a technique for arriving at a pre-event baseline for a rocky shore by calculating, from known factors, a 'derived' community against which observed changes can be compared. It is an extension of work carried out to establish a baseline for a biological monitoring programme for a refinery in Norway. With minor modifications, it will be possible to use it elsewhere in Northern Europe and with a moderate amount of research, it should be applicable to rocky shores in many parts of the world.

"The limitations of the method are discussed."

Cowell, E. B., G. V. Cox and G. M. Dunnet. 1979. Applications of ecosystem analysis to oil spill impact. *In* Proc., 1979 Oil Spill Conference, pp. 517519. Publ. No, 4308, American Petroleum Institute, Washington, D.C.

AUTHOR ABSTRACT: "Ecologists need to be more involved in selection of oil spill clean-up devices, setting clean-up priorities, and evaluation of clean-up techniques. This paper outlines some basic ecological principles and

stresses their proper application to minimize ecological damage and to properly evaluate that damage."

Crow, M. E. and F. B. Taub. 1979. Designing a microcosm bioassay to detect ecosystem level effects. intern. J. Environ. Studies 73: 14 1- 147.

AUTHOR ABSTRACT: "Predicting the effect of a pollutant in an ecosystem requires knowledge of ecological processes such as competition and predator-prey interactions. Chemical and toxicological information are not adequate. Multispecies laboratory microcosms are suggested as a tool for demonstrating ecological effects in a biologically and statistically acceptable way. Some examples of microcosms, the statistical properties of the data, and design criteria for better microcosms are presented."

Dale, M. B. 1970. Systems analysis and ecology. Ecology 51:2-16.

AUTHOR ABSTRACT: "Systems analysis is defined as the use of scientific method with conscious regard for the complexity of the object of study. It has strong relationships with problem solving, in that the same four phases — lexical, parsing, modelling, and analysis — are identifiable in both. Examination of each of these phases reveals some of the problems involved in the use of systems methods in ecology. A model of a precipitation-evaporation system is presented as an example. Problems in experimenting with models of systems and with control, optimization, and comparison of such models are considered."

Daniel, T. C., P. E. McGuire, G. D. Bubenter, F. W. Madison, and J. G. Konrad. 1978. Assessing the pollutional load from nonpoint sources: planning considerations and a description of an automated water quality monitoring program. Environ. Mgmt. 2:55-65.

AUTHOR ABSTRACT: "Planning considerations to be evaluated early in the design of water quality monitoring programs are reviewed. These criteria emphasize the importance of isolating the study area, parameter section (sic), and type of measurements required to ensure meaningful results. A demonstration automatic water quality monitoring program is described. Details with respect to type of equipment, coordination of component parts, sampling program, and analysis of specific parameters are reviewed. General costs of implementation and maintenance of such programs are presented."

DeAngelis, D. L. 1980. Energy flow, nutrient cycling, and ecosystem resilience. Ecology 6 1: 764-77 1.

AUTHOR ABSTRACT: "The resilience, defined here as the speed with which a system returns to equilibrium state following a perturbation, is investigated for both food web energy models and nutrient cycling models. Previous simulation studies of food web energy models have shown that resilience increases as the flux of energy through the food web per unit amount of energy in the steady state web increases. Studies of nutrient cycling models have shown that resilience increase as the mean number of cycles that nutrient (or other mineral) atoms make before leaving the system decrease. In the present study, these conclusions are verified analytically for general ecosystem models. The behavior of resilience in food web energy models and nutrient cycling models is a reflection of the time that a given unit, whether of energy or matter, spends in the steady state system. The shorter this residence time is, the more resilient the system is."

Dooley, J. E. 1979. A framework for environmental impact identification. J. Environ. Mgmt. 9:279-287.

AUTHOR ABSTRACT: "This paper gives a view of environmental impact assessment systems that stress the interaction between human factors and the technical aspects to produce an assessment in the form of an information system appropriate to the review process. One part of the detailed assessment is to identify impacts followed by magnitude prediction, evaluation and communication. This paper shows how structure can be added to the identification stage by including a temporal-societal-spatial-risk framework to place each impact into proper perspective. This framework leads to a more appropriate development of the next three stages and the review process. As part of identification, the paper supports the side of the current debate in favour of separating the project effects from their impact. The application of the framework is illustrated for a transportation system."

Doremus, C., D. C. McNaught, P. Cross, T. Fuist, E. Stanley and B. Youngberg. 1978. An ecological approach to environmental impact assessment. Environ. Mgmt. 2:245-248.

AUTHOR ABSTRACT: "Carbon cycling analysis is presented as a means for assessing anthropogenic perturbations in an ecosystem. Data from oligotrophic, eutrophic, and dystrophic (bog) lakes are used to show general trends in the lacustrine carbon cycle. The oligotrophic lake is an unstressed system and the eutrophic lake is under nutrient enrichment with high algal standing crops and productivity. The bog lake is a pH-stressed environment that is primarily a grazing ecosystem. It is hoped that a more effective environmenal impact assessment will result from the use of carbon cycling as a unifying concept in ecosystem analysis."

Dorney, R. S. 1977. Environmental assessment: the ecological dimension. J. Am. Water Works Assoc. 69: 182-185.

AUTHOR ABSTRACT: "An ecology-systems approach based on a three-point philosophy to questions of development, rather than the traditional approach of economic and political expediency and the technological fix, will dominate decision-making in the future. In developing an environmental assessment, an organizational model, methodology, time, and sufficient money are needed. In this article, the philosophy and process of environmental assessment are explored."

Dorney, R. S., P. F. J. Eagles, B. Evered and D. W. Hoffman. 1981. Ecosystem planning, analysis, and design in Ontario as applied to environmentally sensitive areas.

Paper presented to the Am. Assoc. Adv. Sci. meeting "Ecosystem Approaches in Practice," 5 January 1981, Toronto, Ontario. 25 pp.

The new profession of environmental manager is described as it exists in Ontario, and one of its activities — sensitive area planning — is used to show the linkage between pure science and applied science for landscape management. A proposed methodology for evaluating sensitive areas is presented, and approaches to developing size criteria for the design of remnant forest island sensitive areas are discussed.

Duffy, P. J. B. 1979. The application of ecological land classification to environmental impact assessment. *In* Applications of Ecological (Biophysical) Land Classification in Canada (C.D.A. Rubec, ed.), pp. 91-99. Ecol. Land. Class. Series No. 7, Lands Directorate, Environment Canada, Ottawa, Ontario.

AUTHOR ABSTRACT: "The use of ecological land classification in the environmental impact assessment of Canadian projects is described. Examples are drawn from projects in Newfoundland, Nova Scotia, Quebec, Alberta and the Northwest Territories. Applications of ELC have been limited. However, they confirm the potential usefulness of the system as an organized, efficient, and cost-effective approach to baseline information gathering for this purpose. The flexibility of map scale and report detail of ELC lends itself to the assembly of generalized information at the early stages of the environmental impact assessment process. As more detail is required on specific sites (e.g. pipeline river crossings) and ecologically sensitive areas (e.g. caribou calving grounds) then larger scale maps and more detailed baseline information can be added within an existing ELC framework."

Dunbar, 1977. Are Arctic ecosystems really as fragile as everyone assumes? Sci. Forum *10*:26-29.

EXTRACTED FROM TEXT: "Much publicity has been given to the phrase 'the fragile Arctic'. It has become a cliche of the media, so that the noun Arctic is becoming more and more firmly attached to the adjective fragile, analogous to the Homeric 'wine-dark sea,' or 'rosy-fingered dawn'. The basis for this belief in Arctic fragility, however, is shaky. If we knew enough to say with assurance that Arctic ecosystems are fragile or not fragile, we would be well ahead in precisely the sort of ecosystem research of which we stand in need. Two facts appear to underlie the belief: that the tundra landscape, or any permafrost landscape, is vulnerable to damage by heavy track or wheeled vehicles in summer, and to any heavy mechanical treatment; and second, that Arctic ecosystems are simpler than temperate and tropical systems and contain fewer species. Both these facts stand. But the matter of permafrost vulnerability has long been understood and is now taken into careful consideration by the engineering and industrial fraternities, or so we are told.

"The implications of the simpler ecosystems have been seriously misunderstood. It has long been known that a normal feature of simple ecosystems is population oscillation of wide amplitude, a result essentially of the time-lag between the population growth of prey and predators, to over-simplify the situation somewhat. This is a natural phenomenon and there is not much we can do about it. These oscillations, however, do not imply fragility. On the contrary, such oscillating systems are stable, in the sense that they respond elastically to the stresses of climatic and population fluctuations, buffered as they are by very large geographic scale, so that they return to a viable condition."

Eberhardt, L. L. 1976. Quantitative ecology and impact assessment. J. Environ. Mgmt. *4*:27-70.

AUTHOR ABSTRACT: "Some of the issues of environmental impact assessment are reviewed from the point of view of quantitative ecology, and on the assumption that evaluations are done on a site by site basis. Two approaches are examined in detail, one being the traditional experimental approach and the other one attempting to predict impacts from data and models. The experimental approach suffers from the fact that there is no true replication. A pseudodesign is proposed, employing pre-operational data on a site and a control area contrasted to post-operational data on both areas, and substituting replication in time for true replicate areas. Even so, the limitations of animal census methods and substantial variability make it doubtful that any but major changes can be detected experimentally. Predictive techniques, employing methods developed primarily for fisheries management, may be preferable to the baseline and monitoring concept. However, these methods have not yet been adequately adapted to the present purpose, and some gaps can be foreseen. One is the lack of knowledge about stock-recruitment, when the recruits are at very early life history stages. The population regulation problem is identified as a major issue in impact evaluation. Questions are raised as to the utility of data on productivity and species diversity, as presently used. It is concluded that we must take stock of what has been done in impact evaluation, and attempt to reach a consensus as to future methodology."

Eberhardt, L. L. 1976. Some quantitative issues in ecological impact evaluation. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 307-315. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Environmental impact studies are characterized by a number of problems, including: (1) too wide an initial choice of species, (2) inadequate statistical analyses, (3) reports limited to, at most, one year's work, (4) absence of true replication, and (5) inadequate sample sizes. It is suggested that some of the existing machinery for fisheries management be adapted to impact problems, and that the issue of community analysis be reexamined. It is concluded that a full review of past experience at many sites is needed, and that present practices should be revised on the basis of such a review."

Eberhardt, L. L. 1978. Appraising variability in population studies. J. Wildl. Manage. *42*:207-238.

AUTHOR ABSTRACT: "This paper addresses the general question of determining sample size for population studies. Different objectives for population studies are described as a basis for determining the appropriate approach to selecting a sample size. The bases for mathematical models for various methods of population study are discussed, with particular emphasis on the situations in which indices or relative measures of abundance are used. A classification of population census methods is given. Several "variance-laws" for index data are discussed and an extensive tabulation of data on variability of aquatic and terrestrial indices is presented. Several equations for calculating sample sizes are listed and discussed. References to various published tables and charts for determining sample size follows."

Eedy, W. and K. Schiefer. 1977. 'Innovative' assessment technology allows more accurate prediction. Reprinted from Canadian Pulp and Paper Industry, Vol. 30, No. 16. 3 pp.

Predictive research and studies related to the potential impact of the Donohue — St. Felicien pulp mill in northern Quebec on land-locked Atlantic Salmon in the Ashuapmouchouan River and Lac St.-Jean are described. The overall study, combining special field and laboratory investigations with informed professional judgement, is considered a definite advancement over traditional predictive analysis in environmental impact assessment.

Efford, I. E. 1975. Assessment of the impact of hydrodams. J. Fish. Res. Board Can. 32: 196-209.

AUTHOR ABSTRACT: "At present, assessments of the impact of a dam are becoming part of the design process but they are still not completed early enough to affect the overall decision to construct a particular dam at a particular site. Thus, their real value is lost because attempts to correct social and environmental problems are made after rather than before the problem has arisen.

"Impact statements at the moment assess only alternatives to the design of a dam. They ought to include analyses of alternative uses of the valley, the long-term value of delaying the decision, the relative merits of generating power by other means, and finally the merits of reducing energy demands by rationing or raising prices. The assessment of impact should be considered a positive contribution to helping the decision-maker rather than an annoying complication preventing him from getting on with his job.

"In today's increasingly complex world, we must proceed more cautiously because the synergistic interactions, resulting from major undertakings like dams, pipelines, etc., are many and frequently not obvious. Public access to impact assessments is an essential aspect of the democratic process and will help to anticipate some of these problems."

Efford, I. E. 1976. Problems associated with environmental impact studies in Canada. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 25-4 1. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Canada has no legal requirement for environmental impact assessments (EIA) and those that are produced are frequently of poor quality. This is not always the fault of the scientist, who is often constrained by badly defined objectives and unreasonable temporal or spatial limits. Frequently, his response to these problems is to swamp the client with useless data. At other times, the biologist fails to put the information into a form which is usable by the general public. Either the results are unanalyzed or they are couched in scientific jargon which serves only to project the social superiority of the scientist rather than help to assess the impact of a change. Philosophical problems, such as what is rare, form a particular area of difficulty because neither the biologist nor society as a whole are able to formulate the problem in an immediate social context with a potential solution.

"EIA are increasing in numbers in Canada and are slowly improving but a greater effort is needed to make them more useful to the people they are designed to serve."

Environmental Conservation Service Task Force. 198 1. Ecological Land Survey Guidelines for Environmental Impact Analysis. Ecol. Land Class. Ser. No. 13, Lands Directorate (Environment Canada) and Federal Environmental Assessment Review Office, Ottawa, Ontario. 42 pp.

EXTRACTED FROM PREFACE: "Ecological Land Survey (ELS) has a major advantage over the other types of field surveys, that is, a wide variety of interpretations can be derived from a single data base. In addition, the hierarchical nature of ELS provides for general as well as detailed data gathering, analysis, and interpretation. This feature of ELS is of direct application to environmental impact analysis in general and to the stages of the Environmental Assessment and Review Process in particular.

"In addition to providing requisite environmental baseline information, an ELS serves as a data base for project planning and management. It also forms a framework for environmental monitoring of project operations. Reduced survey costs result from integrated remote sensing and field work activities which characterize this type of data gathering from traditional single discipline surveys. These features lead to substantial savings of time and funds.

"The report has four parts: (1) A description of the Federal Environmental Assessment and review Process and of Ecological Land Surveys; (2) how to plan an ELS; (3) how to conduct the survey; and (4) how to use an Ecological Land Survey Data Base."

Erickson, P. A., G. Camougis and E. J. Robbins. 1978. Highways and Ecology: Impact Assessment and Mitigation. FHWA-RWE/OEP-78-2, Federal Highway Admin., Washington, D.C. 182 pp.

