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PENN STATE STATISTICAL ECOLOGY AND ENVIRONMENTAL STATISTICS - 25 YEARS

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Abstract. This paper provides an overview of the past twenty-five years of statistical ecology and environmental statistics at the Pennsylvania State University with focus on: Center for Statistical Ecology and Environmental Statistics, graduate environmental statistics program, graduate quantitative ecology program, journal of *Environmental and Ecological Statistics*, statistical ecology series, observational economy series, risk assessment consortium initiative, and the spatial environmental and ecological statistics using geographic information systems. The paper also provides a complete listing of the publications of the Penn State Center for Statistical Ecology and Environmental Statistics.

Introduction

Environmental and ecological statistics is poised for dramatic growth both for reasons of societal challenge and statistical opportunity. It is becoming clear that environmental and ecological statistics is demanding more and more of non-traditional statistical approaches. This is partly because environmental and ecological studies involve space, time and relationships between many variables, and require innovative and cost effective environmental sampling and monitoring. Also, environmental and ecological statistics methodology must satisfy environmental policy needs in addition to disciplinary and interdisciplinary environmental and ecological research imperatives.

Largely in response to spatial, temporal, non-identical, and non-independent situations involving sampling, assessment, and decision making for both policy and research, environmental and ecological statistics is already a subject area by itself. And because of the current environmental and ecological crisis and because of the more and more instrumental role that statistics has begun to play, it is more urgent than ever for the nation to have graduate students trained in environmental and ecological statistics, with improved scientific visualization and effective reporting capability included.

Penn State, a major public research and teaching university in the nation, has been continuously involved, since the early seventies, in the combined spectrum of statistics, ecology and environmental studies. The First Advanced Institute on Statistical Ecology in the United States was organized and held at Penn State in 1972 with major support from NSF. The first of a series of conferences on Encountered Data and Representativeness Issues was organized and held at Penn State in 1985. Penn State has been the Home of the International Statistical Ecology Program consisting of the Statistical Ecology Section of the International Association for Ecology and the Liaison Committee on Statistical Ecology of the International Statistical Institute, Biometric Society, and the International Association for Ecology.

The University has courses and programs that relate directly to environmental and ecological statistics. The Department of Statistics has a Doctoral and Masters Option in Environmental Statistics, and the Intercollege Graduate Program in Ecology has a Doctoral and Masters Option in Quantitative Ecology, which are linked and share several key faculty.

Center for Statistical Ecology and Environmental Statistics

The Center for Statistical Ecology and Environmental Statistics is a unit in the Department of Statistics of the Pennsylvania State University and was initiated under a cooperative agreement between the National Oceanic and Atmospheric Administration and the Pennsylvania State University. The Center is the first of its kind in the nation and in the world, and enjoys national and international reputation.

In collaboration with interested agencies, institutions, and projects, the Center has an ongoing program of research that integrates statistics, ecology, and the environment. The emphasis is on individual and collaborative research, training, and exposition on improving the quantification and communication of man's impact on the environment. Major interest also lies in statistical investigations of the impact of the environment on man.

Interested graduate students participate in the Center as graduate research assistants and as interns at the Center and sometimes at the collaborating agency sites. The students benefit from the ongoing miniseminars on individual collaborative research between interested university faculty and visiting scientists. These involvements usually lead to Ph.D. dissertations and Masters term papers for students registered in statistics and related programs in environmental sciences. Sometimes they lead to more theoretical or more substantive investigations.

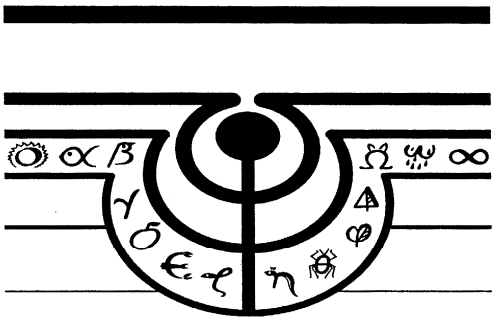
Broad research areas of the Center relate to statistical ecology, environmental statistics, and quantitative risk analysis, with emphasis on mathematical statistics, statistical methodology, and data interpretation and improvement for future use. The adopted approach is to advance statistics for environment, ecology, and environmental health, and to advance environmental and ecological theory and practice using valid statistics.

Current research projects and activities include spatial statistics, geographic information systems and remote sensing, innovative sampling and observational economy, ecological sampling and analysis, environmental monitoring and assessment, integration of environmental data and information, biodiversity measurement and comparison, and superfund site characterization and evaluation under cooperative research agreements with the U.S. Environmental Protection Agency.

