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ASA Reviews of EPA-Funded Acid Precipitation Research

ASA COORDINATING COMMITTEE*

The American Statistical Association, through the Committee on Statistics and the Environment, has completed the first year of a cooperative agreement with the Environmental Protection Agency/Acid Deposition Assessment Staff (EPA/ADAS) to review statistical aspects of certain EPA-funded research projects on the effects of acid deposition. Emphasis of the reviews was on the validity of the research results for the national assessment of the effects of acid precipitation. This cooperative agreement was an outgrowth of a desire by EPA/ADAS to ensure that research results to be used in their assessments were statistically sound and of ASA’s general objective of promoting the use of appropriate statistical methodology.

The interim objectives of the EPA-funded research are assessments of the physical and biological changes due to acid deposition; the ultimate objective is an economic assessment of the effects of and control of acid deposition. These objectives imply establishment of causal relationships, quantification of effects, and extrapolation of the experimental results to large geographical areas. There are very important sampling, experimental design, and statistical inference questions associated with every phase of this research.

The projects to be reviewed were identified by EPA/ADAS in consultation with the ASA Coordinating Committee. Six projects have been reviewed by three different review teams in this first year. One member of the Coordinating Committee was responsible for forming and serving as captain of each review team, again in consultation with the Coordinating Committee and EPA/ADAS staff. Every effort was made to use statisticians who had expertise in the appropriate areas and had no personal involvement with EPA-funded acid deposition research. EPA/ADAS identified and provided the key documents for review and relevant supporting documentation for each project. Each review team had four days in which to study the documentation, meet with EPA/ADAS representatives and key research personnel for discussion of the projects, and then go into executive session to complete the reviews.

The following three review reports of the projects are presented for the general information of the statistical profession and to draw attention to the kinds of statistical problems these review teams found to be of major importance to the assessment of the effects of acid deposition. The purpose of this publication is to stimulate interest and involvement in such projects of concerned statisticians and quantitative scientists from within government, industry, and academia.

The opinions expressed in these reports are the opinions of the members of the respective review teams and are based on the documentation presented by EPA/ADAS and discussions on the status of the research at the time of the reviews. Of course, the reports do not reflect changes made, for whatever reasons, in the research programs subsequent to the reviews. Responses to the reviews follow this article. The Coordinating Committee welcomes this exchange and encourages the reader to study both the reviews and the responses. The educational purpose of this publication will be enhanced as a result.

To preserve the integrity of the reviews, they are reported in their entirety and in substantially the same form in which they were submitted to EPA. Only minor stylistic changes have been made. Key resource materials for Project 1A of the Crops Review have been appended to that report for the benefit of the reader (documents 4 and 8 were unpublished manuscripts at the time of the reviews). The documentation used in these reviews is too voluminous to be summarized here. Those documents not available in the published literature are in the public domain and available from the sources.

The reports were written primarily for a nonstatistical audience. The Coordinating Committee asks the forbearance of the statistician in the sections of the reports discussing some of the more elementary statistical problems.

The projects reviewed are as follows:

**Crops Research Review Team**

- Project A: Dose–response studies—the regionalization of controlled dose–response studies
- Project B: Estimation of crop-yield response to acid precipitation based on U.S. Department of Agriculture crop statistics (cross-sectional analysis)

**FORAST Review Team**

- Project A: Regionalization of forest decline studies
- Project B: Estimation of dose–response from correlation patterns

**Aquatic Research Review Team**

- Project B: Analysis of trends in the chemistry of surface waters of the United States based on the Acidification Chemistry Information Database (ACID)

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*The Coordinating Committee consisted of Emanuel Landau, American Public Health Association, 1015 15th Street, Washington, DC 20005; G. P. Patil, Professor of Mathematical Statistics, Pennsylvania State University, University Park, PA 16802; and John O. Rawlings (Chairman), Professor of Statistics, North Carolina State University, Raleigh, NC 27695-8203. Although the reviews were supported in part by U.S. EPA through the cooperative agreement CR-811019-01-0 with ASA, they have not been subject to EPA’s required peer and policy review and thus do not necessarily reflect the views of the agency.
INTRODUCTION

The Crops Review Team was formed, as one of several review teams, by the ASA Coordinating Committee in consultation with EPA/ADAS (Robert Rosenthal) under a cooperative agreement between ASA and EPA for the review of specified statistical issues in the EPA-sponsored research on the effects of acid deposition. The Crops Review Team had the responsibility of reviewing the two projects identified as follows:

Project 1A: Regionalization of crop dose–response studies
Project 1B: Estimation of acid deposition effects from crop statistics

The team reviewed key documents relating to the critical research (provided by EPA; itemized in a letter from John O. Rawlings to W. R. Barchet, Robert E. Rosenthal, Emanuel Landau, and G. P. Patil, Jan. 30, 1984, and earlier correspondence) and met at the University of Illinois on March 6 and 7, 1984, to hear reports from key research personnel on 1983 research results from controlled experiments (Project 1A), to interact with key research personnel on the statistical methodology and problems associated with the cross-sectional analysis (Project 1B), and to develop the initial draft of this report. The final report was reviewed by the ASA Coordinating Committee.

PROJECT 1A REVIEW

Objectives

The overall objective of the review for Project 1A was to address the question of the inference to a regional basis of the dose–response estimates of the effects of acid precipitation on the yield of crops as obtained from the key research projects funded by EPA at Brookhaven National Laboratory, Argonne National Laboratory, and the University of Illinois. The region to which the inference is to be directed is the Midwest soybean region, consisting of Ohio, Indiana, Illinois, Iowa, and Missouri. The primary crop on which significant data will be available for the 1983 assessment is soybean, cultivars Assoy and Williams. A small amount of data will be available on corn. A second region of interest was defined as North Carolina and Tennessee, for which soybean data from Agricultural Research Service research at Raleigh, North Carolina, and Electric Power Research Institute sponsored research at Oak Ridge National Laboratory would be used for assessment.

More specifically, the review team’s charge was as follows:

1. Review the strengths and weaknesses of the statistical designs for each major project (EPA sponsored) with particular attention to the power of each design to detect meaningful deposition effects.
2. Review the statistical methods used in data analysis, estimation of acid deposition effects, and assessment of the precision of the estimated effects.
3. Review the usefulness and the limitations of each set of data to the regional inference of acid deposition effects on crop yields.
4. Comment on the question of providing measures of certainty for regional estimates of crop loss and on the adequacy for this purpose of the data from the studies being reviewed.

Review of Research

General Comments

Review of the individual projects indicates that considerable effort is being devoted to the use of appropriate experimental designs and appropriate analyses of those designs. The effective use of a Latin square design by the Brookhaven project, for example, is to be commended. (This is not to suggest that all designs should be Latin square designs.) The review did reveal, however, several areas in which closer attention to certain aspects of experimental design, data analysis, and data interpretation would be productive. The cost of this kind of experimentation and the limited resources require that every effort be made to make experiments as efficient as possible and to extract all relevant information from each data set.

1. Consideration should be given to a clear definition of objectives. The optimum design is dependent on the specific objective, or the ordering of objectives if there are several. The best design to estimate a dose–response curve, for example, may not be the best for estimating yield changes between two specific acidity levels. Given the objective(s), the relative power of alternative designs can be compared, for various assumed response models, before the experiment is conducted. In the case of a linear response curve, the dual objectives of developing a dose–response curve and estimating yield loss between two specific pH levels are both satisfied with the same design. As the response curve becomes more complicated, however, the two objectives are more and more in conflict insofar as the optimum design is concerned.

2. An important aspect of experimental design is the proper "laying out" of that design in the field—the shape and size of experimental units and the grouping of the experimental units into blocks. Inappropriate blocking, for example, can be worse than no blocking. Effective blocking is best accomplished with intimate knowledge of the nature of the local variability at the field site and of the manner in which the experiment is managed. The blocking of some of the designs, however, was such as to suggest that alternative blocking would have improved precision.
EMANUEL LANDAU, BENE F. SWINDEL, JAMES R. THOMPSON, and JOHN R. VAN RYZIN*

INTRODUCTION

The FORAST Review Team was formed, as one of several, by the American Statistical Association Coordinating Committee in consultation with EPA/ADAS (Robert Rosenthal) under a cooperative agreement between ASA and EPA for the review of statistical aspects of the EPA-sponsored research on the effects of acid deposition. The FORAST Review Team had responsibility for reviewing the project identified as Forest Responses to Anthropogenic Stress (FORAST), S. B. McLaughlin, Principal Investigator.