AUTHOR ABSTRACT: "The enactment of NEPA expanded the requirements for the highway professional to

consider all aspects of a highway development project. Part of this assessment is the effects of highway projects, highway operations, and highway maintenance on natural resources. These effects occur at both the biological and ecological level. This book uses an ecosystem approach to impact assessments. The components and dynamics of terrestrial, aquatic and wetland ecosystems are described. Potential biological and ecological impacts of a highway project are also described. This analysis is broken down into pre-design, design, construction and operation and maintenance phases. Extensive discussions on methods of mitigating adverse impacts and enhancing the existing biological resources are included. Much material on current practices has been gathered during the presentation of a course sponsored by the National Highway Institute, Eco*logical Impacts of Proposed High Improvements.* Case studies and references are used extensively to provide the reader with a chance for more in-depth review of a particular practice."

Etman, D. C. 1981. Stream macroinvertebrate baseline surveys: a comparative analysis from the oil-shale regions of Colorado, U. S. A. Environ. Mgmt. *5*:531-536.

AUTHOR ABSTRACT: "General surveys of the benthic macroinvertebrates from Piceance Creek and the White River were conducted for nearly a decade prior to oil-shale exploitation in north central Colorado, USA. Comparison of the taxa collected in four studies on Piceance Creek and five studies on the White River shows little similarity among most studies. Studies were generally consistent in methods, site selection, and time of year for collection. Lack of agreement among the studies on what constitutes a baseline of common taxa is probably a result of taxonomic difficulties and differences in technique. More emphasis should be placed on testing possible impacts than on repeated, expensive, and inconclusive baseline inventories."

Evans, D. R. and S. D. Rice. 1974. Effects of oil on marine ecosystems: a review for administrators and policy makers. Fish. Bull. 72:625-638.

AUTHOR ABSTRACT: "A broad selection of recent literature on the effects of oil on marine ecosystems is reviewed. The focus is on studies on crude oil, and the results are discussed with the purpose of providing a summary of findings that will be a useful reference for administrators and policy makers involved in decisions concerning petroleum developments and related activities. The characteristics of crude oil and factors modifying its impact on the marine environment are discussed. Most research on the toxicity of oil has dealt with acute effects and data on long-term impacts at the community level are inconclusive. It is concluded that chronic low-level pollution is potentially more damaging to ecosystems than isolated catastrophic spills. Decision-makers are forced to rely on interpretative judgements rather than conclusive data."

Fahey, J. 1978. The Biological Component of Environmental Assessment: Concepts and Case Studies. Ph.D. Thesis, University of California at Los Angeles, California. 272 pp.

AUTHOR ABSTRACT: "Of the several disciplines contributing to environmental problem-solving, biology is often the most important, as many environmental impacts are ultimately biological. At the same time, shallow, ill-focused biological assessments are frequently the weakest contribution to project planning and impact assessment. Ecological studies are frequently executed and analyzed by environmental consultants, who therefore have the greatest responsibility and opportunity to effect improvements.

"The biological component of environmental assessment is defined by the present activities of applied biologists, by the existing federal, State and local regulatory and legal framework within which they are executed. The deficiencies of these activities and regulations can be discovered in an examination of the ecological concepts which underlie them. Applied biological studies tend to focus on characterizing the physical environment, *developing a species list and, occasionally, measuring physiological tolerances of selected organisms to environmental change. The reality of natural situations is far more complex than these studies can hope to reveal. A species' long-term survival depends on numerous indirect and subtle factors. There occur interspecific and other interactions at other levels of organization which are frequently the most important biological aspect of the problem, though their effects are indirect. These are virtually never treated in applied studies.

"Many factors contribute to this situation, including: the complexity of ecological systems, the current state of biological knowledge, the costliness of biological studies in time and manpower as well as financial resources, the "public good" nature and opportunity costs of environmental quality, the underparticipation of academic biologists in solving applied problems, and the subjective nature of environmental evaluation.

"Such constraints upon and activities of environmental bioloists are illustrated by case studies dealing primarily with environmental impacts of sewage disposal systems. These cases are drawn from the author's applied internship experience at James M. Montgomery, Consulting Engineers, Inc. in Pasadena, California.

"Endangered species concerns, the feasibility of wastewater reclamation through agricultural irrigation and maintenance of artificial habitats are discussed from the Facility Plan for the City of Taft, Kern County, California. Studies of present and future effects of effluent disposal and combined sewer overflows on Puget Sound and neighboring freshwaters for the Municipality of Metropolitan Seattle provide a basis for analysis of the design and application of large-scale impact studies."

Fischer, D. W. and G. S. Davies. 1973. An approach to assessing environmental impacts. J. Environ. Mgmt. *1*: 207-227.

AUTHOR ABSTRACT: "The analysis proposed in this paper is designed to permit the assessment of the likely impact of man's development and management activities on the environment. The complete assessment consists of four sequential steps: (1) identification of planned and

induced activities; (2) identification of relevant elements of the environment likely to be altered, (3) evaluation of initial and subsequent impacts, and (4) management of benficial and adverse environmental impacts that are generated by the planned and induced activities over time. The emphasis in the paper is upon the identification and evaluation of environmental impacts because this subject sets the stage for subsequent management of the environment. Three steps are used to identify and evaluate environmental feasibility. These are briefly illustrated with examples from forestry and water management. The discussion of identification and evaluation assumes that engineering and economic evaluations are being done simultaneously along with the environmental impact analysis. The environmental analysis is to be accomplished by a small multi-disciplinary team which would guide, co-ordinate and interpret environmental studies being done by various technical specialists. The paper also includes a brief review of environmental impact assessment methods developed primarily in the United States."

Franklin, J. F. and R. H. Waring. 1974. Predicting short and long term changes in the function and structure of temperate forest ecosystems. *In* Proc., 1st Intern. Cong. of Ecology, pp. 228-232. Centre for Agric. Publ. and Doc., Wageningen, Netherlands.

Examples of recently developed capabilities in estimating photosynthesis, growth, forest composition, hydrologic properties, nutrient losses and turnover, and erosion are presented.

Fritz, E. S., P. J. Rago and I. P. Murarka. 1980. Strategy for Assessing Impacts of Power Plants on Fish and Shellfish Populations. FWS/OBS-80/34, National Power Plant Team, Biol. Serv. Prog., U.S. Fish and Wildlife Service, Ann Arbor, Michigan. 68 pp.

The strategy was designed for use by biologists who conduct or review assessments of impacts on fish and shellfish. It is a generic strategy that promotes consistency and uniformity in the design and performance of aquatic EIA's. The strategy consists of six steps, namely: (1) conceptualization of the ecosystem to be assessed, (2) design and execution of needed pilot investigations, (3) refinement of conceptualization, (4) design of a study plan, (5) execution of the study plan, and (6) evaluation of impact. Emphasis is given to hypothesis formulation and testing, ecosystem modelling and study design and statistical considerations.

The result of following this strategy should be the collection of information amenable to utility company and regulatory decision-making procedures. Information developed in the course of each step of the strategy is utilizable by decision-makers throughout the period of assessment rather than only at its completion.

Gettleson, D. A. and R. E. Putt. 1979. Ecological damage assessment of hard bottom faunal assemblages. *In* Proc., Ecological Damage Assessment Conference, pp. 135-164. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "The geographic locations of hard bottom areas on the continental shelf of the Atlantic Ocean between Cape Hatteras, North Carolina, and Cape Canaveral, Florida, and the northern Gulf of Mexico are presented. The fauna associated with the hard bottom areas are described, and the areas are discussed in terms of their importance and economic value relative to recreational and commercial fisheries.

"The majority of the hard bottom features and their associated faunal assemblages are considered to be sufficiently unique and sensitive by the U.S. Geological Survey to require protection from the possible deleterious effects of oil and gas drilling operations. For this reason, restrictive regulations pertaining to oil and gas drilling operations in the vicinity of the hard bottom areas have often been required. These were promulgated by the U.S. Geological Survey after consultation with the Bureau of Land Management and U.S. Fish and Wildlife Service. The regulations usually include operational modifications as well as environmental monitoring programs.

"The results of the monitoring programs and other surveys of hard bottom faunal assemblages pertaining to oil and gas operations are described. The underlying concepts and techniques of the assessment efforts are critically examined in order to determine if the monitoring philosophy is realistic and to discern the degree of damage that is detectable relative to natural changes in the biota."

Ghiselin, J. 1978. Environmental reports for the Nuclear Regulatory Commission: guidelines thwart sound ecological design. Environ. Mgmt. 2:99-111.

EXTRACTED FROM TEXT: "The U. S. Nuclear Regulatory Commission requires a detailed description of the ecology associated with every proposed nuclear power station. This article examines the usefulness of much of this information. It evaluates the structure of logic and assumption underlying the requirement that certain information must be presented in applicants' environmental reports. It concludes that the regulation itself makes it impossible to satisfy all of its requirements.

"It is difficult for investigators to identify species that are to be given special treatment. Though these 'important' species can sometimes be recognized only after completing a study, they must be known beforehand if the requirements of the regulation are to be met. The most difficult are species having 'critical' functions in their 'ecological systems.'

"Therefore, the requirement postulates a prolepsis. It mandates feedback without providing for a loop. It calls for using information before it has been gathered.

Another requirement is demonstrating a 'specific causal link' between an organism and a nuclear power plant. This is shown to be logically meaningless, and consequently redundant in practice.

"Demonstrating the illogic of certain central ecological requirements leads to practical suggestions for improving

the regulations. The first is to diminish the demand for useless information. The second is to rely more fully upon professional judgment."

Ghiselin, J. 1982. Reaching environmental decisions: making subjective and objective judgments. Environ. Mgmt. 6: 103-108.

AUTHOR ABSTRACT: "Objective judgments, external to the judge, are compared with subjective, internal judgments. This analysis is made in the context of reaching regulatory decisions affecting the human environment. Examples given include evaluating the potential risk of industrial chemicals and comparing the potential effects of short- and long-term changes in land use. The analysis deals not with the decisions themselves, but rather with the kinds of questions that must be posed in order to reach such decisions. Decision makers may spuriously distinguish objective from subjective types of judgment, though these are rarely wholly separate. Judges can hardly dispute about objective statements, if truly identical definitions are used. But subjective statements can reasonably be voted upon. Scientists, engineers, and economists represent logical or objective decision makers, tending to work in groups. Subjective thinkers include artists and performers, and others who often work alone. Moral and aesthetic aspects of questions, usually seen as intangible, are treated as if subjective. Financial decisions, usually viewed as tangible, are handled as objective problems. This mechanism for making decisions is well-established in environmental assessment. Though objective questions can be treated well in the monetary terms of cost-benefit analysis, subjective ones cannot. Mathematical and other variants are discussed in relation to the comparison of alternative types of tests."

Giddings, J. M. 1980. Field experiments. *In* Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et *al.*), pp. 315-331. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This chapter initially discusses the interactive nature of field perturbation experiments and the conceptual ecosystem model. Strategies and options in the design and implementation of field experiments for impact assessment are outlined with regard to the selection of study sites, the establishment of experimental plots or enclosures, the treatment with pollutants, the monitoring of plots and enclosures, and the analysis and interpretation of results. Field experiments are seen to provide unlimited opportunities for testing hypotheses and answering questions in aid of ecological effects assessment.

Giles, R. H. Jr. 1981. Environmental agency research results: improved information transfer. Environ. Mgmt. *5*:291-294.

EXTRACTED FROM TEXT: "Since so much is known, and there are so many research workers, why should not more research findings in the diverse natural resource and environmental fields enter into practice? Emotion, politics, and dynamic economics all play a part in how the environment is managed, but if a rational approach could be taken to analyzing why more research is not used, then some prescriptions could be developed to improve the use. This paper suggests 23 ways in which significant improvements can be made."

Gilliland, M. W. and P. G. Risser. 1977. The use of systems diagrams for environmental impact assessment: procedures and an assessment. Ecol. Modelling 3: 183-209.

AUTHOR ABSTRACT: "The utility of systems diagrams and of energy as a unit of measure for environmental impact assessment is illustrated using results from the White Sands Missile Range, New Mexico Environmental Impact Statement. A set of procedures for developing and evaluating the diagrams is given and applied to White Sands. The utility of results obtained using this method is compared to those obtained from other methods, and the inadequacies of each are discussed.

"These procedures guide data collection; organize and summarize data; make explicit interactions between the environment and the 'proposed project'; place various kinds of impacts and alternatives in perspective with each other and with the entire system; identify components of a macroscale system which need microscale analysis; and permit quantification of total impact and quantitative comparisons of impact types, of alternatives, and of environmental control strategies. The procedures do not guarantee that important impacts have not been overlooked, do not deal with so called aesthetic impacts, and do not guarantee that the appropriate system boundary has been chosen.

"Impacts at White Sands were evaluated at two system levels of detail. At a macroscale, five types of impacts resulting from missile range activities were analyzed. Results indicated that stresses on the environment caused by those activities represent 1.0% of the natural energy flow through the system. At a more detailed level of analysis, the effect of water consumption by the Missile Range on the aquifer from which the water is obtained was analyzed by means of a hydrologic model. Model simulations indicated that salt water intrusion into the aquifer was eminent and identified two aquifer management strategies that could prevent that intrusion."

Goldstein, R. A. 1979. Development and implementation of a research program on ecological assessment of the impact of thermal power plant cooling systems on aquatic environments. *In* Environmental Biomonitoring, Assessment, Prediction and Management: Certain Case Studies and Related Quantitative Issues (J. Cairns Jr., G. P. Patil and W. E. Waters, eds.), pp. 117-130. Intern. Co-op. Publ. House, Fairland, Maryland.

AUTHOR ABSTRACT: "The development and implementation of an intergrated research program on assessing ecological effects of thermal power plant cooling systems is traced from its inception in the fall of 1975. The program is developed around four major themes: analysis of effects on the population and ecosystem levels, ecosystem management, chemical effects, and reduction of entrainment mortality. In addition, several information bases have been

created and are maintained. Development ot generic assessment methodologies is emphasized because: (1) the discipline of ecological assessment, being in its infancy, lacks such methodologies, and (2) the program is intended to address as large a fraction as possible of the diverse aquatic cooling situations (lacustrine, riverine, estuarine, marine) existing in the United States. Mathematical modeling and analysis are also major components of the overall program. The general philosophy and approach that underlies the development and implementation of the program should be applicable to other ecological assessment research programs."

Goodall, D. W. 1977. Dynamic changes in ecosystems and their study: the roles of induction and deduction. J. Environ. Mgmt. 5:309-3 17.

AUTHOR ABSTRACT: "Wise management of ecosystems presupposes an ability to predict their responses to proposed management strategies. Predictive ability rests on an understanding of the dynamics of the system.

"Inductive approaches to ecosystem dynamics may be based on observations of the behaviour of the systems as they exist in the field, or on experimentation. Possibilities of experimentation are limited, partly because of the large scale (in space and time) that experiments would usually need to encompass, partly because of the extensive replication needed to secure generalizable results. Conclusions from observation are subject to the same difficulties, in addition to the fact that an observational approach rarely permits an unequivocal separation of cause and effect.