Professor G. P. Patil is the Director of the Center. Professors M. Akritas, J. G. Babu, M. T. Boswell, K. Chatterjee, I. Feller, Colin Goodall, P. C. Jurs, Alan MacEachren, W. L. Myers, J. K. Ord, D. Peuquet, C. R. Rao, J. Rosenberger, A. Tempelman, S. K. Thompson, and F. M. Williams are Faculty Associates. Professors S. D. Gore and A. Kaur are Visiting Faculty Associates. Dr. C. Taillie is a Senior Research Associate. Barbara Freed is a Research Aide. Graduate Interns are: Senin Banga, Loredana Di Consiglio, Dario Gregori, Matteo Grigoletto, Glen Johnson, Jo Orsin, and Rachael Williams.

During the 12-year period since its inception, the Center has brought in $3,000,000 in research grants and in cooperative research grants in statistical ecology and environmental statistics with the Center Director as the principal investigator. In response to the topical expertise involved, the statistics faculty that have been grant (proposal) co-investigators include: J. G. Babu, M. T. Boswell, Colin Goodall, J. K. Ord, J. L. Rosenberger, A. Tempelman, and S. K. Thompson. The university faculty outside statistics include: J. S. Fairweather, W. L. Myers, and R. H. Yahner. Several on the campus participated in the Center initiative for NSF STC National Center Without Walls, and several are now participating in the Risk Assessment Initiative of the Environmental Science and Technology Council of the University Future Committee, with the Center Director as the leader of the initiative.

The Center has a very insightful and unique logo suggestive of its function and the mission. Conceptualized by G. P. Patil for Statistical Ecology and Environmental Statistics and designed by Yeshwant Chaudhary, former President of Indian Society for Industrial Design, the symbol design has won a first-place award in a Communication Artists' Guild. The symbol design visualizes the graphic concept of the Earth and establishes the harmonious environment between humankind and ecological beings in statistical symbols. Interesting still is the rhythm achieved between the gradation of spaces and the thickness of lines weaving through each other into a total structural harmony. This symbol is appreciated world over for the design thinking that has gone into its expressing the message of statistical ecology and environmental statistics.



Graduate Program in Environmental Statistics

PhD in Statistics with Environmental Statistics Option. The requirements for the environmental statistics option are similar to those for the Ph.D. in statistics. They differ slightly in the course work. With the environmental statistics option, the student receives a Ph.D. in statistics, with a coherent and intensive specialization in environmental statistics. The difference in required courses is that 6 credits of mathematical analysis may be substituted for the 6 credits in advance probability.

Elective Courses. 1. Environmental statistics electives: 15 credits from 500-level courses on topics involving environmental statistics as approved by the program committee. Topics courses may come from such areas as statistics, geography, remote sensing, quantitative ecology, resource modeling, environmental epidemiology, environmental policy, etc. Designated statistics electives include several statistics courses, such as Ecometrics, Quantitative Ecology, Statistical Ecology Spectrum, Environmental Statistics, and Statistical Distributions in Scientific Work; and 2. Mathematical statistics and probability: 9 credits from 500-level courses such as Stochastic Processes, Probability Theory, Categorical Data Analysis, Nonparametric Statistics, Multivariate Analysis, Statistical Decision Theory, and Spatial Statistics.

Master's Degree in Statistics with Environmental Statistics Option. The goal in proposing a master's degree with en-

vironmental statistics option is to recognize degree candidates who have pursued a coherent academic program in environmental statistics. The requirements of the environmental statistics option are, in addition to those of the master's degree in statistics, at least 12 credits in topics involving environmental statistics.

The Advisory Committee on Environmental Statistics. An advisory committee on environmental statistics will consist of fifteen members at a time, six from statistics and nine from participating substantive departments. The role of the committee will be two-fold. First, to act as a focal point in graduate education in environmental statistics. This includes student advising, for students whose primary affiliation is statistics, but also for students whose primary affiliation is elsewhere with a strong interest in environmental statistics. Second, to take the initiative in obtaining additional support for environmental statistics, including training and internship grants, and to provide research assistantship funding to students in their last two years.