The team reviewed individually key documents relating critical aspects of the research, provided by the Principal Investigator (see Appendix).

The team then met at the Oak Ridge National Laboratories (ORNL) on April 25 and 26, 1984, to (a) hear further reports from research and sponsoring personnel, including S. B. McLaughlin, T. J. Blasing, T. W. Doyle, and V. A. Dale from ORNL and D. Bennett from EPA; (b) interact with research and sponsoring personnel on statistical problems, principles, and procedures for FORAST; and (c) develop the initial draft of this report. Invited observers included

Gary Oehlert, Princeton University, and Donald C. Peterson, Energy and Resource Consultants, Inc.

This report was reviewed by the ASA Coordinating Committee.

The illness of Robert Rosenthal, who had intended to put the FORAST work into context, prevented his participation in the evaluation.

PROJECT 2A REVIEW: REGIONALIZATION OF THE FOREST DECLINE STUDIES

Objective

The overall objective of this review was to address questions of inferences to a regional basis of forest decline statistics and presumed effects of acid precipitation on the yield of forests, as obtained from research projects funded primarily by EPA at ORNL and other institutions. The region to which the inference is to be directed is the Eastern United States.

More specifically, the review team was to do the following:

1. Review the statistical methods used in data analysis, estimation of acid deposition effects, and assessment of the precision of the estimated effects.

2. Review the usefulness and the limitations of each set of data to the regional inference of acid deposition effects on forest yield.

*Emanuel Landau, Team Captain, is with the American Public Health Association, 1015 15th Street, N.W., Washington, DC 20005. Benee F. Swinadel is Project Leader, U.S. Forest Service, and Adjunct Professor of Forestry at the University of Florida, Gainesville, FL 32611. James R. Thompson is Professor of Mathematical Sciences at Rice University, Houston, TX 77251. John R. Van Ryzin is Professor of Statistics at Columbia University, New York, NY 10022.
APPENDIX: KEY RESOURCE MATERIALS


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Aquatc Research Review Report

G. P. PATIL, WALTER LIGGETT, FRED RAMSEY, and WOOLLICOTT K. SMITH*

1. INTRODUCTION

The Coordinating Committee on EPA–ASA peer review of statistical aspects of EPA-sponsored research on the effects of acid deposition formed the Aquatic Review Team in consultation with EPA/ADAS (Richard Barchet and John Malanchuk) under a cooperative agreement between ASA and EPA. As identified in earlier correspondence, the Aquatic Review Team had the responsibility of reviewing two documents pertaining to the following projects:

- Project ACID: Analysis of Trends in the Chemistry of Surface Waters of the United States Based on the Acidification Chemistry Information Database

The Aquatic Review Team reviewed the two documents from a statistical standpoint, met with concerned research investigators and sponsors July 23-25, 1984, and prepared this report.

The following EPA/ADAS scientists participated in the review meetings and discussions with John Malanchuk, coordinating the EPA participation: David Bennett, Ted Hinds, Tony Janetos, and John Malanchuk (all RD-676). The following research investigators of Project NSWS participated in the review meetings and discussions: Rick Linthurst, Kilkelly Associates, and Scott Overton, Oregon State University. The following Brookhaven National Laboratory investigators of Project ACID participated in the review meetings and discussions: George Hendrey, Chris Hoogendyk, Ed Kaplan, and Neal Oden.

This report was reviewed by the ASA Coordinating Committee.

2. PROJECT 3A: REVIEW OF NSWS DOCUMENT

**Overall Conclusion.** A primary goal of the NSWS National Lake Survey (NLS) is to obtain interval estimates of the number of lakes in defined geographic regions that may be sensitive to acid deposition. The proposed sampling design shows sizable effort behind it. Whether this is a most efficient design to achieve the multiple objectives needs to be examined in the light of alternative design options. The NSWS report assures that the survey is designed to meet concrete objectives. The objectives could be more specific, and as stated, they do not state the error bounds desired. The design should be specifically linked with all of the important objectives—in particular, with the task of obtaining representative samples for Phases II and III.

2.1 Introduction

We divide our comments into two parts: general comments on the plan, followed by specific comments about the technical details or the lack of technical details in the plan. A short summary and recommendations follow this.