"Deductive approaches — with systems as complex as most ecosystems — must usually involve modelling. The role of generalizable models in the study of ecosystem dynamics is discussed — in particular, in their application to environmental management. The problems of model validation are outlined. Validation is regarded as part of an induction process, within which the deductive processes of modelling are nested."

Gore, **K. L., J. M. Thomas and D. G. Watson.** 1979. Quantitative evaluation of environmental impact assessment, based on aquatic monitoring programs at three nuclear power plants. J. Environ. Mgmt. 8: l-7.

AUTHOR ABSTRACT: "Aquatic monitoring programs conducted at three nuclear power plants were quantitatively reviewed. Explanation of type of data sets available and types of statistical analyses performed are provided. Suggestions are offered on how future efforts could be reallocated to provide a more quantitative approach to aquatic impact assessment."

Gray, J. S. 1980. Why do ecological monitoring? Marine Pollution Bulletin *11*:62-65.

A strategy for ecological monitoring of effects of pollution along known gradients is outlined. The strategy emphasizes intensive studies on a few selected species. Physiological and biochemical monitoring are considered important complements to ecological monitoring. The former are based on the individual and useful in predicting effects on populations; the latter is the only means of testing those predictions.

Great Lakes Research Advisory Board. 1978. The Ecosystem Approach: Scope and Implications of an Ecosystem Approach to Transboundary Problems in the Great Lakes Basin. Special Report to the International Joint Commission, Windsor, Ontario. 47 pp.

This report responded to a request by the International Joint Commission for a detailed analysis of the concept of the "ecosystem approach" and of means of implementing it with respect to the current "water quality objective" approach. In brief, the ecosystem approach to problem identification, research and management in the Great Lakes Basin departs from current approaches by including man and technology within problem analyses rather than considering them external to nature. The text provides examples in which the use of the ecosystem approach in environmental problem-solving would be a great improvement over water quality approaches.

Green, R. H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. John Wiley and Sons, Toronto. 257 pp.

PUBLISHER REVIEW: "This book provides a comprehensive guide to the principles of sampling design and statistical analysis methods. The first section of the book, Principles, reviews the principles of inference, sampling and statistical design, and hypothesis formulation and testing — all with special reference to ecological data. This section also includes a simple impact study example illustrating the principles presented. Decisions, the next section of the text, contains a key to five broad categories of environmental studies and specific decisions that must be made in any environmental study. Section Three, Sequences, discusses and illustrates — with in-depth examples-the five broad categories defined in the previous section. Examples are cited extensively from the literature and new examples based on simulated data or actual field data are also presented. The book also includes a comprehensive bibliography which is cross-referenced to the text and keyed to a specific topic code (types of methods and environments studied)."

Gruber, D., J. Cairns Jr., K. L. Dickson, A. C. Hendricks and W. R. Miller Ill. 1780. Recent concepts and development of an automated biological monitoring system. J. Water Pollution Control *52*:465-471.

The shortcomings of traditional bioassays and of chemical /physical monitoring of water quality are discussed. The paper reports on a system of biological monitoring that relies on computer-assisted measurements of fish breathing behavior.

Haedrich, R. L. 1975. Diversity and overlap as measures of environmental quality. Water Research *9*:945-952.

AUTHOR ABSTRACT: "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 using data on demersal fishes from nine Massachusetts estuaries and embayments. Annual diversity ranged from H (log) = 0.4-2.4, 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. For their calculation, both H and PS require the number of individuals in each species in a sample. This data should be considered important in the conduct of faunal surveys that contribute to an environmental impact statement."

Hall, C. A. S., R. Howarth, B. Moore III, and C. J. Vorosmarty. 1978. Environmental impacts of industrial energy systems in the coastal zone. Ann. Rev. Energy 3:395-475.

This paper is an extensive literature review on the effects of oil-related (extraction, processing and transportation) and electricity-related (construction and operation) energy activities on coastal ecosystems. Special emphasis is given in the last section of the paper to the impact of energy facilities on major fisheries.

Hart, B. T. and P. Cullen. 1976. Principles of environmental impact assessment. Search 7:231-235.

AUTHOR ABSTRACT (INCOMPLETE): "This arcticle looks at the various steps involved in impact assessment-identification of impacts, prediction of their likely magnitude, evaluation of their importance and the communication of this information to the decision-maker. Various techniques are outlined for carrying out these steps."

Hartzbank, D. J. and A. McCusker. 1979. Establishing criteria for offshore sampling design. *In* Proc., Ecological Damage Assessment Conference, pp. 59-78. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "A basic tenet of benchmark type studies is the preoperational characterization of potentially impacted biological populations prior to a development-related activity. This characterization can be geared either toward quantitative (based on change in actual abundances estimated from sampling) or qualitative (e.g. based on community parameters such as trophic structure or multivariate similarity structure) analysis of change. This paper addresses the level of sampling required to yield quantitatively analyzable data. Our objectives are to: present and evaluate a mathematical technique for this determination by comparison of its application with that of alternative mathematical constructs; and to provide a preliminary assessment of the sampling effort required to meet specified test criteria using selected data from four U.S. OCS areas.

"The criterion applied to determine the level of sampling effort needed to preoperationally characterize species populations is based on detecting abundance changes of individual numerically dominant species: what is the number of replicate samples needed to be able to determine a 50% change in population mean (x) at a probability level of 90% ($a = 0.10$). To analyze this question, three statistical techniques are applied to existing data: two evaluate the number of replicates needed by analysis of sample statistics with respect to a parametric probability distribution, such as Students t; a third construct (NE), developed by the senior author, uses an empirical probability distribution.

"Results of application of the three constructs support the validity and usefulness of the NE construct. Using this index as a standard, the number of replicate samples needed to adequately sample dominant species in four different OCS areas was lowest in Baltimore Canyon samples (2-20), intermediate on Georges Bank and in the MAFLA area (l-48 and 4-55, respectively) and highest in the Georgia Embayment (20-52).

"Based on these results, recommendations are made for employment of quantitative techniques in benchmark situations."

Heath, R. T. 1979. Holistic study of an aquatic microcosm: theoretical and practical implications. Intern. J. Environ. Studies *13*:87-93.

AUTHOR ABSTRACT: "The behaviour of any system cannot be understood fully unless it is investigated as an intact unit over a range of states. The main task of holistic investigation is to determine the patterns of the set of responses and state transitions of a system and to examine the state space for trends, phases, and thresholds. Small laboratory ecosystems are ideal tools for holistic investigation of ecosystem function because they are replicable and state settable. A small aquatic microcosm was characterized holistically as an example of this approach. Comparison of the nominal behavior of this system with its behavior under various degrees of cadmium stress (1, 10 or 100 ppm Cd) indicated that holistic investigation of such systems is a sensitive and rapid means of assessing stress at the community level of organization.''

Hilborn, R. 1979. Some failures and successes in applying systems analysis to ecological systems. J. Applied Systems Analysis 6:25-31.

This paper describes four attempts to get systems analysis methods used by institutions within government and by private consulting companies. Some conclusions about the requirements for successful implementation of systems analysis within ecological management institutions are given and compared with those of workers in other fields.

Hilborn, R. and C. J. Walters. 1980. Adaptive management of natural resources. Manuscript, Inst. of Animal Resource Ecology, Univ. of British Columbia, Vancouver, B. C. 26 pp. append.

EXTRACTED FROM TEXT: "Adaptive management can be used in problems where there is large uncertainty about outcomes of management actions and the only way to reduce this uncertainty is by management action. The design of adaptive management policies weigh the tradeoffs between the value of immediate yield and the value

of information. If the action that produces the most information also increases short term yield, such experiments are likely to be of value. If, however, the informative action reduces short term yields, these tradeoffs are more difficult and informative experiments may not be preferred. We have attempted to show that many resource decisions can and should be viewed as sequential decision problems in which the possibilities of informative experimentation should be considered. We have presented a methodology that emphasizes the explicit consideration of the consequences of possible actions upon uncertainty. The recognition that uncertainty exists, and can be reduced by management actions, is the major step."

Hilborn, R., C. S. Holling and C. J. Walters. 1980. Managing the unknown: approaches to ecological policy design. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 103-I 13. FWS/OBS/-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

Environmental impact assessment is discussed in relation to the multiple equilibria phenomenon of ecosystems. A number of misconceptions about EIA are presented along with alternatives to them. Techniques for mobilizing existing knowledge, and mechanisms that lead to unexpected events, are discussed. Several methods for designing environmental management policies that are resilient to unexpected events are proposed. Finally, recommendations are given that should make the EIA process more responsive to unexpected events.

Hinkley, A. D. 1980. Guidelines for ecological evaluation. *In* Symp. Proc., Biological Evaluation of Environmental Impacts. pp. 33-39. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

This paper presents an approach to EIA based on general principles of ecology and science. The steps of (a) description of baseline conditions, (b) delineation of natural changes, and (c) prediction of effects of manipulation, are discussed. Monitoring and mitigation are stressed as necessary steps subsequent to normal EIS preparation.

Hipel, K. W., D. P. Lettenmaier and A. I. McLeod. 1978. Assessment of environmental impacts. Part I: intervention analysis. Environ. Mgmt. *2*:529-535.

AUTHOR ABSTRACT: "Intervention analysis is a rigorous statistical method for analyzing the effects of man-induced or natural changes on the environment. For instance, it may be necessary to determine whether a newly installed pollution control device significantly reduces the former mean level of a pollutant. By using intervention analysis, the actual change in the pollutant levels can be statistically determined. Previously, no comprehensive method was available to assess changes in the environment. Intervention analysis is an advanced type of Box-Jenkins model. A general description of Box-Jenkins models and their extensions is given. Also, the importance of adhering to sound modeling principles when fitting a stochastic model to a time series is emphasized. Following a discussion of intervention models, three applications of intervention analysis to environmental problems are given. Two applications deal with the environmental effects of man-made projects, while the third example demonstrates how a forest fire can affect the flow regime of a river."

Hirsch, A. 1980. The baseline study as a tool in environmental impact assessment. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 84-93. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Dept. of the Interior, Washington, D.C.

A proposed definition of baseline is "a description of conditions existing at a point in time against which subsequent changes can be detected through monitoring." It is shown that this definition is not universally accepted, and the term baseline is used to describe a range of EIA studies This paper makes distinct and describes two study approaches for the purpose of describing ecosystems subject to impact: (1) ecological characterization, which consists of a reconnaissance-type study to determine the structure, function and relationships of various parts of the ecosystem, and is not impact-specific, and (2) the continuum of baseline and monitoring studies, in which specific key parameters are measured pre- and post-development in order to detect changes. The baseline portion of these studies may be used for (a) prediction of impacts, or (b) impact detection.

Hollick, M. 1981. Environmental impact assessment as a planning tool. J. Environ. Mgmt. *12*:79-90.

AUTHOR ABSTRACT: "The Environmental Impact Assessment process is examined in the light of planning and decision-making theory and found to have three important shortcomings. First, it does not encourage monitoring and modification of environmental protection measures, but relies on uncertain predictions. Second, there is a mismatch between the needs of the proponent and those of reviewers. And, third, land use planning is an essential prerequisite for effective EIA. The Management Programme approach used in Western Australia, and the integrated planning and assessment legislation in New South Wales are described, and proposals for a more satisfactory system outlined."

Hollick, M. 1981. The role of quantitative decision-making methods in environmental impact assessment. J. Environ. Mgmt. *12*:65-78.

AUTHOR ABSTRACT: "The nature of rational decisions is examined, and the problems of applying quantitative decision-making methods to environmental impact assessment are discussed. It is concluded that:

(i) quantitative methods are not essential to rational decisions, and may even be inimical to them;

(ii) there are fundamental problems of goal setting, evaluation, prediction and aggregation that make a satisfactory quantitative decision-making method difficult to achieve;

(iii) quantitative decision-making methods would only be applicable if a number of changes occurred in socio-political processes, but these changes seem unlikely;

(iv) mathematical methods can play an important role in informing and assisting decision-makers,"

Holling, C. S. 1973. Resilience and stability of ecological systems. Ann. Rev. Ecol. Syst. 4: i-23.

The concepts of resilience and stability are discussed in the context of animal populations, with specific emphasis on predator-prey interactions. Examples involving fish and insect populations are used to address the concepts of closed vs. open ecosystems, the randomness of events, and spatial heterogeneity. It is recommended that resource management would be more successful by changing its focus from stability of ecosystems to resilience.

Holling, C. S. (ed.). 1978. Adaptive Environmental Assessment and Management. No. 3, Intern. Ser. on Appl. Syst. Anal., Intern. Inst. for Appl. Syst. Anal. John Wiley and Sons, Toronto, Canada. 377 pp.

This book presents the philosophy and approaches to adaptive environmental assessment and management. Among other things, it stresses (i) systematic analysis of environmental problems, and (ii) environmental planning based on uncertain futures. The approach usually involves interdisciplinary workshops and computer modelling, and is grounded firmly is sound scientific principles. Five case studies are presented which illustrate various successes and problems with the adaptive approach.

Holling, C. S. and M. A. Goldberg. 1971. Ecology and planning. J. Am. Inst. Planners *37*:221-230.

AUTHOR ABSTRACT: "Certain remarkable similarities can be found between the concerns of ecologists and planners. Like complex urban systems, ecological systems appear to be characterized by four distinctive properties. These include their functioning as interdependent systems, their dependence on a succession of historical events, their spatial linkages, and their non-linear structure. Both systems appear to have considerable internal resilience within a certain domain of stability. However, programs such as insecticide spraying or urban renewal, that disturb the complex balance of either system, can generate unexpected and undesirable results. Use of an ecological framework for planning suggests new principles based more on recognition of our ignorance than presumption of our knowledge about the systems in which we try to intervene."

Hornberger, G. M. and R. C. Spear. 1981. An approach to the preliminary analysis of environmental systems. J. Environ. Mgmt. *12*:7-18.

AUTHOR ABSTRACT: "In the preliminary analysis of environmental problems, mathematical modelling studies can sometimes aid in hypothesis development and in the integration preliminary data. Circumstances usually require models used in this way to be simulation models closely based on traditional scientific descriptions of component processes. As a result, such models contain many ill-defined parameters, a fact which severely limits the reliance that can be placed on the outcome of any single simulation. In an attempt to overcome this difficulty, it has been proposed that parameters be assigned statistical distributions which reflect the degree of parametric uncertainty and that these distributions be used in Monte Carlo simulation analyses. We propose a variation on this theme in which we first stipulate the systems' problem-defining behaviour and define a classification algorithm to be applied to the model's output. This algorithm results in each simulation run being classified as a behaviour, B, or not a behaviour, B. The parameters leading to the result are stored according to the behavioural outcome. Subsequently, all parameter vectors are subjected to analysis to determine the degree to which the a priori distributions separate under the behavioural mapping. This separation, or lack thereof, forms the basis for a generalized sensitivity analysis in which parameters and their related processes important to the simulation of the behaviour are singled out. The procedure has been applied to a eutrophication problem in the Peel-Harvey Inlet of Western Australia with encouraging results."