Graduate Quantitative Ecology Program

Ecology has entered a phase of development wherein much of the subject matter is approached by quantitative reasoning. This occurs through application of deterministic or stochastic models to theoretical questions in ecology, or it occurs through sophisticated use of applied statistics for experimental design and hypothesis testing. We experience greater fusion of these approaches as new generations of researchers become better educated in quantitative methods. Thus, there is a demand not only for the practitioners of quantitative ecology but also for field ecologists who are more accomplished in quantitative techniques.

The importance of quantitative ecology is apparent in recent developments of employment opportunities, both at academic and applied levels. A large fraction of job descriptions include mathematical modeling or statistical capability in addition to the ecological subject matter; this is a trend that will, undoubtedly, continue. The trend is visible in the increasing devotion of journals to the quantitative aspects of ecology; relatively new journals such as Theoretical Population Biology and Ecological Modeling join The American Naturalist as exclusively devoted journals, but also Ecology, Journal of Animal Ecology, Oikos, etc., are becoming increasingly quantitative in content.

Penn State has long been producing graduates in the field of quantitative ecology through the Biology, Ecology, and Statistics Graduate Programs. In order to centralize and formalize the student's education in this area, the Quantitative Ecology Option for the M.S. or Ph.D. in Ecology has been instituted. Graduation with this option will document the student's preparation and competence to contribute to this increasingly important area of science.

Program of Study

This intercollege program emphasizes the properties of ecosystems by focusing attention on interactions of single organisms, populations, and communities with their environment. It is designed to give students a basic understanding of ecological theory and research techniques and is complementary to other Penn State environmental programs that emphasize man's role in ecosystems. The program is administered through the Graduate School by an Interdisciplinary Committee on Ecology. The faculty comprises more than 45 members from twelve academic departments. Both Ph.D. and M.S. degrees are awarded. To ensure breadth of training in the fundamentals of ecology, students are required to take at least one course from each of three core areas: physiological ecology, population ecology, and community/ecosystem ecology. Beyond these basic courses, course requirements are determined by the student and the student's adviser and graduate committee. Completion of a thesis acceptable to the committee is required for both degrees.

The ecology program offers an option for the Ph.D. degree emphasizing the quantitative aspects of ecology, including mathematical and statistical modeling of ecological phenomena and applications of statistics to experimental design and data analysis. The option entails some extra course requirements plus a thesis in quantitative ecology directed by a member of the quantitative ecology faculty.

Research Facilities

The University Park campus is ideally situated for research in varied ecosystems ranging from undisturbed upland bogs, forests, streams, and lakes to areas severely affected by strip mining, deforestation, sewage effluents, and agriculture. Penn State has an excellent biological library. Collections include herbaria for mosses, fungi, and higher plants; excellent fish, herp, mammal, and bird collections; and the collection of the Frost Entomological Museum. Penn State has extensive animal-care facilities, experimental gardens, greenhouses, climate-controlled growth chambers, and well-equipped laboratories for air pollution monitoring, studies of plant and animal physiological ecology, and continuous culture of aquatic organisms. Remote-sensing equipment for photoanalysis and digital data analysis is available, as are completely equipped photogrammetry and photointerpretation laboratories. The University has a full range of computer facilities, including many terminals and many microcomputers. Consultants in statistics and computer science are available to graduate students. Students in the ecology program have access to the Stone Valley Experimental Forest, state gamelands, state forestlands, and the Spruce Creek Experimental Area.

Cross-Disciplinary Statistical Ecology and Environmental Statistics

The pressing problems in environmental and ecological resource management can be addressed on theoretical grounds, but empirical observations and experimentation are required to test the theories, and importantly, to answer specific real-world questions. Experience has shown that in the general fields of ecology and environmental science, con-

ventional research designs often are inadequate and the data involved usually have nonstandard features due to spatial and temporal variations and to social, economic, and political constraints. We cannot change natural selection and evolution, the behavior of organisms, and the complexities of population-community-ecosystem dynamics. Nor do we have perfect measuring devices for the many variables involved. Statistics becomes the key to dealing with the probabilistic nature of natural processes and their responses to man-made perturbations and stress.

Statistical theory and techniques already have contributed greatly to advances in the natural sciences and, together with technological advances in computing and other fields such as remote sensing, to environmental and ecological resource management. But serious problems remain. Definition and resolution of these problems require a multidisciplinary approach involving collaboration of biologists, ecologists, environmental scientists, social scientists and economists, and mathematical and applied statisticians. This collaboration also needs a coherent intellectual focus.