A probability sample drawn from a fixed, well-defined sampling frame is a good general method for achieving the primary goal of the survey, which is to estimate the percentage of susceptible lakes by region. With this well-defined sampling plan, standard results can be used to obtain
Proceedings of the Eighth Symposium on Statistics, Law, and the Environment

Preface Clifford S. Russell

Prediction of Tropical Storm Tracks

Preface Clifford S. Russell

The Use of Meteorological Data in the Prediction of Tropical Cyclones Arthur C. Pike

The Role of Statistical Models in the Prediction of Tropical Cyclone Motion Charles J. Neumann

Natural Hazard Research and Policy: Time for a Gadfly John H. Sims and Duane D. Baumann

Fishery and Forestry Management

Surveys for Monitoring Changes and Trends in Renewable Resources: Forests and Marine Fisheries Joseph Barnard, Wayne Myers, John Pearce, Fred Ramsey, Michael Sissenwine, and Woolcott Smith

Problems of Modeling Growth and Yield of Renewable Resources B. Dennis, B. E. Brown, A. R. Stage, H. E. Burkhart, and S. Clark

Forecasting for Resources in Forestry and Marine Fisheries in the Year 2000 David R. Darr and Richard C. Hennemuth

Ecological Community Structure Analyses in the Formulation, Implementation, and Enforcement of Law and Policy Jared Verner, Robert Pastorok, Joel O’Connor, William Severinghaus, Norman Glass, and Bennie Swindel

Material Effects of Ambient Pollution

Preface Emmanuel Landau

Conceptual and Statistical Problems in Identifying Thresholds of Effect for Materials Damage and Soiling Frederick H. Ruter

Materials Damage by Environmental Pollutants: Data Requirements James P. Lodge

Air Pollution Materials Damage: Economics and the Law Roger C. Dower

Forecasting Materials Damage From Air Pollution Ronald E. Wyzga and Fred W. Lipfert

Health Effects of Workplace Pollution

Preface Kenneth Cantor

The Collection and Management of Occupational Exposure Data M. Gerald Ott, S. K. Norwood, and R. R. Cook

Analyzing Cohort Mortality Data Alice S. Whittemore

Methods for Quantitative Risk Assessment Using Occupational Studies Kenny S. Crump and Bruce C. Allen
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The papers in this volume of proceedings from the Eighth Symposium on Statistics, Law, and the Environment represent a modest change from earlier volumes in this series. The symposium itself was organized to accentuate that change.

As the reader will see, the Eighth Symposium operated with a broad view of the meaning of environment. Whereas earlier symposia had emphasized research on health effects of ambient or workplace pollution, this one devoted three-quarters of the 16 papers given to non-health issues and fully half of the papers to topics outside the pollution field entirely. The fields covered were

Tropical Storm Track Prediction
Fishery and Forestry Management
Material Effects of Ambient Pollution
Health Effects of Workplace Pollution

In this volume, the papers are arranged by these topic groups, but the symposium itself was organized around generic statistical problems: data gathering and management, model building and validation, prediction, and public policy implications. The idea behind this organization was to highlight the problems and techniques shared across disciplinary and substantive problem lines.

As an intellectual device, the organization was reasonably if not brilliantly successful. The discussant for each session was asked to make explicit the connections among papers, and the original plan was to use written versions of their remarks as prefatory material for each group of papers.

We have reverted to the subject matter organization for two reasons. First, the organization by problem seems to have been one reason for discouraging attendance at the symposium. Second, not all of the discussants actually produced written material. We expect that our decision will make it easier for subject matter specialists but hope that not all readers will be discouraged from reading across lines and drawing their own conclusions about shared problems.

Clifford S. Russell
Chairman of the Symposium
Steering Committee
For the first time in its 15-year history, the ongoing program of the national Symposium on Statistics, Law, and the Environment identified ecological systems of renewable resources in fisheries and forestry as one of its substantive components. The earlier symposia were devoted to habitat issues, involving air, water, and so forth, and health effects. Our intention for the present symposium was partly to identify the common and contrasting concepts, techniques, and issues in forestry and fisheries and their statistical versions for the mutual benefit of statistics, ecology, environment, and society. To achieve comprehensive and generic emphasis and integration, each paper was planned to have multiple authorship across disciplines, agencies, and institutions. The papers that follow were thus prepared to cover four major themes in statistical ecology and environmental statistics: data gathering and management, modeling, forecasting, and policy implications.