Horst, T. J. 1977. Use of the Leslie Matrix for assessing environmental impact with an example for a fish population. Trans. Am. Fish. Soc. *106*:253-257.

AUTHOR ABSTRACT: "The Leslie matrix model for discrete population theory is examined for the assessment of the effects of environmental alterations on a species population using an eigenvalue analysis. This analysis provides estimates of population growth rate and stable age distribution A sensitivity analysis is conducted for changes in elements of the population matrix and the resultant effect on population growth rate and stable age distribution. An example of this technique is presented for the cunner (*Tautogolabrus adspersus*). This example considers the effect of entrainment of cunner eggs and larvae at the intakes of power stations."

Howmiller, R. P. 1976. Analysis of benthic invertebrate assemblages: potential and realized significance for the assessment of environmental impacts. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 151-172. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Analysis of the macroinvertebrate bottom fauna can provide a sensitive means of detecting and documenting change in the quality of aquatic environments. As commonly carried out however, many studies offer only a crude impression of existing environmental conditions and have little potential for detection of impacts which are less than catastrophic. Common deficiencies of benthic studies include the use of inefficient or highly selective sampling gear, failure to identify organisms as fully as possible, uncritical application of various numerical indices which ignore important biological information, and failure to take into consideration the seasonal variation in composition of the fauna.

"The full potential of benthic studies for impact assessment can be realized only with quantitative data at the species level, interpreted in light of existing information on environmental requirements of the species."

Hufstader, R. W. 1977. Generalized criteria and environmental impact analysis. J. Environ. Systems 7: 1 15- 119.

AUTHOR ABSTRACT: "The systematic use of generalized information in impact analysis is discussed. A semiquantitative method is developed through examples drawn from vegetation studies. The method involves (1) determination of criteria, (2) criteria rationale and impact designation and (3) impact assessment. Limitations and advantages are discussed, and indicate that the method does provide an explicit impact analysis."

Hughes, M. K., N. W. Lepp and D. A. Phipps. 1980. Aerial heavy metal pollution and terrestrial ecosystems. Adv. Ecol. Research *11*:2 18-327.

This extensive review contains a short section describing various approaches to determining the ecological significance of aerial heavy metal pollution. These approaches include (a) problem-related research, focussing on individual pollution cases perceived as problems, (b) research on heavy metal transport, both at the organism/population level and at the ecosystem/watershed level, and (c) research on the role of heavy metals in ecosystem processes, again at the organism/population level and at the ecosystem/watershed level.

IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP). 1980. Monitoring Biological Variables Related to Marine Pollution. Rep. and Stud. No. 12, UNESCO, Paris. 22 pp.

EXTRACTED FROM TEXT: "In discussing the scientific requirements for biological monitoring, the Working Group proposed a set of principles for selecting suitable variables. It then evaluated a selection of possible variables in the light of the principles, and listed measurements that could be recommended for immediate inclusion in monitoring programmes. The list included certain biochemical and physiological procedures, as well as several morphological, population and community measurements.

"In addition to these procedures and measurements, which are sufficiently well developed for immediate use as monitoring tools, there are other approaches that show promise, but require further study. It is recommended that countries with well developed research organizations take the lead in such development.

"The Working Group noted the lack of any general framework for applying biology to monitoring programmes." It therefore developed a three-part strategy for dealing with the three phases: identification, quantification and causation; and it provided guidelines for implementing it. The strategy recognizes that appropriate chemical analysis is always required and that the biological input is most effectively deployed in a suite of procedures carefully tailored to the requirements of individual programmes."

Inhaber, H. 1977. Indices of environmental quality and their use in environmental assessment. *In* Environmental Impact Assessment in Canada: Processes and Approaches (M. Plewes and J. B. R. Whitney, eds.), pp. 99-107. Publ. No. EE-5, Institute for Environmental Studies, University of Toronto, Toronto, Ontario.

This paper contrasts two approaches to impact assessment -the traditional impact statement approach, and that of environmental indices. In discussing the merits of each approach, the proposed MacKenzie Valley Pipeline is used as an example.

Ivanovici, A. M. 1980. Application of adenylate energy charge to problems of environmental impact assessment in aquatic organisms. Helgolander Meeresunters 33:556-565.

AUTHOR ABSTRACT: "Various physiological and biochemical methods have been proposed for assessing the effects of environmental perturbation on aquatic organisms. The success of these methods as diagnostic tools has, however, been limited. This paper proposes that adenylate energy charge overcomes some of these limitations. The adenylate energy charge (AEC) is calculated from concentrations of adenine nucleotides [ATP + 1/2ADP)/(ATP + ADP + AMP], and is a reflection of metabolic potential available to an organism. Several features of this method are: correlation of specific values with physiological condition or growth state, a defined range of values, fast response times and high precision. Several examples from laboratory and field experiments are given to demonstrate these features. The test organisms used (mollusc species) were exposed to a variety of environmental perturbations, including salinity reduction, hydrocarbons and low doses of heavy metal. The studies performed indicate that the energy charge may be a useful measure in the assessment of environmental impact. Its use is restricted, however, as several limitations exist which need to be fully evaluated. Further work relating values to population characteristics of multicellular organisms needs to be completed before the method can become a predictive tool for management."

Jeffers, J. N. R. 1974. Future prospects of systems analysis in ecology. *In* Proc., 1st Intern. Cong. of Ecology, pp. 255-259. Centre for Agric. Publ. and Doc., Wageningen, Netherlands.

This short paper reviews the application of quantitative modelling and systems analysis in applied ecology, and convincingly argues in favour of more such applications. The result of greater use of sound modelling techniques in environmental problem solving will be improved environmental management and decision-making.

Jenkins, R. E. and W. B. Bedford. 1973. The use of natural areas to establish environmental baselines. Biol. Conserv. 5: 168- 174.

AUTHOR ABSTRACT: "In order that wise decisions are made in environmental management, an understanding is needed of ecosystem functioning and reaction to change. To obtain this information we must have continuing knowledge of the undisturbed ecosystem as a baseline against which to measure the effects of modifications. It is proposed that relatively undisturbed natural areas form the basic research tool for the establishment of such baselines. Thus, there is a need for a comprehensive natural area system to preserve, manage, and catalogue for use, the full range of natural area types. This, together with a network of environmental monitoring stations, should lead to the long-term continuation of the many baseline measurements required for necessary ecosystems analysis programmes. It is expected that such a system of natural area/baseline programmes will lead away from the narrow focus on pollution and towards an integrated approach to environmental quality and management."

Johnston, S. A., Jr. 1981. Estuarine dredge and fill activities: a review of impacts. Environ. Mgmt. 5: 427-440.

AUTHOR ABSTRACT: "Dredge and fill activities in estuaries have many environmental effects, most, although not all, of them deleterious. These effects include reduced light penetration by increased turbidity; altered tidal exchange, mixing, and circulation; reduced nutrient outflow from marshes and swamps; increased saltwater intrusion; and creation of an environment highly susceptible to recurrent low dissolved oxygen levels. Coral, oysters, and barnacles are particularly vulnerable to the effects of siltation. Both estuarine flora and fauna may be harmed by contaminants released into the water column by dredging operations. Ways to mitigate the effects of dredge and fill operations include careful pre and post construction environmental studies; use of bridging to create roadbeds where coastal wetlands cannot be avoided; use of a turbidity diaper and other means to control turbidity; dredging during periods of low benthic populations or during tides that would carry coarser sediments away from productive areas such as oyster reefs; and thoughtful disposal of spoil sites on the uplands with proper diking."

Kerr, S. R. and M. W. Neal. 1976. Analysis of large-scale ecological systems. J. Fish. Res. Board Can. 33:2083-2089.

AUTHOR ABSTRACT: "Large spatial and temporal scales imply a proportional need for large volumes of data. Ecological systems exhibit different patterns of variability as a function of scale. It follows that large-scale ecological systems are appropriately observed at a number of different spatial and temporal scales, further complicating the data requirements for various kinds of analysis. The concept of an 'information model,' in conjunction with an effective data base management system, enables an analytical approach to large-scale ecological systems that is relatively unconstrained by preconceived organizational structures in the data base."

van Keulen, H. 1974. Evaluation of models. *In* Proc., 1st Intern. Cong. of Ecology, pp. 250-252. Centre for Agric. Publ. and Doc., Wageningen, Netherlands.

EXTRACTED FROM TEXT: ... "Proper validation of simulation models is an extremely difficult and time-consuming procedure. It is, however, an essential procedure, as this phase of the modelling process must prove the validity of the opinions on which the model is based. It will also lead to the design of relevant experiments and thus to increasing understanding of the system in which we are interested."

Klinka, K., W. D. van der Horst, F. C. Nuszdorfer and R. G. Harding. 1980. An ecosystematic approach to forest planning. For. Chron. 56:97- 103.

AUTHOR ABSTRACT: "Ecological and planning studies were carried out to develop and demonstrate a new method for integrated management of a forest resource. This method, combining an ecosystematic approach and a new subunit planning procedure, was applied to the Koprino River watershed on Vancouver Island.

"Following an analysis, forest ecosystems were classified according to the taxonomy proposed by Krajina and his students. Eighteen associations, divided into 26 types, were recognized in the watershed. These biogeocoenotic taxa were integrated for practical application into fourteen treatment units which were subsequently mapped at the scale of 1:20,000. Each treatment unit was designated by a numerical symbol and a selected color to convey ecosystem productivity and sensitivity. For resource planning, a resource management map at the scale 1:20,000 was prepared using the treatment unit map as a base. To guide forest harvesting, the watershed was subdivided into seven resource management areas, each with a specific combination of resource values and management prescriptions."

Klose, P. N. 1980. Quantification of environmental impacts in the coastal zone. In Estuarine Perspectives-5th International Estuarine Research Conference, pp.27-35. Academic Press, New York.

AUTHOR ABSTRACT: "Protection of coastal zone ecosystems historically has been hampered by an inability to quantify environmental impacts of various types of development. Also, the completion of environmental impact assessment studies has been an involved, subjective process hindered by a lack of quantitative techniques which could aid in establishing cumulative impacts of a project. However, several studies have established some of the economic values of wetlands or other ecological systems and the biological functions they support. This has allowed for the direct comparison of economic with ecological impacts of certain environmental alternations. A study funded by the National Science Foundation allowed further investigation of the feasibility of developing a methodology for assessing onshore impacts for outer continental shelf oil and gas development. Results of this study indicated that no impact assessment methodologies were available which could be used to predict ecosystems' changes quantitatively from most types of expected coastal zone developments. For coastal ecosystems to be adequately considered in policy decisions affecting their fate, increased use of valuational techniques of an ecosystem's natural functions must be made. ''

Knauss, J. D. 1973. Aquatic aspects of ecological surveys. Dames and Moore Eng. Bull. 43: 17-22.

AUTHOR ABSTRACT: "Aquatic environmental studies include qualitative and quantitative investigations of the physical, chemical and biological aspects of aquatic systems and their interrelationships. The particular program is dependent on the objectives of the study and is designed to obtain necessary information for describing possible environmental impacts. General considerations for data collection and analysis are described in this paper."

Kumar, K. D. 1980. Statistical considerations. *In* Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et *al.*), pp. 333-348. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The difficulty in controlling and even identifying sources of natural variation in ecosystem studies is recognized. The use of a "conceptual ecosystem model" is recommended for assisting the formulation of hypotheses and for defining the parameters needed in a sound monitoring program. Generalized impact models are discussed in mathematical terms, and the use of higher order moments of variance is suggested for testing impact hypotheses. Finally, a method is proposed for encouraging researchers to use smaller time intervals between sampling dates.

Lee, D. W. 1980. Groundwater and surface water. *In* Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et a/.), pp. 135- 177. Environ. Sci. Div. Publ. No. 1639, Oak Ridge national Laboratory, Oak Ridge, Tennessee.

A conceptual framework is provided for the formulation of a groundwater and surface water monitoring program linked to ecological effects assessment. The framework is built around the monitoring and modelling considerations of various hydrodynamic regimes (groundwater, rivers, lakes, and coastal zones) and of the transport of various types of pollutant (sediment, heat, and chemicals).

Lettenmaier, D. P., K. W. Hipel and A. I. McLeod. 1978. Assessment of environmental impacts, Part II: data collection Environ. Mgmt. *2*:537-554.

AUTHOR ABSTRACT: "Intervention analysis is a relatively new branch of time series analysis. The power of this technique, which gives the probability that changes in mean level can be distinguished from natural data variability, is quite sensitive to the way the data are collected. The principal independent variables influenced by the data collection design are overall sample size, sampling frequency, and the relative length of record before the occurrence of the event (intervention) that is postulated to have caused a change in mean process level.

"For three of the four models investigated, data should be collected so that the post-intervention record is substantially longer than the pre-intervention record. This is in conflict with the intuitive approach, which would be to collect equal amounts of data before and after the intervention. The threshold (minimum) level of change that can be detected is quite high unless sample sizes of at least 50 and preferably 100 are available; this minimum level is dependent on the complexity of the model required to describe the response of the process mean to the intervention. More complex models tend to require larger sample sizes for the same threshold detectable change level.

"Uniformity of sampling frequency is a key consideration. Environmental data collection programs have not historically been oriented toward data analysis using time series techniques, thus eliminating a potentially powerful tool from use in many environmental assessment applications."

Levings, C. D. (compiler). 1980. An Account of a Workshop on Restoration of Estuarine Habitats. Can. MS Rep. Fish. Aquat. Sci. No. 1571. Canada Department of Fisheries and Oceans, Vancouver, B.C. 29 pp.

AUTHOR ABSTRACT: "Summaries, abstracts and preliminary results from talks given at a workshop on restoration of estuarine habitats are presented. Topics include choosing sites for marsh and eel grass restoration in the Fraser estuary, preliminary results of two pilot projects for marsh transplants at the Fraser estuary, preliminary results of eel grass transplants at the Nanaimo River estuary, tidal re-activation of a portion of the Englishman River estuary, and the possibility of sand/mud flat restoration."

Lewis, E. L. 1979. Some possible effects of Arctic industrial development on the marine environment. Paper presented at POAC '79 (Port and Ocean Engineering Under Arctic Conditions), Norwegian Institute of Technology.

AUTHOR ABSTRACT: "Marine environmental disturbances associated with the exploratory, production, and transporation phases of the exploitation of the arctic by primary industry are discussed. Some essential prerequistes for these developments are to possess sufficient knowledge to identify potential conflicts between the industrial and animal usage of an area, and to know ocean currents, ice movements, etc. sufficiently to predict effluent transport. Probable physical changes to the environment to be expected from routine operations and those that may result from disasters are outlined, with some suggestions as to the possible biological consequences. The use of biological information within an engineering context is discussed."

Likens, G. E. and F. H. Bormann. 1974. Linkages between terrestrial and aquatic ecosystems. Bioscience *24*:447-456.

This paper explores some of the ecological interactions that occur between terrestrial and aquatic ecosystems within the broad context of watersheds. The focus is on general principles of materials movement from terrestrial to aquatic systems, the factors controlling this movement, and the results of anthropogenic disturbance on the nutrient status of ecosystems.