Several of the principal faculty participants at Penn State have been involved with multidisciplinary approaches to assessing and solving several real-world environmental problems of both qualitative and quantitative in nature. At Penn State, we have both the formal and informal mix of graduate programs in quantitative ecology and in environmental statistics which have largely resulted from the informal groups we have had on the campus for some years interested in statistics, ecology, and the environment.

Consider, for example, the research and training effort of the Center for Statistical Ecology and Environmental Statistics. Over the past twenty-five year period, we have had a variety of involvements with statistical methods and issues pertaining to environmental monitoring and assessment of a variety of ecological resources, such as: Forest Service, USDA: Spatial Statistics and Statistical Distributions, 1971; Stochastic Models and Sampling Designs for Forest Insect Populations, 1974; National Marine Fisheries Service, NOAA: Distributions and Geographic Distributions of Fish and Shell-Fish in Georges Bank, 1977-79; Chesapeake Bay Stock Assessment Committee: Monitoring, Sampling, and Assessment in the Chesapeake, 1985-1992; EPA Office of Policy, Planning and Evaluation: Mathematical Statistics and Stochastics for Data Interpretation and Improvement for Environmental Protection Research and Management, 1989-1993; Research and Outreach on Observational Economy, Environmental Sampling, and Statistical Decision Making in Statistical Ecology and Environmental Statistics, 1993- ; EPA Office of Research and Development: Research and Outreach on Sampling Design and Status Estimation for Environmental Monitoring and Assessment Program, 1993- . As per need, interest, and expertise, the faculty and research associates that have participated in these research and outreach activities include G. J. Babu, J. S. Fairweather, C. R. Goodall, S. D. Gore, A. Kaur, G. Lovison, W. L. Myers, J. K. Ord, Donna Peuquet, C. Taillie, S. K. Thompson, and several others. Several graduate students and interns have also benefitted from various disciplines, such as statistics, ecology, entomology, forestry, fish and wildlife, geoscience, plant pathology, and others.

Penn State is also uniquely positioned to proffer pioneering programs of graduate study in spatially-based statistical analysis of environment. The scope of such programs can extend well beyond the conventional concept of "spatial statistics".

The Office for Remote Sensing of Earth Resources (ORSER) (Co-Director: W. L. Myers) in the Environmental Resources Research Institute (ERRI, Director: Archie McDonnell) has formal roles in geographic informations systems (GIS) technology support for USDI, National Park Service (NPS) at the federal level and for the Department of Environmental Resources (DER) at the state level. Issues addressed in these support roles provide rich arrays of both real-world environmental challenges and extensive spatial databases on which to test new analytical approaches. ORSER has an interdisciplinary research focus which nicely complements the educational strengths of academic units.

The School of Forest Resources has an Analytical Landscape Statistics Laboratory (ALSL, Director: W. L. Myers) which serves both research and educational purposes. Like the facility at ORSER, this laboratory has multi-system GIS capability along with workstation Splus and GeoLink bridge between the statistical and spatial software domains. The School of Forest Resources is developing modularized programs of self-study in GIS whereby students with varying backgrounds can work progressively into GIS spatial technologies at an individually appropriate pace while minimizing course schedule conflicts.

The Department of Geography has an Advanced GIS Laboratory appropriate for group instruction in a classroom environment. This instructional facility supports a substantial complement of courses in spatial technologies offered by the Geography Department. The Geography lab has close liaison with the Earth Systems Science Center (ESSC, Director: Eric Barron) which is internationally known for its research in modeling of global hydrologic cycles using GCM approaches on super computers.

The Geography-ESSC and Forestry-ORSER spheres are linked across campus and beyond by the Penn State University computing backbone conduit to the Internet. The Land Analysis Laboratory in the Department of Agronomy is yet another facility with multi-system GIS capability. This laboratory has a special place in the campus distributed systems infrastructure by virtue of its global positioning systems (GPS) base station.

The College of Agriculture has long-standing emphasis on collaborative work in artificial intelligence and expert systems which complements the spatial and statistical capabilities interwoven through the campus fabric as outlined above.

The Penn State Department of Statistics is well known for its research and outreach in both disciplinary and cross-disciplinary statistics.

Journal of Environmental and Ecological Statistics

Professor Patil is the founding editor of the journal which has been initiated to provide a timely cross-disciplinary forum with appropriate emphasis on discussion under the initiative of a prestigious editorial board of one hundred and twenty five eminent professional experts. The journal is published by Chapman and Hall.

Environmental and Ecological Statistics will publish papers on practical applications of statistics and related qualitative methods to environmental science addressing contemporary issues. Emphasis will be on applied mathematical statistics, statistical methodology and data interpretation and improvement for future use with a view to advance statistics for environment, ecology and environmental health, and to advance environmental theory and practice using valid statistics.