The subject area of statistical ecology and environmental statistics is relatively young. Various interdisciplinary efforts and activities by concerned professional organizations have been instrumental in the promotion of scientific dialogues and in the dissemination of the results in an impressive variety of valuable publications. Among others, the following organizations and groups come to mind in this connection: the Committee on Statistics and the Environment of the American Statistical Association, the Society for Industrial and Applied Mathematics Institute for Mathematics and Society, the Mathematical Ecology Group in Great Britain, and the International Statistical Ecology Program of the International Statistical Institute, International Association for Ecology, and the Biometric Society. Broadly speaking, the latter two groups have so far emphasized statistical ecology in their programs, whereas the former have had primary emphasis on environmental statistics. Publications listed at the end of this preface provide in one place the enormous amount of interdisciplinary material that the reader of this program component should know of to appreciate and fully use the content in the papers that follow.

"Surveys for Monitoring Changes and Trends in Renewable Resources: Forest and Marine Fisheries" discusses various conceptual and methodological issues involving the observer, the observed, and the observing. Several problems that are not typical of modern traditional statistics also arise and would be of interest to the reader concerned with observational studies, encountered data, and related representativeness issues that may involve weighted distributions and weighted methods of various sorts. Everyone concerned also needs to find conceptual and methodological ways and means of, not contributing to, but breaking into the unaffordable cycle of no information, new information, and non-information.

"Problems of Modeling Growth and Yield of Renewable Resources" identifies several quantitative and statistical needs for more effective modeling and describes some of the areas in which resource modeling and decision making can benefit from incorporating stochastic and statistical factors in the models. Problems of single versus several models and solutions also abound and provide good statistical problems to work on substantive issues of current concern.

"Forecasting for Resources in Forestry and Marine Fisheries in the Year 2000" should lead the reader to the challenging issues and answers that need to go into the making of appropriately empirical crystal cubes, since the greatly desired crystal balls are usually lacking. This is particularly so in the area of statistics, ecology, and environment, where one finds oneself in the exploratory and confirmatory situations of soft data, hard looks, and prudent decisions.

"Ecological Community Structure Analyses in the Formulation, Implementation, and Enforcement of Law and Policy" dramatically raises the requirements of comprehensive data and their meaningful analysis to guide managerial and pollution abatement policies. The computer age has surely brought public policy and theoretical statistics together, by bending into the circle what otherwise looked like a line with theoretical statistics and policy making at the distant ends!

I hope that the four papers will collectively help provide the following working message for the substantive scientist, the statistical theorist, and the resource manager to realize well-integrated interdisciplinary results of timely importance: engage in individual efforts and, at the same time, engage in simultaneous collaborative efforts, but not in mere sequential pairwise encounters.

G. P. Patil
Pennsylvania State University

REFERENCES


Surveys for Monitoring Changes and Trends in Renewable Resources: Forests and Marine Fisheries

JOSEPH BARNARD, WAYNE MYERS, JOHN PEARCE, FRED RAMSEY, MICHAEL SISSENWIN, and WOOLLCO T SMITH*

The purpose of this article is to provide a perspective on present technology for acquisition of information relative to the status of renewable natural resources, with particular emphasis on forest and marine resources. Commonalities and dichotomies are emphasized in the hope of achieving a synthesis that will promote shared understanding and dialogue between statisticians and natural resource discipline specialists, with the ultimate goal being improved survey methodology.

KEY WORDS: Renewable resources surveys; Environmental monitoring; Forestry; Sampling.

1. BACKGROUND

The topic of this article was the subject of a major international conference held in August of 1983 at Corvallis, Oregon. This conference produced a 737-page proceedings (Bell and Atterbury 1983). Although terrestrial resources were addressed in much more detail than marine resources, the participants collectively considered all of the fundamental issues involved in monitoring renewable resources. The Satellite Program in Statistical Ecology of the International Statistical Ecology Program also addressed several relevant problems in Cairns et al. (1979) and Cormack et al. (1979). (See also Hennemuth and Patil 1983 and Patil 1984b in this connection.)