Longley, W. L. 1979. An environmenal impact assessment procedure emphasizing changes in the organization and function of ecological systems. *In* Proc., Ecological Dam-

age Assessment Conference, pp. 355-376. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "There are many environmental impact assessment methods currently in use; all have both advantages and shortcomings. In an attempt to improve upon current assessment methods, a new procedure was designed that combines desirable elements of a number of methods. This paper describes the procedure and its analytical steps.

"The procedure consists of six parts: (1) identification and analysis of specific physical operations expected to occur; (2) identification of direct physical, chemical, and biological changes; (3) determination of the direction, duration, probability, and magnitude of changes in ecosystem components; (4) identification of indirect physical, chemical, and biological changes; (5) determination of significance of changes on the basis of natural resource policy standards; and (6) summarization of the results of the analysis.

"Some of the advantages of this methodology are that it makes use of predefined ecosystem models; it allows flexible use of data; it employs consistent definitions of duration, magnitude, direction, probability, and significance; and it documents all assessment decisions. Some of the disadvantages are that the methodology does not consider cumulative impacts; it is difficult to set significance standards; replicability is untested; and there are theoretical problems associated with parts of the procedure.

"While many of its elements are accepted in other assessment methods, the procedure as a whole has not been widely tested and is still largely experimental."

Lucas, H. L. 1976. Some statistical aspects of assessing environmental impact. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 295-306. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Many current environmental problems cannot be satisfactorily solved because of insufficient quantitative knowledge about the effects of human activities on the biotic and abiotic (environmental) aspects of ecosystem state and behavior. Mathematical modeling and ecosystem simulation are efforts in the right direction and should be strongly encouraged, but the models now available are of limited practical utility. Since steps toward solution of environmental problems cannot await good general models, more empirical approaches must receive considerable emphasis. Controlled experiments, comparing perturbed with unperturbed, but otherwise similar, sites would be ideal, but such are unfeasible in the case of, for example, nuclear power plants and other heavy industry. Instead, comparison must be made using data from existing or planned situations. This poses the problems inherent in survey data. Many factors besides the ones of interest can differ markedly between perturbed and unperturbed sites and they can vary with time. They may be confounded with the factors of interest so that effects cannot be separated. Even if not confounded, they can introduce variability sufficient to mask effects of interest. Ways of designing surveys and analyzing data that minimize the uncertainties involved will be suggested. Designs considered include matched sites and before-and-after patterns. Methods of data analysis briefly discussed include univariate and multivariate analysis of variance, covariance, and regression, including time and space series analysis, and certain approaches based on ecosystem concepts. Emphasis is placed on choice of good mathematical models to serve as bases for taking and analyzing data."

Lugo, A. E. 1978. Stress and ecosystems. *In* Energy and Environmental Stress in Aquatic Systems (J. H. Thorp and J. W. Gibbons, eds.), pp. 62-101. DOE Symp. Ser. 48, Technical Information Centre, U.S. Department of Energy.

AUTHOR ABSTRACT: "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 energies (highly concentrated energy sources) that divert low-quality energy flows 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 ecosystem 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."

MacKintosh, E. E. 1977. The Hanlon Creek Study: an ecological approach to planning. *In* Managing Canada's Renewable Resources (R. R. Krueger and B. Mitchell, eds.), pp. 324-333. Methuen Publications, Toronto.

This paper reports on the use of an "ecological" or "physical resource" approach in developing and planning an area for urban use. The Hanlon Creek watershed is noted as an ecosystem very sensitive to disturbance, and hence deserving of ecological considerations in development. The study includes a baseline survey (including studies to determine the impacts of a new highway across the watershed), a detailed ecological study for the planning

process, and a watershed monitoring program to gauge the success of the development plan.

Marcus, L. G. 1979. A Methodology for Post-EIS (Environmental Impact Statement) Monitoring. Geol. Surv. Circ. 782, U.S. Geological Survey, U. S. Department of the Interior, Arlington, Virginia. 39 pp.

AUTHOR ABSTRACT: "A methodology for monitoring the impacts predicted in environmental impact statements (EIS's) was developed using the EIS on phosphate development in southeastern Idaho as a case study. A monitoring system based on this methodology: (1) coordinates a comprehensive, intergovernmental monitoring effort; (2) documents the major impacts that result, thereby improving the accuracy of impact predictions in future EIS's; (3) helps agencies control impacts by warning them when critical impact levels are reached and by providing feedback on the success of mitigating measures; and (4) limits monitoring data to the essential information that agencies need to carry out their regulatory and environmental protection responsibilities. The methodology is presented as flow charts accompanied by tables that describe the objectives, tasks, and products for each work element in the flow chart."

Mason, W. T., Jr. (ed.). 1978. Methods for the Assessment and Prediction of Mineral Mining Impacts on Aquatic Communities: A Review and Analysis. Workshop Proceedings, FWS/OBS-78/30, Fish and Wildlife Service, U.S. Department of the Interior, Harpers Ferry, W. Virginia. 157 pp.

This volume presents historical overviews of studies dealing with mineral development impact assessments, and recommends methods for inventorying and evaluating the aquatic biota of the Eastern United States. It also provides an overview of predictive methods for estimating the potential impacts of mining activities on aquatic life.

Mason, W. T., Jr. 1979. A rapid procedure for assessment of surface mining impacts to aquatic life. Paper presented at Coal Conference and Expo V, October 1979, Louisville, Kentucky. 11 pp.

AUTHOR ABSTRACT (INCOMPLETE): "The procedure evaluates benthic invertebrate, niche occupant forms consisting of aquatic insects, molluscs, worms, crustaceans, and other macroscopic organisms as indicators of aquatic life health and vigor. The biologist arrives at an index value, indicating the degree of environmental stress, based on dividing the observed diversity of forms by the expected diversity. The observed diversities are obtained by simple, on-site collection and analysis procedures. The expected diversities are obtained from published data and in cases where no historical data exists, a control station diversity is selected as the expected. A value of unity in observed/expected diversity indicates no observable impact. Values less than unity indicate moderate to highly stressed communities and values more than unity indicate conditions better than the norm. The technique has application for the assessment of surface mining impacts and other types of manmade environmental stresses to aquatic life."

May, R. M. 1975. Stability in ecosystems: some comments. *In* Unifying Concepts in Ecology (W. H. van Dobben and R. H. Lowe-McConnell, eds.), pp. 161-168. Dr. W. Junk B. V. Publ., The Hague, and Centre for Agric. Publ. and Doc., Wageningen, Netherlands.

In this paper, the idea that ecosystem stability is inversely related to complexity is developed. Complex natural ecosystems are considered to be fragile, while many natural monocultures are very stable. Agricultural monocultures are shown to be fragile not because of their simplicity but because of their lack of a significant history of coevolution with pests and pathogens.

McFadden, J. T. 1976. Environmental impact assessment for fish populations. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 89-137. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "Assessment of environmental impacts is evaluated at the organism, population, and ecosystem levels. The population level is most workable under current state-of-art limitations. Basic population processes for fishes are reviewed and the ways in which environmental impacts are reflected in changes in population parameters are explored. The measurement and interpretation of these parameter changes are developed in detail. The paper concludes with a demonstration of the use of population data in decision-making, where the question of acceptability of environmental impacts is dealt with on at least a partially ecological basis. The final decision process can accommodate social judgments as well as ecological data."

Monk, D. C., C. Girton and K. Tapper. 1979. Biological monitoring of the effects of oil refinery effluents in rivers. In Proc., Ecological Damage Assessment Conference, pp. 199-214. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "For several years it has been the policy of British Petroleum to monitor the effects of its own operations upon the local environment. This has been achieved by relatively simple biological monitoring programmes designed to provide management with information directly relating to the effectiveness of environmental protection measures. This requires a cost-effective approach, minimizing the production of redundant information and the time spent on the survey and data analysis. The surveys carried out are not intended to be whole-ecosystem research studies.

"Initial attention was concentrated upon coastal installations but during 1978 the monitoring programme was extended to cover refineries which discharge into rivers in France and Germany. Considerable attention was paid to determining which methods of sampling and data analysis were most applicable to the objectives of the surveys. The methods evaluated included artificial substrates, grab sam-

pling and dredge sampling, and particular attention was paid to the use of biotic indices.

"Dredge sampling was generally found to be the most practical method for undertaking surveys of this type, whilst artificial substrates allowed a more quantitative assessment of ecological damage. The results obtained so far suggest that the refinery effluents studied cause relatively minor or no ecological damage in the receiving ecosystem."

Moriarty, F. 1977. Prediction of ecological effects by pesticides. *In* Ecological Effects of Pesticides (F. H. Perring and K. Mellanby, eds.), pp. 165-l 72. Linnean Society Symposium Series, No. 5. Academic Press, London.

AUTHOR ABSTRACT: "Direct field trials to test the ecological effects of pesticides are difficult, especially so beyond the areas of application. Various indirect approaches have been made. Some, such as the idea of concentration along food chains, partition coefficients and model ecosystems can be misleading. Two tentative assumptions may be made, that organisms have little effect on the amounts of pesticide in the physical environment, and that if individual organisms are affected adversely, then ecological effects are imminent or already happening. Then the physical chemistry of the pesticide will help us to predict distribution in the physical environment, compartmental models help us predict amounts within organisms, and toxicological studies have often to substitute for ecological ones. This approach is clearly not infallible, and some monitoring is important."

Moss, B. 1976. Ecological considerations in the preparation of environmental impact statements. *In* Environmental Impact Assessment (T. O'Riordan and R. D. Hey, eds.), pp. 82-90. Saxon House, Farnborough, England.

The premise of this paper is that most specific events occurring in ecosystems cannot be predicted with acceptable accuracy. The only predictions that can be made are broad ones based on experience. Unsuspected changes, and changes based random events, are not amenable to prediction.

Munn, R. E. (ed.). 1979. Environmental Impact Assessment: Principles and Procedures. 2nd Ed., SCOPE 5; John Wiley and Sons, Toronto, Canada.

This book was prepared in response to a need for an international review and synthesis of current practices in environmental impact assessment. The principles outlined are equally applicable in developed and developing countries. Various components of environmental impact assessment are defined and described, and a general approach to undertaking an assessment is given. The text covers both the technical and scientific aspects of impact assessment as well as procedural and related topics.

Nair, K. and A. Sicherman. 1980. Making decisions on environmental problems. Environ. Intern. 3: 11-2 1.

A comprehensive methodology of decision analysis is presented and discussed in the context of environmental impact assessment. Special advantages of the methodology include the explicit treatment of preferences and value tradeoffs between various impacts, and the inclusion of the uncertainty associated with assessment of various levels of impact. The use of the methodology is demonstrated with an example involving the siting of an electrical transmission line in Western U.S.

Norton, G. A. and B. H. Walker. 1982. Applied ecology: towards a positive approach. I. The context of applied ecology. J. Environ. Mgmt. *14*:309-324.

AUTHOR ABSTRACT: "Applied ecology is concerned with problems of resource allocation. In a positive (scientific) role, it is concerned with assessing the effect of planning, design and management decisions on ecological components and processes. In a' normative (ethical) role, it questions how to match ecological capability with the objectives of society. The purpose of this paper is to describe the practical context in which applied ecology operates. To reduce 'ecological costs' to society, governments can modify resource allocation in two ways: through comprehensive (forward) planning and by development control. To provide a basis on which decisions can be made, two procedures have been developed-integrated resource analysis (IRA) and environmental impact analysis (EIA). It is to these procedures that the contributions of applied ecology are made. In a review of IRA, the main problems identified concern potential vs. existing resource capability, how to identify the 'best' pattern of land use, and how to account for interactions between different activities. The main problems of EIA, which becomes relevant at this last point, concern the choice of assessment methods to suit particular situations, and how assessed impact is evaluated."

Odum, E. P. 1969. The strategy of ecosystem development. Science *164*:262-270.

Succession is defined and described in terms of twenty-four characteristics of ecosystems. These characteristics are used to contrast young ecosystems and mature ecosystems. It is argued that an understanding of ecosystem succession is essential for improving man's relationship with the natural environment.

Odum, E. P. and J. L. Cooley. 1980. Ecosystem profile analysis and performance curves as tools for assessing environmenal impact. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 94-102. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Department of the Interior, Washington, D.C.

It is suggested in this paper that EIA should rapidly evolve from the present, descriptive, component approach to a holistic approach combining the analysis of broad ecosystem properties with "red flags" (specific local factors of public concern). Two case studies are reviewed to emphasize the importance of integrating economic and ecological considerations in EIA. A number of graphic models are presented and discussed as appropriate devices for combining

large amounts of information into easily understood forms for comparative analysis and presentation.

Odum, E. P., J. T. Finn and E. H. Franz. 1979. Perturbation theory and the subsidy-stress gradient. Bioscience 29: 349-352.

Most impacts can be shown to have a continuum of effect that varies with the degree of perturbation. This continuum has been termed the subsidy-stress gradient. Subsidy refers to favourable deflections in a system parameter, while stress refers to unfavourable deflections. The subsidy-stress concept is discussed with the aid of hypothetical "performance curves" and simplified systems modelling. For impacts that follow a simple, single-hump performance curve, the zone of optimality of subsidy can be determined with relatively few experiments.

Ogawa, H. and W. J. Mitsch. 1979. Modeling of power plant impacts on fish populations. Environ. Mgmt. 3:321-330.

This paper provides a good example of sensitivity analysis in simulation modelling as an aid to making decisions on mitigation. The analysis showed that prevention of juvenile impingement loss may be more effective than prevention of larval entrainment loss in minimizing the reduction of fish populations resulting from power plant operation.

O'Neill, R. V., B. S. Ausmus, D. R. Jackson, R. I. Van Hook, P. Van Voris, C. Washburne and A. P. Watson. 1977. Monitoring terrestrial ecosystems by analysis of nutrient export. Water, Air, and Soil Pollution *8*:271-277.

AUTHOR ABSTRACT: "Current methodology for environmental impact assessment relies heavily on population parameters to detect ecological effects of perturbation. We 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, we 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."

O'Neill, R. V., W. F. Harris, B. S. Ausmus and D. E. Reichle. 1975. A theoretical basis for ecosystem analysis with particular reference to element cycling. *In* Mineral Cycling in Southeastern Ecosystems (F. G. Howell, J. B. Gentry and M. H. Smith, eds.), pp. 28-40. Conf-740513, Tech. Info. Cen., Off. of Public Affairs, U.S. Energy Res. and Dev. Admin., Washington, D.C.

AUTHOR ABSTRACT: "A conceptualization of ecosystem function is presented which considers: (1) the significance of ecosystem processes, such as element cycling, to the persistence of systems in a fluctuating environment; (2) the control mechanisms regulating these processes; and (3) the construction of a theoretical framework to synthesize available information and to suggest future investigations. The theory assumes that the central strategy of ecosystems is to maintain maximum persistent organic matter. A minimal set of state variables (an autotrophic base, a complex of heterotrophic regulators, and a detrital pool) is identified. When the complexity of the system is reduced to a set of minimal parameters, critical interactions between the components can be identified."