Besides clarity of exposition, a single most important criterion for publication will be the appropriateness of the statistical method to the particular environmental problem. The Journal will cover all aspects of the collection, analysis, presentation and interpretation of environmental data for research policy and regulation. The Journal is cross-disciplinary within the context of contemporary environmental issues and the associated statistical tools, concepts and methods.

The Journal will broadly cover theory and methods, case studies and applications, environmental change and statistical ecology, environmental health statistics and stochastics and related areas. Special features include invited discussion papers; research communications; technical notes and consultation corner; mini-reviews; letters to the Editor; news, views and announcements; hardware and software review; data management etc.

EPA Observational Economy Series

The EPA Observational Economy Series is a result of the research conducted under a cooperative agreement between the U.S. Environmental Protection Agency and the Pennsylvania State University Center for Statistical Ecology and Environmental Statistics.

The EPA grant entitled "Research and Outreach on Observational Economy, Environmental Sampling and Statistical Decision Making in Statistical Ecology and Environmental Statistics" consists of ten separate projects in progress at the Penn State Center: 1) Composite Sampling and Designs; 2) Ranked Set Sampling and Designs; 3) Environmental Site Characterization and Evaluation; 4) Encounter Sampling; 5) Spatio-temporal Data Analysis; 6) Biodiversity Analysis and Monitoring; 7) Adaptive Sampling Designs; 8) Statistics in Environmental Policy and Regulation for Compliance and Enforcement; 9) Statistical Ecology and Ecological Risk Assessment; and 10) Environmental Statistics Knowledge Transfer, Outreach and Training.

The series is published by the Statistical Analysis and Computing Branch of the Environmental Statistics and Information Division in the EPA Office of Policy, Planning and Evaluation, Washington, DC.

Environmental Risk Assessment Initiative of the Environmental Science and Technology Council of the University Future Committee

Professor Patil has been asked by the Council to lead its initiative on risk assessment. The present concept and motivation are as follows:

The physical environment is a major determinant of the quality of human life. At the same time, how we attempt to manage the environment at the margin contributes to our ability to produce, distribute, and enjoy the services and material goods that also help to define our quality of life.

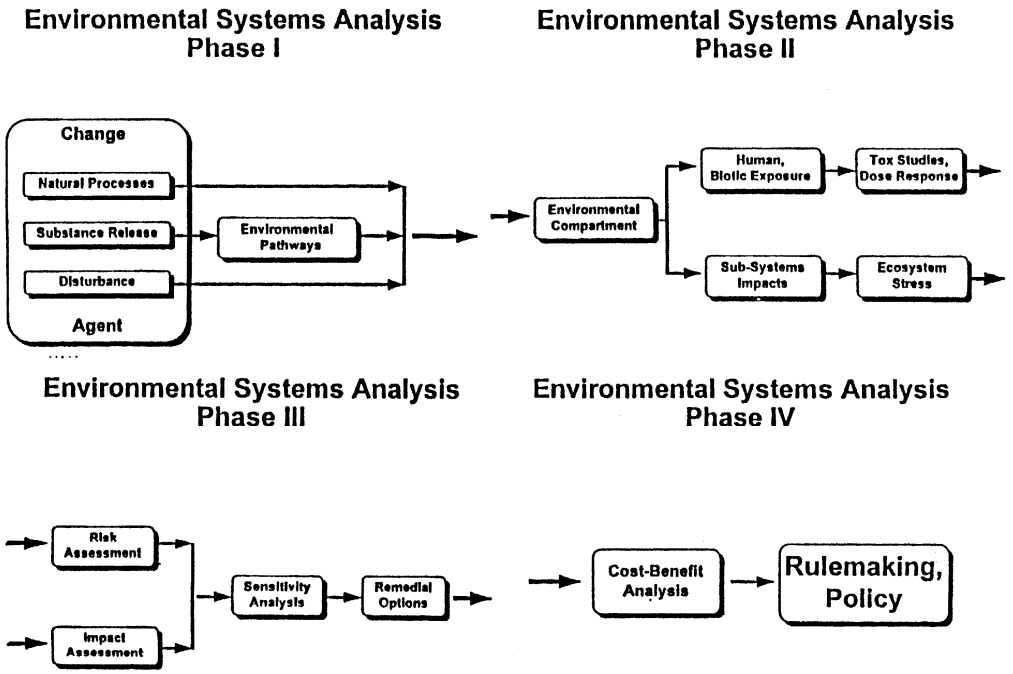
It is vital for our society to understand the opportunities and constraints it faces in deciding how to relate to the natural world. This understanding has been and still continues to be hampered by the difficulty of devising and conducting controlled experiments. We face cycles of no information, new information, and non-information. We encounter in one setting data gathered in other setting and for different purposes. We confront the results of advocacy in the design of data gathering effort and choice of rules of analysis. And we face non-linear dynamic systems with largely linear static tools. More sophisticated concepts and methods translated into more widely applicable methodologies can help with environmental risk assessment and risk based decision making. This demands timely revitalization and integration of cross disciplinary research, instruction, and outreach for interested faculty, students, and sponsors at the University. The purpose of the proposed initiative is precisely to help meet this demand in a manner that is synergistic for the University community and the concerned society at the time of this critical national need. The schematic diagrams on the next pages may help provide the picture of the scientific concept and the proposed cross-disciplinary approach.