Since the complexion of the situation has not much changed since these programs, the goal of this article is to provide a synthesis of points raised by participants in the earlier forum along with insights into certain areas of research that offer potential for progress. We begin by laying a framework of commonalities and identifying points of divergence where objectives and problems differ between institutional settings and types of resources. At this point of beginning it is also appropriate to declare our intention to interpret "forest resources" in a broad sense that is not limited to fiber production as an end use. Even so, more attention has been devoted to timber as the major commercial aspect of forests than to other noncommercial resource values. This emphasis cannot be avoided, but we compensate in part by deferring to the proceedings of the Corvallis conference as a source of abundant literature references and examples of timber surveys.

2. OVERVIEW

A rather obvious point of beginning is to note that renewable resource populations typically consist of large numbers of individual elements distributed over appreciable areas in such a manner that it is either logistically impossible or economically impractical to conduct a complete census. The few exceptions involving extremely small populations are of no interest in the present context, since monitoring in such instances is relatively straightforward although not necessarily easy. Less obvious is the broad commonality among existing approaches to inventory of renewable resources.

Such inventories normally involve three fundamental components. The first component is an area classification or stratification portion in which relatively homogeneous environments are recognized. The second part is a direct measurement component in which selected readily observable characteristics are determined for a sample of population elements. The third part is an indirect measurement component in which less readily observable characteristics of the sampled elements are inferred through mathematical models of the resource developed in advance of the inventory and driven by variables measured in the second phase. This third component may be absent in some cases, but such cases are becoming less frequent as ecological knowledge develops.

Each of these phases may involve several subcomponents and alternative designs. Monitoring necessarily involves determination of change over time. Time comparison is achieved by repetition of some or all of the inventory phases. Quite different types of technologies are involved in the respective components of monitoring, so it becomes important to recognize these components in considering future development of monitoring systems. Remote sensing and geographic information systems dominate the first component. Sampling theory, plot design, mensurational techniques, and collection apparatus dominate the second component. Ecological theory, mathematical formulation, and algorithms dominate the third component.

Monitoring can be divided into two broad categories of application having major differences in locational specificity, parametric detail, and time reference. The first category consists of descriptive monitoring on a regional basis directed at provision of information for formulation of public policy and signaling alarms relative to broad-scale environmental degradation. The second category consists of location-specific monitoring for prescriptive purposes relative to implementation of management plans or impact assess-

tactic management plans for harvesting different species could be developed. Cohort strength could be predicted from the abundance of other species, and manipulation of the populations might be possible.

We believe that the problem of species interactions is one of the most difficult questions in fishery science. It is certainly the most difficult to deal with in a statistically satisfactory way. Yet significant restraining management decisions have been made on the basis of hypothesized interactions without definitive analysis. On the U.S. Pacific Coast there is a reduction in the level of harvest of anchovies to maintain an abundance of forage for larger fish. Definitive information supporting the size of such reduction, or measuring the effect of it, is not available. What is known is that anchovies are an important food for the larger species. Statistical models for analyzing data on species interactions are needed to help fisheries managers make intelligent decisions, when faced with situations such as depicted in Figure 8 involving reciprocal trends in species abundance.

An initial attempt to provide such quantitative advice to managers concerning krill and whale populations in the Antarctic was undertaken by May et al. (1979). They constructed simple systems of differential equations to study the effects of harvesting more than one level of an ecological food chain. However, their study was far more an illustration of the importance of the problem than a specific guide to managers. Nevertheless, even this simplistic model of the Antarctic species complex predicted that the species interactions would create many management problems.

We conclude this fisheries section by mentioning some modeling developments with the potential to change drastically the way commercial marine fisheries are managed. In the fisheries management literature, there has been increasing recognition in recent years that commercial fishing is an economic enterprise. Clark (1976, 1985) provided a good introduction to the rapidly growing field of bioeconomics, consisting of a marriage between biological resource modeling (primarily, but not limited to, fisheries) and mathematical economics. The principal idea is to use a resource growth model along with dynamic control theory to determine an optimal harvest policy. Such a harvest policy would maximize some economic functional (such as net present value of the resource) subject to biological and regulatory constraints. Fisheries' managers have been understandably cautious in implementing the recommended harvest policies for the following reasons: (a) The optimal policies are often radical departures from existing policies (i.e., recommendations such as "pulse" fishing: shutting down the fishery for several years, followed by a burst of tremendous harvesting effort). (b) The elaborate economic superstructures erected on resource models are only as sturdy as the sometimes greatly oversimplified resource models themselves. Nonetheless, as the models increase in sophistication, these investigations are bound to become more influential in fisheries management. Mangel (1985), for instance, recently incorporated explicit stochastic forces into resource models and used techniques from stochastic control and Bayesian decision theory for finding optimal harvesting strategies. See Chapman and Gallucci (1981) also in this connection for recent contributions that develop principles of modeling and population dynamics for both natural and exploited or harvested populations.