Orians, G. H. 1974. An evolutionary approach to the study of ecosystems. *In* Proc., 1st Intern. Cong. of Ecology, pp. 198-200. Centre for Agric. Publ. and Doc., Wageningen, Netherlands.

In this paper the customary productivity approach to the study of ecosystems is discussed, criticized and praised, and an alternative, an evolutionary approach, is described. This approach has the focus of determining the degree to which the evolution of community structure and processes is predictable from a knowledge of the physical environment in which the community has evolved.

Orians, G. H. 1975. Diversity, stability and maturity in natural ecosystems. *In* Unifying concepts in Ecology (W. H. van Dobben and R. H. Lowe-McConnell, eds.), pp. 139-150. Dr. W. Junk B. V. Publ., The Hague, and Centre for Agric. Publ. and Doc., Wageningen, Netherlands.

This paper focusses on the concept of stability and its many elements, including constancy, persistence, inertia, elasticity, amplitude, cyclic stability and trajectory stability. Consideration is given to the evolutionary responses of organisms to perturbations caused by the physical environment, competitors and predators. It is suggested that community and ecosystem behaviour in response to perturbations depend primarily on the adaptive characteristics of the organisms in the system.

Owen, R. M. 1977. An assessment of the environmental impact of mining on the continental shelf. Marine Mining *1*:85-102.

AUTHOR ABSTRACT: "The ocean is a complex system and oceanographers have a limited understanding of the potential impact of mining on the marine environment. However, this lack of knowledge probably will not deter developed nations from commencing marine mining in the near future, because these nations are hard pressed to obtain critical minerals. This study is focused on an assessment of possible environmental disturbances associated with mining on the continental shelf, because a variety of political, economic, and technological factors suggest that the initial large-scale marine mining efforts will occur here. Mining activities on the continental shelf can disrupt the sediment budget and interfere with sediment dispersal patterns, resulting in coastal erosion and the formation of navigation hazards. The biogeochemical processes involved in photosynthesis and primary productivity, secondary productivity, and detoxification are also susceptable to environmental impacts caused by mining. The consequences of altering these processes may include the destruction of organisms and habitats, oxygen depletion, and the release of toxic substances from the sediments. Pre-mining base-

line data and continuous monitoring of certain critical parameters at each mining site will be necessary to minimize adverse effects. Certain shelf environments will require special attention. These include fishing grounds, semi-enclosed embayments, and coral reefs."

Paine, R. T. 1981. Truth in ecology. Bull. Ecol. Soc. Am. *62*:256-258.

The author calls for ecologists to divulge their inabilities to predict changes in natural systems. Such open recognition is necessary to prevent decision-makers from placing undue reliance on impact predictions which appear to be well-grounded but in fact may have a very feeble basis.

Parryck, D. C., R. W. Brocksen and W. R. Emanuel. 1980. Regional analysis and environmental impact assessment. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 114-122. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Department of the Interior, Washington, D.C.

A number of analysis techniques used in the regional environmental assessment program at Oak Ridge National Laboratory are briefly discussed. The techniques illustrate some aspects of the environment that are important from the standpoint of assessing impacts on a regional scale. Emphasis in this paper is placed on models developed to assess and predict impacts.

Peterken, G. F. 1974. A method for assessing woodland flora for conservation using indicator species. Biol. Conserv. *6*:239-245.

AUTHOR ABSTRACT: "A method is proposed for assessing the flora of woodlands based on a simple count of a selected list of species. The species selected are those which (a) are especially associated with woodland conditions, and (b) exhibit a poor colonizing ability. The results of a study in central Lincolnshire are used to test the method and demonstrate its advantages. The practicability of the method for general application is discussed."

Peterman, R. M. 1980. Influence of ecosystem structure and perturbation history on recovery processes. *In* The Recovery Process in Damaged Ecosystems (J. Cairns Jr., ed.), pp. 125- 139. Ann Arbor Science Publ. Inc., Ann Arbor, Michigan.

The characteristics of multiple equilibria for ecosystem and population parameters are discussed in relation to resilience, and natural and anthropogenic perturbations. The perturbation history of a population or ecosystem is shown to strongly influence its resilience to further perturbation. These relationships suggest a shift in management regime from maximum "production" to a combination of production and risk reduction.

Peters, J. C. 1975. Environmental evaluation: water pollution. *In* Proc., Symp. on Environmental Evaluation, pp. 97- 105. Planning and Transport Research Advisory Council, and Department of the Environment, U.K.

AUTHOR ABSTRACT: "Increasing density of population increases the usage of water as a resource. As the environmental carrying capacity is reached competition between competing interests increases. The users of water are prevented from eliminating one another by social activities that relieve direct competitive pressures. The methods by which pollution control agencies assess the state of the environment are discussed. These include problems of chemical monitoring both for health hazards and more general environmental requirements. The meaning of the results of biological sampling are discussed and the importance of species diversity in the environment questioned. A plea is made for environmental standards for water that are flexible and which relate to both advances in knowledge and changes in the carrying capacity of a river rather than relying on river control by the content of individual effluents. The need for education of the public and the importance of multi-disciplinary teams to act as an interface between the general public and decision makers is stressed. The difficulty of obtaining adequate cost data on the interest of users is discussed. The iterative process of objective and subjective judgement in evaluation is stifled without adequate data collection and some areas requiring further attention on this front are suggested."

Rapport, D. and A. Friend. 1979. Towards a Comprehensive Framework for Environmental Statistics: A Stress-Response Approach. Cat. 1 l-5 10 Occasional, Statistics Canada, Ottawa, Ontario. 90 pp.

This volume comprises three papers which attempt a fusion of ecological and economic viewpoints on a framework for environmental data and information. The first paper discusses general needs for environmental information, the second outlines a proposed environmental information system for Canada based on an ecological perspective, and the last reviews some experience of Statistics Canada in developing a framework for environmental statistics.

Regier, H. A. 1976. A scientific analysis of the assessment function, with examples related to aquatic ecosystems. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 1 l-24. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "The 'biological significance of environmental impacts' could encompass an indeterminately large set of considerations. This paper is mainly directed toward establishing useful contexts and pragmatic boundaries concerning the subject. Following an analysis from policy, scientific, and technique perspectives, I propose a screen by which proposals for developments that will have environmental impact can be sorted into four types. The screen is based on graphically specified functions of first approximations of the expectation and the uncertainty to be associated with the impact. For two of the four types of assessment problems so identified, the science and techniques are now reasonably well developed to judge what is biologically significant. More research is urgently needed for the other two groups."

Regier, H. A. and D. J. Rapport. 1977. The application of ecological modelling to impact assessment. *In* Environmental Impact Assessment in Canada: Processes and Approaches (M. Plewes and J. B. R. Whitney, eds.), pp. 79-97. Publ. No. EE-5, Institute for Environmental Studies, University of Toronto, Toronto, Ontario.

AUTHOR ABSTRACT: "Models and modelling — broadly defined — play central roles in the initiation, further development and application of scientific information to practical purposes, as in environmental impact assessment. Ecologists have developed -as have workers in other disciplines — quite a variety of models and modelling methods of potential utility. This paper proposes a rationale for selecting ecological models for assessing environmental impacts of a number of general types of human influences. The approach is eclectic, pragmatic, interdisciplinary and use-oriented."

Reichle, D. E. 1975. Advances in ecosystem analysis. BioScience *25*:257-264.

The contribution of the U.S. International Biological Program to the understanding of the structure and function of ecosystems is described. Various examples of ecosystem research are used in discussing the structural and dynamic features of ecosystems. The use of ecosystem simulation modelling is advocated for environmental impact assessment.

Rigby, B. G. 1982. Environmental Impact Assessment and the Need for Environmental Monitoring. M.A. Thesis, Department of Geography, Carleton University, Ottawa, Ontario. 78 pp.

AUTHOR ABSTRACT: "The Federal Environmental Assessment and Review Process has been in place in Canada since 1973. In this time, little study has taken place to determine what effects the assessment process has had on the performance of projects. The Eastern Arctic South Davis Strait drilling program is used as a case study to determine whether the lack of evident measurable negative impact is due to the environmental assessment, good project design, pure chance or some combination of the three.

"In this analysis, what becomes evident is that to evaluate the performance of a project, a timely, organized, and rigorous method of collecting information on projects is required. Through a synthesis of evidence collected mainly through interviews, the need for a project monitoring program is established. A general framework for environmental monitoring is proposed that includes such necessary elements as: goals, timing, spatial characteristics, considerations for inclusion in a monitoring program, and criteria for a monitoring body."

Risser, P. G. 1976. Identification and evaluation of significant environmental impacts on terrestrial ecosystems. *In* Proc., Workshop on the Biological Significance of Environmental Impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 223-238. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "The question of evaluating the significance of biological impacts brings together current ecosystem theory and the practical aspects of environmental impact analysis. Eight concepts or methods are discussed: sample variability, susceptible organisms, recovery time, terrestrial islands, destruction of ecosystems, ripple effect, carrying capacity, and ecosystem models. Each provides a mechanism for establishing biological significance, but all require a stronger ecological basis to permit immediate application."

Rosenberg, D. M. and V. H. Resh et *al*. 1981. Recent trends in environmental impact assessment, Can. J. Fish. Aquat. Sci. *38*:59 l-624.

AUTHOR ABSTRACT: "The objectives of this paper are to characterize an 'ideal' environmental impact assessment (e.i.a.); to review the contemporary status of e.i.a. for several major activities and areas of development; and to identify successes, failures, and future needs in e.i.a.

"The institutional procedures to be followed for e.i.a. have been formalized in a number of countries, but the scientific basis and methods are still developing. We propose that the following elements comprise an ideal e.i.a.: (1) definition of scientific objectives, (2) background preparation, (3) identification of main impacts, (4) prediction of effects, (5) formulation of usable recommendations, (6) monitoring and assessment, (7) sufficient lead time, (8) public participation, (9) adequate funding, and (10) evidence that recommendations were used.

"The 'best available' predictive, preoperational e.i.a.'s involving aquatic resources (power plants, fossil fuels, recreation, reservoirs, wastewater treatment, forestry, and dredging and water diversion in estuaries) were reviewed adn scored on a O-5 scale for each of the elements identified above. Mean scores for the criteria which could be assessed (nos. l-8) indicated that the quality of the best available e.i.a.'s does not exceed our defined average but improves when legally required documents are excluded from the calculations. The lowest means, for criteria within the scientist's control (nos. 1-5), were obtained for 'Prediction of effects' and 'Formulation of usable recommendations.' Overall mean scores for each development area (criteria l-5) indicated three broad groups which included studies of above average quality (wastewater treatment, recreation); studies of approximately average quality (estuarine impacts, power plants, reservoirs, and fossil fuels); and studies of below average quality (forestry practices).

"Environmental impact assessment has had the following successes: increased environmental awareness due to public involvement in e.i.a., some environmental protection, and elucidation of intriguing research problems. The list of failures of e.i.a. is, however, longer: 'tokenism,' unrealistic time constraints, uncertainty of program or development schedules, difficult access to e.i.a. literature, questionable ethics, lack of coordination among studies, and poor research design.

"Future organizational/administrative needs of e.i.a. include improved access to e.i.a. literature, increased accountability for e.i.a.'s and their authors, improved public input into project decisions and designs, and improved organization and presentation of e.i.a. reports. Future scientific/research needs include development of methods to define and quantify relationships between biological, esthetic, and economic impacts; support for independent biological inventory programs; adequate time frames; improved design of research; inclusion of monitoring and assessment in every e.i.a.; study of cumulative impacts on a regional or national scale; and improved communication between scientists and planners."

Sage, B. 1980. Ruptures in the Trans-Alaska Oil Pipeline: causes and effects. Ambis 9:262-263.

This short paper recounts an oil spill into the Atigun River in Alaska, and suggests that the actual effects of the oil spill on fish in the river cannot be determined because of the absence of pre-spill information.

Saila, S. B. 1979. Models for marine environmental assessments. Marine Environ. Res. 2: l-2.

The author suggests that autoregressive-moving average time series models may provide a useful alternative to systems models for the study of certain types of marine environmental problems.

Sanders, F. S. 1980. Synthesis. In Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et *al.*), pp. 349-377. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sanders provides an excellent summary of the content of the first eleven chapters of the report. After reviewing briefly some important properties of ecosystems, he outlines four fundamental activities that constitute the basis for a scientifically valid assessment of ecological impacts: (1) field monitoring, (2) experimental field perturbation studies, (3) laboratory studies, and (4) mathematical assessment methods. Sanders closes the chapter with a synopsis of an interative ecological effects assessment process including prediction, monitoring and assessment.

Sanders, F. S. and G. W. Suter, II. 1980. General considerations for ecological effects monitoring and assessment. In Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et *a*/.), pp. 9-60. Environ. Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Important concepts in applied ecology are outlined as they relate to ecological effects assessment. These include ecosystem dynamics, variation within ecosystems, perturbation theory, and ecosystem response to perturbation. Four areas of activity in ecological effects assessment — namely, field monitoring, experimental perturbation studies, laboratory, studies, and analytical efforts (modelling) — are then described. Important organizational aspects are discussed and include an interdisciplinary team, adequate study resources, administrative flexibility, and iterativity within the assessment process. Additional monitoring considerations, such as spatial and temporal boundaries, are outlined. Finally, some current misconceptions about various aspects of ecological effects assessment are revealed, and the importance of sound professional judgement is stressed.

Schiefer, K. and W. Eedy. 1977. Wreck Cove Hydroelectric Project: an example of environmental problem solving and resource management. *In* Proc., Environment III: Conference of the Assoc. of Consulting Engineers of Canada, Sept. 1977.

AUTHOR ABSTRACT (INCOMPLETE): "One of the most unique aspects of this project has been the application of innovative technology to resolve some of the major environmental and resource use conflicts related to the development. These include:

"Reservoir *Management Policy* — Flexibility in the synchronization of waste movement between reservoirs has been utilized to enhance the quality of the aquatic environment in those reserviors with the greatest recreational of fisheries potential. This included the application of a computerized simulation model for predicting reservoir water quality under various operational alternatives. Optimization of important water quality parameters and management of reservoir water levels will create favourable environmental conditions within the reservoirs and guarantee suitable quality of riparian releases to the lower rivers.

"Laboratory Simulation of Bog Decomposition — Long term laboratory studies have been undertaken to determine the nature of decomposition of organic peat soils in the reservoir flood zones and the implication this has on future water quality conditions. These data have been fed directly into the reservoir simulation models described above.

''*Riparian Flow Policy* — A riparian flow policy has been described to relate to the specific biological requirements of downstream salmon populations in the river affected, ensuring maximum environmental benefit of all water released and safeguarding valuable resources, even under the worst of natural drought conditions."