Technical Reports and Preprints

- 86-1001 Statistical issues in combining ecological and environmental studies with examples in marine fisheries research and management by G.P. Patil, G.J. Babu, M.T. Boswell, K. Chatterjee, E. Linder and C. Taillie
- 86-1101 Estimation of relative fishing power of different vessels by G. J. Babu, M. Pennington and G. P. Patil
- 86-1102 Field based coastal and estuarine statistical indices of marine degradation by M. T. Boswell and G. P. Patil
- 86-1103 Time series regression methods for the evaluation of the causes of fluctuation in fishery

-A SCHEMATIC ENVIRONMENTAL ASSESSMENT PERSPECTIVE-

-Stressor-Stress-Response Paradigm-
(NAFTA, OECD, UNEP, World Bank)

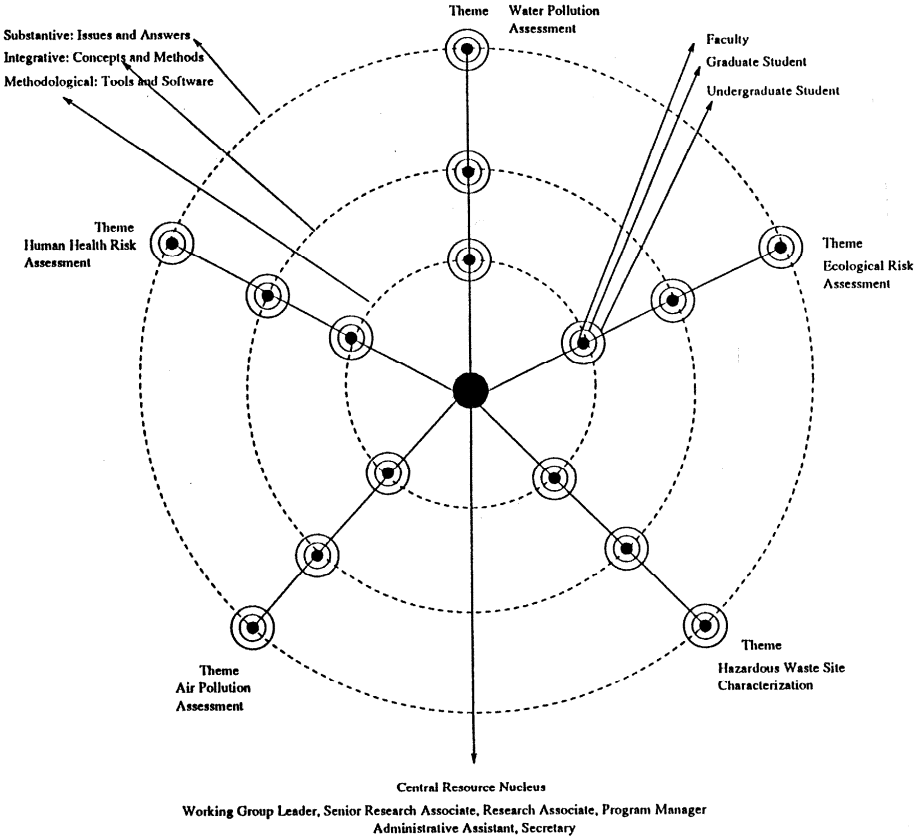


stock sizes by M. T. Boswell, E. Linder, J. K. Ord, G. P. Patil and C. Taillie

- 86-1104 Effects of toxic pollutants on aquatic resources using statistical models and techniques to extrapolate acute and chronic effects benchmarks by Ernst Linder, G. P. Patil, Glenn W. Suter II and C. Taillie
- 86-1201 Lognormal distributions and their applications in ecology by Brian Dennis and G. P. Patil
- 86-1202 Power series distributions and their conjugates in stochastic modeling and Bayesian inference by R. S. Abdul-Razak and G. P. Patil
- 86-1203 A general technique for generating pseudo multivariate random variables: A Markov process approach by Subhash R. Lele and M. T. Boswell
- 86-1204 A study of the relationship between diversity indices of benthic communities and heavy metal concentrations of Northwest Atlantic sediments by N. C. Bolgiano, G. P. Patil, and R. N. Reid
- 86-1205 Application of event tree risk analysis to fisheries management by Ernst Linder, G. P. Patil, and Douglas Vaughan
- 87-0401 Weighted distributions by G. P. Patil, C. R. Rao, and M. Zelen