5. CONCLUSIONS

It can be seen that the inherent variability in the growth and yield of renewable resources is large. The statistical methodologies to cope with this variability are not readily available. One might speculate what the difference might have been if Fisher had been employed at a fishery or forestry experiment station; but in any case there is a real need for statisticians to interact with population biologists, fishery scientists, and forestry scientists to assist in developing appropriate tools for dealing with this variability. The recent establishment of a Center for Statistical Ecology and Environmental Statistics at Pennsylvania State University is a major step toward institutionalizing the capabilities to address these problems. Such efforts need to be expanded if we are going to make significant progress in difficult resource management problems.

REFERENCES


Forecasting for Resources in Forestry and Marine Fisheries in the Year 2000

DAVID R. DARR and RICHARD C. HENNEMUTH*

Forestry and fisheries are major industries using renewable living resources. The resources have in common principles of ecology that control productivity, but there are differences in the time scales and dynamics of productivity that affect the management and economics of harvesting. These differences lead to the need for different approaches to forecasting the supply and possible yields. The factors that need to be considered in developing forecasts are described with examples of application.

KEY WORD: Harvest.

1. INTRODUCTION

Forest and marine ecosystems provide renewable living resources that have important social and economic values on both global and national scales. They share the common traits of relatively rapid and sustained renewability. Their productivity depends on much the same ecological relationships in the physical and biological environments. The rate of self-generation differs, within and among both ecosystems, but both are limited in this respect. Both resources are stable in the long run, but the basis of stability is different, with much more dynamic change in fishery resources than in forests. The basic and important difference in resource production is that in forestry trees are a dominant sector of primary productivity on land, whereas the marine fishery resources are dominated by secondary and higher productivity. One should not, therefore, draw analogies too finely. Our perspectives may also be influenced by the fact that both trees and forests are readily observable, whereas fish for the most part lie beneath an opaque surface.

Harvest management and prediction of yields add other differences. Marine fishery resources are almost entirely common-property resources—much of them were in a global commons until the late 1970s, but almost all fall under some public domain. A large amount of forests are privately owned; in the U.S. they are divided about equally between public and private. Inventory of forests provides a basis of predicting how much of what species will be available for harvests in the decades scale. It is much more difficult to estimate the unseen standing crop of fishery resources, and it is possible to predict the available species harvest only a few years in advance. Although in both resource sectors, selective harvest by species and clear cuts or "pulse" fishing (fishing on dense concentrations of a species until catch rates are reduced below that desired and then moving the fleet to another such aggregation) are preferred harvesting strategies in the highly capitalized segments of industry, it is more possible to apply them in forests than in fisheries.

The current methods of harvesting timber radically change the environment and often eliminate the previous "natural" forest production. Fishing has much less effect on the marine environment. The physical habitat changes caused by fishing that reduce or eliminate future production seem not to be significant. This is not the case, however, in other uses of the ocean, which, willfully or not, are mostly detrimental in effect on productivity.

The supply of marine fishery resources depends almost totally on natural production; the catch of fish depends on the skill of the fisherman and, to a variable degree, luck. The supply of wood resources is increasingly affected by replanting, in many cases of different species composition than naturally occurring there. Global demand for fish seems always greater than supply and affects the forecasts of harvest much less than in forestry.

These and other factors are reflected in the forecasts of forest and fisheries productivity and harvest presented in this article.

2. FORECASTING FOR RESOURCES IN FORESTRY

The U.S. Forest Service has a long-standing interest in making projections of supplies and demands for the various renewable resource areas. The type and extent of Forest Service programs depend on the agency’s views of the future. The role of the Forest Service in making projections was reinforced by the Renewable Resources Planning Act of 1974 as amended by the National Forest Management Act of 1976. Among other things, the Resources Planning Act (RPA) directs the Secretary of Agriculture to prepare “An analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis of pertinent supply and demand and price relationship trends.” Renewable resources are considered to be outdoor recreation and wilderness, wildlife and fish, range, timber, and water. Since mineral resources are frequently found on lands where renewable natural resources are produced, our analyses also include minerals. The findings of these assessments are to be used in the development of Forest Service programs to deal with the projected resource situations. Lead times can be long for Forest Service programs to have much influence in a resource area such as timber, so projections are made 50 years into the future. Plans are now under way for the third assessment, due in 1989. The last assessment was done in 1979, with an update in 1984, and contained projections to 2030.