Severinghaus, W. D. 1981. Guild theory development as a mechanism for assessing environmental impact. Environ, Mgmt. 5: 187-190.

Procedures are proposed which, through the use of guild theory, should permit relatively accurate, quantifiable predictions of environmental impact. Guild theory, in original form, states that species can be grouped on the basis of similarities in the use of environmental resources. For use in environmental assessment, the author suggests a modified perspective — actions that affect environmental resources will affect members of guilds using those reosurces in a similar way. This implies that once the impact on any one species in a guild is determined, the impact on every other species in the guild is known.

Sharma, R. K. 1976. Determining biological significance of environmental impacts: science or trans-science? *In*

Proc., Workshop on the Biological Significance of Environmental impacts (R. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp. 3-10. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "In assessing ecological impacts of environmental perturbation, it is imperative to examine what changes in the ecosystem would constitute significant environmental damage or potential for such damage. Although the types of environmental impacts have been identified and their effects studies to some extent, the methodology for determining the extent of perturbation that can result in significant impact on the ecosystem is meager, if not entirely wanting. In spite of a multitude of impact-assessment studies now in progress, one prime question that remains unanswered is: What are the nature and extent of biological changes that constitute significant impact on the ecosystem?

"Determination of the significance of environmental impacts is discussed in the context of statistical, biological, and socio-economic perspectives and in the context of organism, population, and community levels. An approach, based on the concept of maximum sustained yield, is advanced for the allocation of living natural resources to accommodate environmental impacts. Concepts of environmental impact studies are examined in the light of baseline and post-impact study programs, natural variability in ecosystems, selection of study parameters, geographical extent of the study, etc."

Sharp, J. M., S. G. Appan, M. E. Bender, T. L. Linton, D. J. Reish and C. H. Ward. 1979. Natural variability of biological community structure as a quantitative basis for ecological impact assessment. In Proc., Ecological Damage Assessment Conference, pp. 257-284. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "Since cause-and-effect have not, in general, been determined in real ecosystems, it is suggested that ecological assessment and monitoring be based on effects rather than on suspected causes that have evolved from laboratory or microcosm studies. Ecological impact can be assessed on the basis of changes induced in the biological community which cannot be attributed to natural causes. Where statistically adequate data are available, natural variabilities can be quantitatively defined. Activities which do not produce variations beyond natural variability limits can be judged to be ecologically benign. Such data may be used, also, to make statistical comparisons of spatial and temporal similarities between biological communities within the given ecosystem. Minimum monitoring systems can be designed based on such similarity evaluations.

"This paper describes a method which has been developed to determine variabilities and similarities. It does not attempt to define those assessment limits nor those biological indices which should be used. The method requires: (1) statistically adequate data; (2) the capability to rapidly and economically address all data in any pertinent combinations and permutations; and (3) the ability to display and document the data in quick and thorough manner. These capabilities are demonstrated in the paper."

Skalski, J. R. and D. H. McKenzie. 1982. A design for aquatic monitoring programs. J. Environ. Mgmt. *14*:237-251.

AUTHOR ABSTRACT: "An objective of ecological aquatic monitoring at nuclear power plants has been the detection of impacts on the important fauna and flora in the vicinity of the plant site. A control-treatment pairing (CTP) design for monitoring programs is presented for impact assessment in benthic and plankton communities. A scheme for the establishment of monitoring programs using CTP designs is discussed which accounts for the influence of plant site characteristics, the quantitative objectives of the monitoring study, the expected magnitude of experimental error and the limitations of time and effort. A graphical technique is presented which can be used to incorporate these often competing constraints into the design of aquatic monitoring studies. Estimates of the experimental error computed from a *posteriori* applications of CTP designs to benthic and plankton communities at six nuclear power plants are presented."

Slawson, G. C., Jr. and B. C. Marcy, Jr. 1975. Evaluation of effects of multiple power plants on a river ecosystem. *In* Proc., Intern. Conf. on Environ. Sensing and Assessment, Vol. 1, 8 pp.

AUTHOR ABSTRACT: "The evaluation of environmental impacts of power plant development activities is not only a legal requirement but also a logical necessity. This paper discusses the impact of power plants on a river ecosystem. The relative magnitude of these effects as related to plant siting and to plant design factors is presented. The biological components considered are groups of organisms selected to allow interpretation as to the desirability of induced changes. A biological data set is outlined which allows identification of alternative site locations and designs to minimize the effects of entrainment of organisms in cooling water intakes. Alternative plant locations and operational schemes are further evaluated by projecting the impact of waste heat discharges on the river biota. These projections are in the form of impact profiles of the power plant-river system. A methodology for defining the overall impact of alternative basin power plant systems is outlined. These assessment procedures provide information useful for the siting of new plants and for the delineation of cumulative impacts of existing and proposed power plant systems."

Slobodkin, L. B., D. B. Botkin, B. Maguire, Jr., B. Moore III and H. Morowitz. 1980. On the epistomology of ecosystem analysis. *In* Estuarine Perspectives — 5th International Estuarine Research Conference, pp. 497-507. Academic Press, New York.

AUTHOR ABSTRACT: "It is impossible to construct a general theory or model of any particular ecosystem which will be useful for answering all possible questions about that system, although if we know enough about any ecosystem it is possible to construct such models once a specific

question has been posed. This knowledge cannot be gained entirely from the system at issue, due to restrictions in time and resources, as well as to the fact that certain kinds of thorough ecological analysis may damage the system analyzed. Therefore, it is advisable to use relevant information from ecosystems other than the one of immediate interest. A partial list of species present in an ecosystem permits access to the information gained by naturalists working on other systems. We therefore justify the usual practice of making species lists because such a list is the best (i.e., cheapest and most useful) preliminary step in answering questions about any ecosystem. While explicit measurements must also be made in the object ecosystem in order to usefully model it, it is likely that the number of such necessary measurements may be reduced and their usefulness enhanced by the background natural history information implicit in a partial species list. To demonstrate that the information of natural history can be communicated in a relatively complete way, we provide a partial representation of an adaptive response surface for Hydra sp. in which much of the kind of information about these organisms that might be useful for model construction can be presented in a relatively simple diagram."

Smith, A. L. 1973. Terrestrial aspects of ecological surveys. Dames and Moore Eng. Bull. *43*:9- 16.

AUTHOR ABSTRACT: "The methodology used in a terrestrial survey involves the efforts by investigators in various disciplines. The biotic community is divided into components -soils, vegetation, birds and mammals, insects, and amphibians and reptiles — which are, in turn, broken down into more basic subdivisions. This allows for a study of individuals within a population as well as a study of the interrelationships of populations within the community. Types of surveys, such as site selection and monitoring programs, are discussed, with emphasis on baseline studies."

Smith, W. H. 1974. Air pollution — effects on the structure and function of the temperate forest ecosystem. Environ. Pollut. 6: 111-129.

AUTHOR ABSTRACT (INCOMPLETE): "Air pollution has had, is having, and will continue to have an influence on forest ecosystems throughout the temperate regions of the world. The nature of this relationship can be divided into three classes. Under conditions of low dosage-Class 1 relationship-the vegetation and soils of forest ecosystems presumably function as a very important sink for air contaminants. When exposed to intermediate dosage — Class II relationship — individual tree species or individual members of a given species may be adversely and subtly affected by nutrient stress, reduced photosynthetic or reproductive rate, predisposition to entomological or microbial stress, or direct disease induction. Exposure to high dosage — Class III relationship — may induce acute morbidity or mortality of specific trees. The ecosystem impact of these various relationships would be very variable In the Class I relationship, pollutants would be transferred from the atmospheric compartment to the biotic (organic) or available nutrient compartments. Depending on the nature of the pollutant, the ecosystem impact of this transfer could be undetectable (innocuous effect?) or stimulatory (fertilising effect). If the effect of air pollution exposure on some component of the ecosystem biota is inimical then a Class II relationship is established. The ecosystem impact in this case could include reduced productivity or biomass, shifts in species composition, increased secondary effects, such as insect outbreaks or disease epidemics, or increased morbidity and reduced vigour. The ecosystem impacts of Class II relationships are extraordinarily important because of their potentially widespread significance. In the presence of high air pollution dosage-Class III relationship — impact on the structure of the ecosystem may be gross simplification, and disturbances to the function of the ecosystem may include basic changes in hydrology, nutrient cycling, erosion, microclimate and overall stability.

"While these numerous ecosystem impacts, resulting from air pollution stress, have been identified, few have been quantified in the field. We are especially deficient in our ability generally to assess Class I and II relationships. This hiatus of knowledge is due to several factors in addition to the obvious difficulty of making accurate measurements of subtle processes in expansive and frequently remote forest ecosystems."

Stirling I. and H. Cleator. 198 1. Polynyas in the Canadian Arctic. Occasional Paper No. 45, Canadian Wildlife Service, Dept. of the Environment, Ottawa, Ontario. 73 pp.

EXTRACTED FROM TEXT: "This volume contains five reviews of subjects vital to our understanding of the biological importance of polynyas in the Canadian Arctic. The first paper describes the distribution of polynyas and shoreleads and discusses variability in their size and locations. Although some of this information is available in various reports and ice maps, nowhere before has the distribution of polynyas been reviewed so thoroughly in one paper. The second paper discusses the physical causes and biological significance of polynyas and other open water areas in sea ice. The remaining three papers discuss the importance of polynyas to marine mammals (including polar bears), sea birds, and sea ducks, using the available literature and the baseline information provided in the first two papers.

"The purpose of this review is to assemble the scattered body of information on polynyas in one place in order to help focus attention on specific areas where research is required. As such, it is not intended that this volume be the definitive work, but rather than it can serve as a useful starting point for more thorough, integrated, interdisciplinary research. Although the papers deal with fairly independent topics, several themes are recurrent. One, of course, is the limited nature of the available data base. More importantly, several areas in which information is required are identified by more than one writer. These include evaluating the significance of biological productivity at the edge of the ice, the basic biology of key invertebrates, site-specific data on biological oceanography on a year-round basis, the biology and distribution of the two cod species, and specific evaluation of how critical each polynya is to the survival of viable regional populations of different species."

Stirling, I. G., R. R. Wallace and G. T. Glazier. 1979. An environmental research and management strategy for the Eastern Arctic region: a discussion. Northern Perspectives 7(6):4-5, 8-9.

To complement current impact studies sponsored by industry as part of the project approvals process, the authors call for a much greater, long-term research effort on the part of the government to provide the understanding of natural processes needed in order to adequately predict the effects of development in the Eastern Arctic.

Straughan, D. 1979. The importance of sampling strategy in ecological damage assessment. *In* Proc., Ecological Damage Assessment Conference, pp. 3-27. Society of Petroleum Industry Biologists, Los Angeles, California.

AUTHOR ABSTRACT: "Ecological damage is usually difficult to assess because it is being measured against a nonstatic background. The community is continually responding to variability in natural parameters, and in most locations, to variability in man-made parameters as well. This paper illustrates another source of variability frequently encountered in ecological assessment — variability due to sampling methods. A number of methods for sandy beaches are described and their limits discussed. Data are also presented to show the different results obtained when several methods were used simultaneously on the same beach. This stresses the importance in sampling design as well as data management in ecological assessment and underlies the dangers in comparison with other data when the sampling methods and methods of data analysis are unknown or poorly documented."

Suffling, R. 1980. An index of ecological sensitivity to disturbance, based on ecosystem age, and related to landscape diversity. J. Environ. Mgmt. *10*:253-262.

AUTHOR ABSTRACT (INCOMPLETE): "Attempts at mapping ecological sensitivity to disturbance are weakened by a dearth of indices which are both theoretically satisfying and practical. There has also been difficulty in defining a landscape cell's sensitivity relative to that of its neighbours. A sensitivity index, Sx, is proposed, based on the principle that, following disturbance, old ecosystems are less easily replaced than pioneer systems. Sx is also related to the relative area of each ecosystem type found in the landscape.

"Sx is analogous, but not equivalent, to Shannon's information statistic, H. It satisfied predictive theoretical tests of ecological sensitivity and was significantly rank-correlated ($P < 0.05$) with other objective and subjective ecological sensitivity indices. These tests indicate that subjective judgements of ecological sensitivity appear to be more closely related to ecosystem age than to ecosystem rarity."

Suter, G. W. II. 1980. Terrestrial ecology. *In* Strategies for Ecological Effects Assessment at DOE Energy Activity Sites (Sanders et *al.*), pp. 107- 133. Environ, Sci. Div. Publ. No. 1639, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

This chapter provides a review and commentary on methods and techniques of terrestrial ecological studies as they pertain to environmental impact prediction and monitoring. Specific topics covered include measurement of population size, symptomology, functional properties of ecosystems, and faunal behavioural responses.

Suter, G. W. II. 198 1. Commentary: Ecosystem theory and NEPA assessment. Bull. Ecol. Soc. Am. 62: 186-192.

Several factors which contribute to the lack of ecosystem theory in environmental impact assessments are outlined. These factors include problems of credibility, foresight, absoluteness, specificity, economy and necessity.

Suter, G. W. II. 1982. Terrestrial perturbation experiments for environmental assessment. Environ. Mgmt. 6:43-54.

AUTHOR ABSTRACT: "The National Environmental Policy Act of 1969 (NEPA) was initially interpreted as requiring full disclosure of the environmental impact of a federal action. Because of the limitations of time, money, and manpower, the requirement that all impacts be considered has led to superficial analysis of many important impacts. Data collection has largely been limited to the enumeration of species because this information can be applied to the analysis of any problem. The President's Council on Environment Quality (CEO) has provided a solution to this problem by reinterpreting NEPA as requiring analysis of those impacts that have significant bearing on decision making. Because assessment resources can now be concentrated on a few critical issues, it should be possible to perform field perturbation experiments to provide direct evidence of the effects of a specific mixture of pollutants or physical disturbances on the specific receiving ecosystem. Techniques are described for field simulation of gaseous and particulate air pollution, polluted rain, soil pollutants, disturbance of the soil, and disturbance of wildlife. These techniques are discussed in terms of their realism, cost, and the restrictions that they place on the measurement of ecological parameters. Development and use of these field perturbation techniques should greatly improve the accuracy of predictive assessments and further our understanding of ecosystem processes."

Swartz, R. C. 1980. Application of diversity indices in marine pollution investigations. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 230-237. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildl. Service, U.S. Department of the Interior, Washington, D.C.

The two basic elements of diversity (richness and equitabilty) are discussed in some detail in this paper. Examples from nine literature sources are used to show how the magnitudes of various diversity indices change along pollution gradients in marine benthic ecosystems. For most pollution investigations, an index combining areal richness and the reciprical of Simpson's index of dominance concentration is recommended.

Thomas, J. M. and L. L. Eberhardt. 1976. Ecological impact assessment. *In* Proc., Conference on Computer

Support of Environmental Science and Analysis, pp. 181-197. U.S. Energy Research and Development Administration, Washington, D.C.