- 87-0402 Bivariate weighted distributions and related applications by G. P. Patil, C. R. Rao and M. V. Ratnaparkhi
- 87-0501 Selection of endpoints for a crystal cube, and development of indices for coastal and estuarine degradation for use in decisionmaking by M. T. Boswell and G. P. Patil
- 87-0502 A Perspective of composite sampling by M. T. Boswell and G. P. Patil

PSU ESTC RISK ASSESSMENT INITIATIVE

-SCHEMATIC DIAGRAM-



- 87-0503 Data-based sampling and model-based estimation for environmental resources by G. P. Patil, G. J. Babu, R. C. Hennemuth, W. L. Myers M. B. Rajarshi, and C. Taillie
- 87-0504 Role and use of composite sampling and capture-recapture sampling in ecological studies by M. T. Boswell, K. P. Burnham, and G. P. Patil
- 87-0505 On transect sampling to assess wildlife populations and marine resources by F. L. Ramsey, C. E. Gates, G. P. Patil, and C. Taillie
- 88-0301 Statistical analysis of recruitment data for eighteen marine fishstocks by C. Taillie, G. P. Patil, and R. C. Hennemuth
- 88-0302 Modeling and analysis of recruitment distributions by C. Taillie, G. P. Patil, and R. C. Hennemuth
- 88-0303 Recruitment distributions and inferences about long-term yields by G. P. Patil, C. Taillie, and R. C. Hennemuth
- 88-0304 Kernel methods for smoothing recruitment data: comparison of constant and variable bandwidths by C. Taillie, G. P. Patil and R. C. Hennemuth
- 88-0305 A simulation model for fish recruitment and fish stock size: An implementation for micro computers by M. T. Boswell and Joan Palmer
- 88-0306 Incorporation of statistical models in the analysis of Georges Bank catch per tow data by M. T. Boswell and G. P. Patil
- 88-1201 Statistical ecology, encountered data, and meta analysis: A few perspectives of statistical ecology (Parma) by G. P. Patil