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Ecological Community Structure Analyses in the Formulation, Implementation, and Enforcement of Law and Policy

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Most of what is currently known about ecosystems derives from two sources: comprehensive studies by classical ecologists and economically motivated studies by resource specialists. The former have traditionally concentrated on natural or long-undisturbed ecosystems, the latter on those few species in managed or polluted ecosystems that are harvested, hunted, or fished. A recent genre of legislation, drafted with insight provided by the scientific community, recognizes the dearth of ecological information on managed or polluted communities (which are becoming far more ubiquitous and important) and dramatically raises the requirements for comprehensive data and data analyses to guide managerial and pollution abatement policies. This paper describes several important current efforts to use ecological community structure analyses to implement and enforce such legislation and some effects of such analyses on environmental policy.

KEY WORDS: Clean Water Act; Conservation; Diversity; National Forest Management Act; Guilds; Numerical classification; Pollution.

MARINE SEWAGE DISCHARGES: CLEAN WATER ACT

Section 301(h) of the 1977 Clean Water Act allows publicly owned sewage treatment plants to apply for a permit to discharge effluent receiving less-than-secondary treatment to marine waters. Regulations were first issued by the U.S. Environmental Protection Agency (EPA) in June 1979 (44 FR 34784, 40 CFR, Part 125), and amended in November 1982 (47 FR 5366, 40 CFR, Parts 124 and 125). Technical evaluation of more than 200 applications received by the EPA includes review of effluent chemical composition and receiving-water characteristics, effluent dispersion modeling, and analyses of impact study designs, data quality, and results by a multidisciplinary team of marine scientists. Ecological community structure analyses are conducted by applicants to support the application, by EPA and its contractor (Tetra Tech, Inc.), during evaluation of each application, and by all involved parties during an enforcement phase if a waiver is granted.

Balanced Indigenous Population (BIP) Concept

The 301(h) regulations require that applicants demonstrate that the modified discharge will allow for maintenance of water quality that assures “protection and propagation of a balanced indigenous population (BIP) of fish, shellfish, and wildlife.” A BIP is defined as an ecological community that exhibits characteristics similar to nearby communities living under unpolluted conditions. To meet these criteria, an applicant must test whether biological parameters measured near the sewage discharge fall within the range of natural variability found in a comparable but unpolluted habitat. Although the regulations are also concerned with alterations of functional aspects of marine ecosystems (e.g., primary productivity, presence of disease epicenters, and abnormal bioaccumulation of toxic substances), the analysis of biological community structure is deemed critical to the regulatory process. In theory, the BIP encompasses the entire biological community. In practice, however, emphasis is usually placed on assessment of benthic macroinvertebrate communities because (a) their sedentary nature ensures that they are exposed continually to pollution stresses, (b) their spatial patterns therefore reflect spatial gradients in discharge effects, (c) benthic communities are of prime importance to near-shore food webs, and (d) methods for sampling and analyzing the macrobenthos are relatively standardized.

Community Structure Analysis

Community variables measured in various 301(h) field surveys are (a) abundances of individual species, including dominant species, indicator species (Pearson and Rosenberg 1978), and species important to community structure or energy flow; (b) total faunal abundance; (c) species richness; and (d) community indexes (Washington 1984), especially Shannon’s diversity, Piérou’s evenness, and Simpson’s dominance. Word (1978, 1980) has developed a measure of benthic community trophic structure (calculated from the relative numbers of suspended detritus feeders, sediment surface detritus feeders, surface deposit feeders, and subsurface deposit feeders) that correlates closely with organic enrichment potential, as measured by the mass emissions rate of suspended solids (Mearns and Word 1982). Measurements of the biomass of benthic communities are highly variable and costly and, in general, have not been used.

Analyses of community structure data include simple graphic displays, parametric and nonparametric univariate statistical analyses, multivariate analyses, and combinations of these techniques (Tetra Tech, Inc. 1982; Ginn and Grieb

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