AUTHOR ABSTRACT (INCOMPLETE): "Quantitative problems associated with 'ecological impact assessment' with particular reference to defining population effects are discussed. Under the assumption that site-by-site evaluation will continue, we offer some comments on the two approaches most commonly used, the experimental and simulation models. In addition, we suggest some alternatives because both methods will probably fail to detect real population effects mostly due to either our poor understanding of ecosystems or limitations inherent in field census methods. Thus, we believe most, except the obvious, judgments of ecological impact are not quantitatively defensable but are qualitative, subjective, or political in nature. Finally, we suggest that an examination of aggregates of data from various nuclear power plant sites may be one way to obtain enough replication to judge ecological impact. Currently available data from such studies as well as appropriate demographic, vegetation, census, and bibliographic material could offer an interesting challenge to computer professionals if such an undertaking were contemplated."

Tips, W. and H. Gysels. 1979. Ecological evaluation for planning purposes in Western Europe: a critical analysis of the state of the art. Intern. J. Environ. Studies 14: 113-125.

AUTHOR ABSTRACT: "A decade after their birth, ecological evaluations are gaining increasingly in interest in town and country planning. This paper will review and try to analyze critically the literature of some Western European countries with regard to a number of requirements for ecological evaluations. These requirements are derived from the role of ecological evaluation in society, and its commitment to both the planning and the reality of our environment from an ecological point of view."

Truett, J. C. 1978. Ecosystem process analysis: a new approach to impact assessment. *In* Energy/ Environment '78, Symp. on Energy Development Impacts, pp. 69-75. Society of Petroleum Industry Biologists, Los Angeles, California.

This paper defines ecosystem processes as interactions within and among the parts of ecosystems (as opposed to the more static concepts of abundance and distribution of system components). An Arctic marine case study is used to illustrate to application of process analysis to impact assessment.

Important processes in this case study include food chains, nutrient 'cycles, water movement and erosion. "Critical" processes and "key" species were selected for intensive study, and food chains were examined from the top down. Advantages of process analysis include (a) the facilitation of impact prediction, (b) the possibility of extrapolating results of studies to other areas and (c) the more adequate accounting of societal values by examining "key" species.

Truett, J. C. 1979. Pre-impact process analysis: design for mitigation. *In* The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, pp. 355360. Gen. Tech. Report RM-65, Rocky Mountain For. Range Exp. Sta., Fort Collins, CO.

AUTHOR ABSTRACT: "A study of physical and biological processes supporting important fish and wildlife species along Alaska's Beaufort Sea coast suggests how petroleum development can proceed with the least possible impact. The study's strategy — process analyses — is generic in nature and is broadly applicable for identifying mitigative measures to accompany many kinds of development. This strategy is preferable to a more traditional inventory-based environmental assessment."

Valentine, D. W. 1973.. Ecological considerations of industrial development: an introduction. Dames & Moore Eng. Bull. *43*:3-7.

AUTHOR ABSTRACT: "Prior to development, project planners and designers must consider certain biological concepts, There must be an understanding of the basics required to sustain a healthy ecosystem: sufficient food, a stable reproductive level and suitable habitat. This paper emphasizes that other factors, such as the presence of a rare or endangered species or a unique ecosystem, may preclude development or at least warrant the selection of an alternative site."

Van Voris, P., R. V. O'Neill, W. R. Emanuel and H. H. Shugart, Jr. 1980. Functional complexity and ecosystem stability. Ecology 6 *1*:1352- 1360.

AUTHOR ABSTRACT: "The hypothesis that complexity and stability are positively correlated was experimentally tested at the ecosystem level of organization using intact terrestrial microcosms. Power spectral densities of hourly carbon dioxide efflux, from 11 old-field microcosms, were analyzed for the number of low-frequency components. We postulate that the number of peaks is related to functional interactions among system components (i.e., population interactions, physical-chemical reactions, and biological turnover rates) influenced by nonlinearities, feedbacks, and time delays. Thus, the number of low-frequency peaks can be taken as an index of 'functional complexity.' Relative stability was based on the capacity of the system to retain essential nutrients and was measured by net loss of calcium after the system was stressed with a heavy metal, cadmium. Rank correlation supported the hypothesis that increasing ecosystem functional complexity leads to increasing ecosystem stability."

Van Winkle, W., S. W. Christensen and J. S. Mattice. 1976. Two roles of ecologists in defining and determining the acceptability of environmental impacts. Intern. J. Environ. Studies *9*:247-254.

AUTHOR ABSTRACT: "A framework is presented for defining the environmental impact of a project on an ecosystem. An 8-step decision tree is introduced which leads to operational definitions of unacceptable and acceptable impacts. Within this framework, two roles ecologists play in

the field of environmental impact assessment are considered: (1) To supply scientifically sound and objective predictions of the potential impact of a project on an ecosystem, and (2) to reach conclusions, based on his own value system, concerning the acceptability of the predicted impact."

Vogl, R. J. 1980. The ecological factors that produce perturbation-dependent ecosystems. *In* The Recovery Process in Damaged Ecosystems (J. Cairns, Jr., ed.), pp. 63-94. Ann Arbor Science Publ. Inc., Ann Arbor, Michigan.

Various types of natural perturbations, such as rain, floods, wind storms, fire, snow, frost, erosion, animal-induced perturbations, and geologic perturbations, are described in detail. Natural perturbations, upon which the existence of many ecosystems depend, are then contrasted with anthropogenic perturbations, which are generally stressful and degrading to ecosystems.

Wagner, F. H. 1980. Integrating and control mechanisms in arid and semiarid ecosystems: considerations for impact assessment. *In* Symp. Proc., Biological Evaluation of Environmental Impacts, pp. 145- 158. FWS/OBS-80/26, Council on Environ. Quality, and Fish and Wildlife Service, U.S. Dept. of the Interior, Washington, D.C.

This paper reviews three aspects of the ecology of arid and semiarid systems: (1) characteristics of the moisture constraint and its impact implications; (2) some patterns of biotic interactions within the plant community that are involved in community change; and (3) some implications of those patterns for impact prediction. Of the three ecosystem entities of structure, functions, and controls, the focus in this review is on the third.

Since impact prediction for arid and semiarid ecosystems is so difficult, based on the observation that the relative variation of the major system control (i.e., water) is high compared to that in mesic ecosystems, it is suggested that improvements could be realized in being able to predict community changes based on the physiological and morphological mechanisms involved in the change.

Waldichuk, M. 1979. Review of the problems. Phil. Trans. R. Soc. Lond. B *286*:399-424.

AUTHOR ABSTRACT: "Sublethal effects of pollution may be significant to survival of a stock of marine fish or even a species. Such effects sometimes lead to reproductive failure and have been identified so far only in freshwater systems. Atlantic salmon have disappeared from many streams in Europe and eastern North America, partly as a result of pollution in their freshwater spawning areas and in their estuarine nursing grounds. Reductions in populations of marine fishes due to pollution solely have not yet been demonstrated. However, Baltic Sea seals, where reproductive failure is apparently associated with high concentrations of DDT and polychlorinated biphenyl in the blubber, may have suffered a decline owing to the presence of these organochlorines.

"Sublethal effects of pollutants have been studied in the laboratory, essentially under four categories: (1) physiology (growth, swimming performance, respiration, circulation); (2) biochemistry/cell structure (blood chemistry, enzyme activity, endocrinology, histochemistry); (3) behaviour/neurophysiology; and (4) reproduction. Not all pollutants elicit meaningful responses in all categories, and a resonse is not always linear with pollutant concentration. For application to survival of populations, the response has to be ultimately related to a healthy progression through a full life cycle, including successful reproduction.

"In recent time, physiological studies have moved into polluted marine environments with mobile laboratories having continuous sampling capability, to observe effects of pollutants *in situ* on marine organisms. The Controlled Ecosystem Pollution Experiment (Cepex) in Saanich Inlet, British Columbia, endeavours to investigate the effects of low concentrations of pollutants on marine organisms in large plastic silos having a slow replacement of water."

Walker, B. H. and G. A. Norton. 1982. Applied ecology: towards a positive approach II. Applied ecological analysis. J. Environ. Mgmt. *14*:325-342.

AUTHOR ABSTRACT: "Two crucial problems involved in the practice of applied ecology are (i) the allocation of limited time, funds, and manpower to different impact assessment problems, and (ii) the choice of appropriate analysis tehcniques to suit the problem at hand. A screening procedure is suggested as one means of improving this selection process. There are two ecological features of this screen: one normative, being concerned with the 'social value' of the ecosystem affected, the other positive, concerned with those properties of the ecosystem that determine the full consequences of the planning, design and management options involved. Concentrating on the latter, the problem is to assess the effect that changes in the physical environment, biotic components, and the spatial size and form of the ecosystem have on the five variables of concern: namely, environmental quality, productivity, species composition, ecosystem behaviour and landscape characteristics. To make a 'first shot' assessment of ecological impact it is suggested that a systems approach be adopted and relevant ecological 'principles' employed. A preliminary set of 32 ecological 'principles' (concepts or working hypotheses) is described, and an example is given to show how these 'principles' can be used to 'think through' a particular assessment problem."

Walters, C. 1975. An interdisciplinary approach to development of watershed simulation models. J. Fish, Res. Board Can. 32: 177- 195.

AUTHOR ABSTRACT: "A workshop approach for the rapid development of simulation models is described. The key feature of the approach is intimate involvement of resource specialists in the model building process, so that communication between resource disciplines is greatly enhanced. Two watershed models that have been developed in 1-wk workshop meetings are described to show the kinds of factors that can be considered. One model is concerned with small coastal watersheds in the Pacific Northwest, and the other deals with part of the James Bay area,

Quebec. Both of these models have helped scientists of Environment Canada identify major information needs that are not being considered in current research and management programs; in particular, little is known about the dynamics of recreational demand."

Westman, W. E. 1977. How much are nature's services worth? Science *197*:960-963.

EXTRACTED FROM TEXT: "Ecosystem functioning-the flow of materials and energy in biotic communities and the effects of these dynamics on soil and atmosphere-is vital to human welfare. To date, those concerned with quantifying and evaluating benefits of natural ecosystems to man have largely focused on the standing stocks of nature rather than the flows. The quantification of ecosystem functions, here illustrated by absorption of air pollutants, radiation balance, soil binding, and nutrient cycling, is likely to produce evidence on the extent of socially significant damage from pollution. At present, our understanding of ecosystem functioning is limited, but much can be done even now to develop quantitative relationships between pollution levels and damage to ecosystem functions."

Westman, W. E. 1978. Measuring the inertia and resilence of ecosystems. Bioscience 28: 705-7 10.

The concepts of resilience and inertia are discussed and contrasted with similar terms and meanings that appear in ecological literature. Inertia is defined as the resistance a system has to disturbance, while resilience, incorporating the concepts of elasticity, amplitude, hysteresis and malleability, refers to the ability of a system to restore its structure after disturbance. Emphasis in providing measures of inertia and resilience is placed on a descriptive, species-oriented approach.

Wiederholm, T. 1980. Use of benthos in lake monitoring. J. Water Pollution Control *52*:537-547.

EXTRACTED FROM TEXT: "Biological variables are particularly useful in measuring (a) environmental conditions over a long period of time coupled with the possibility of detecting occasional disturbances, (b) the summation of effects of substances occurring at low concentrations, and (c) the integrated effects of several environmental variables individually or in concert. In addition, biological monitoring can provide (a) resolution in time and space, for instance, gradients within a water body and (b) analysis with fairly simple and cheap equipment and facilities.

"The benthic, that is, bottom — dwelling, communities in a lake or stream fulfill all of these requirements, and experience points to a potentially greater usefulness of benthic biological monitoring compared with most other biological variables."

Woodwell, G. M. 1970. Effects of pollution on the structure and physiology of ecosystems. Science *168*:429-433.

EXTRACTED FROM TEXT: "The accumulation of various toxic substances in the biosphere is leading to complex changes in the structure and function of natural ecosysterns. Although the changes are complex, they follow in aggregate patterns that are similar in many different ecosystems and are therefore broadly predictable. The patterns involve many changes but include especially simplification of the structure of both plant and animal communities, shifts in the ratio of gross production to total respiration, and loss of part or all of the inventory of nutrients."

Woodwell, G. M. 1975. The threshold problem in ecosystems. *In* Ecosystem Analysis and Prediction: Proc. of a Conference on Ecosystems (S. A. Levin, ed.), pp. 9-21. Soc. Ind. and App. Math., Philadelphia, Pennsylvania.

Threshold is defined as the maximum exposure, to a hazard, having no discernable effect. It is argued that while thresholds can be determined for species and populations, in general they cannot be for ecosystems. This is attributed to two factors: 1) Current state-of-the-art in ecology can elucidate the nature of short-term, acute disturbances but not long-term, chronic disturbances, and 2) ecosystem responses to disturbance are often continuous and do not display threshold characteristics.

Yorke, T. H. 1978. Impact Assessment of Water Resource Development Activities: A Dual Matrix Approach. FWS/OBS-78/82, Fish and Wildlife Service, U.S. Dept. of the Interior, Harpers Ferry, West Virginia. 27pp.

PREFACE TO THE TEXT (INCOMPLETE): "The Water Resource Analysis Project, Office of Biological Services, has developed a dual-matrix concept for planning and evaluating the impact of water development projects on fish and wildlife resources. The matrices provide the framework for collecting, synthesizing, and developing information on the impacts of stream flow regimes and channel alterations resulting from water development activities, and they may eventually provide the base for a computerized assessment system. The system will have direct application for early and effective input by the Fish and Wildlife Service into the planning and decisionmaking processes of the Federal agencies responsible for implementing water development projects.

"The dual matrix system utilizes the commonality of impacts of fish and wildlife resources that are associated with diverse projects such as reservoirs, navigation jetties, and flood control levees. These projects cause changes in various physical characteristics of streams such as water depths and velocity distribution, and these physical changes have the same impact on the biota no matter what the cause of the physical change. The system accounts for the common impacts by assembling water resource developments and physical characteristics in one matrix, Using this two step approach will provide for effective use of existing information and efficient information development which will result overall in better and more thorough planning of water development projects."

Zar, J. H. 1976. Statistical significance and biological significance of environmental impacts. *In* Proc., Workshop on the Biological Significance of Environmental Impacts

(Ft. K. Sharma, J. D. Buffington and J. T. McFadden, eds.), pp.285293. NR-CONF-002, U.S. Nuclear Regulatory Commission, Washington, D.C.

AUTHOR ABSTRACT: "In assessing environmental impact, it is common and accepted practice to employ statistical analysis in order to conclude whether a difference in a variable of interest exists between locations or between times. By such a procedure, one might conclude that a difference does exist, and the probability of this being an erroneous conclusion is known from statistical considerations If a difference is not determined to exist, however, the probability of this conclusion being in error is hardly ever considered. In the case of either conclusion, one should present estimates of the magnitude of the difference, for it is the size of differences, over and above their statistical significance, that is of basic importance in assessing biological significance. Furthermore, when a statistical testing procedure is employed,it should be determined how small a difference the test is capable of detecting."

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