- 89-0101 Probing encountered data, meta analysis and weighted distribution methods by G. P. Patil and C. Taillie
- 89-0501 Performance of the largest order statistics relative to the sample mean for the purpose of estimating a population mean by G. P. Patil and C. Taillie
- 89-0601 Evaluation of the kriging model for abundance estimation of marine organisms by N. C. Bolgiano, M. T. Boswell, G. P. Patil, and C. Taillie
- 89-0602 Assessing scales of spatial variability in Chesapeake Bay trawl data by N. C. Bolgiano, M. T. Boswell, G. P. Patil, and C. Taillie
- 89-1001 Analsyis of white perch abundance trends in the Choptank and York rivers by N. C. Bolgiano, M. T. Boswell, and G. P. Patil
- 89-1002 Statistical ecology, encountered data, and meta anslysis: A few perspectives of statistical ecology (Poona) by G. P. Patil
- 90-0901 Efficiency of various composite sample retesting schemes to classify samples with presence/absence measurements by M. T. Boswell, S. Gore and G. P. Patil
- 90-0904 Small-sample behavior of Rao's efficient scores test for the two-sample gamma problem by G. P. Patil, C. Taillie, and R. P. Waterman
- 90-1001 Composite sample designs for characterizing continuous sample measures relative to a criterion by M. T. Boswell, and G. P. Patil
- 90-1002 A statistical approach to the evaluation of the attainment of interim cleanup standards by G. P. Patil and C. Taillie
- 90-1103 Proceedings of the workshop on superfund hazardous waste: Statistical issues in characterizing a site: Protocols, tools, and research needs by (eds.) Herbert Lacayo, Royal J. Nadeau, G. P. Patil, and Larry Zaragoza
- 91-0201 Composite sampling for estimating population parameters: Some extensions and a unifying model by G. Lovison, S. D. Gore, and G. P. Patil
- 91-0710 The art of computer generation of random variables by M. T. Boswell, S. D. Gore, G. P. Patil, and C. Taillie
- 91-0725 Encountered data, statistical ecology, environmental statistics, and weighted distribution methods by G. P. Patil
- 91-1201 Ranked set sampling: An annotated bibliography by G. P. Patil, A. K. Sinha, and C. Taillie
- 91-1202 Ranked set sampling by G. P. Patil, A. K. Sinha, and C. Taillie
- 91-1203 Relative precision of ranked set sampling for some statistical distributions useful in ecological work by G. P. Patil, A. K. Sinha, and C. Taillie
- 91-1204 Ranked set sampling from a finite population in the presence of a trend on a site by G. P. Patil, A. K. Sinha, and C. Taillie
- 92-0101 Studies on the applications of composite sample techniques in hazardous waste site characterization and evaluation: I. Onsite surface soil sampling for pcb at the Uniontown site by S. D. Gore, M. T. Boswell, G. P. Patil, and C. Taillie
- 92-0201 Dose-response models for the probabilities of differential toxic effects in developmental toxicity study by S. Talwalker, G. P. Patil, and C. Taillie
- 92-0202 Qualitative and quantitative assessment of the risk from the exposure to fetotoxic chemical compounds by S. Talwalker, G. P. Patil, and C. Taillie
- 92-0301 Detection of a contaminated observations in binomial sampling: A Bayesian approach by O. Ozturk, G. P. Patil, and C. Taillie
- 92-0305 Studies on the applications of composite sample techniques in hazardous waste site characterization and evaluation: II. Onsite surface soil sampling for pcb at the Armagh site by S. D. Gore, G. P. Patil, and C. Taillie
- 92-0401 Composite sampling protocols for site characterization and evaluation of cleanup attainment by M. T. Boswell, S. D. Gore, G. D. Johnson, and G. P. Patil
- 92-0402 Encounter sampling and modeling in ecological and environmental studies using weighted distribution methods by G. P. Patil, C. Taillie, and S. Talwalker
- 92-0701 Diversity measurement and comparison with examples by J. H. Gove, G. P. Patil, and C. Taillie
- 92-0702 Plant species diversity on even-aged harvests at the Hubbard Brook Experimental Forest: 10 year results by J. H. Gove, C. W. Martin, G. P. Patil, D. S. Solomon, and J. W. Hornbeck
- 92-0801 A Bayesian approach to classifying samples as polluted or not polluted by M. T. Boswell, S. D. Gore, G. P. Patil, and C. Taillie
- 92-0802 Annotated bibliography of composite sampling by M. T. Boswell, S. D. Gore, G. Lovison, and G. P. Patil
- 92-0803 Environmental sampling and statistical modeling with examples by G. P. Patil, S. D. Gore, and A. K. Sinha
- 92-0804 Environmental chemistry, statistical modeling, and observational economy by G. P. Patil, S. D. Gore, and A. K. Sinha
- 92-0805 Sampling dust from human dwellings to estimate the prevalence of indoor allergens by T. J. Lintner, C. L. Maki, K. A. Brame, and M. T. Boswell
- 92-0806 Certain multivariate considerations in ranked set sampling and composite sampling designs by S. D. Gore, G. P. Patil, A. K. Sinha, and C. Taillie

- 92-0807 Maximizing the diameter class diversity of uneven-aged northern hardwood stands by J. H. Gove, D. S. Solomon, S. E. Fairweather, and G. P. Patil
- 92-1005 Finite population corrections for ranked set sampling by G. P. Patil, A. K. Sinha, and C. Taillie
- 92-1006 Ecological diversity and forest management by J. H. Gove, G. P. Patil, B. F. Swindel, and C. Taillie
- 92-1007 Design and analysis of composite sampling procedures: A Review by G. Lovison, S. D. Gore, and G. P. Patil
- 92-1008 A unified linear model for estimation with composite sample data by G. Lovison
- 92-1009 Observational economy of ranked set sampling: Comparison with the Regression estimator by G. P. Patil, A. K. Sinha, and C. Taillie
- 92-1011 Ranked set sampling for multiple characteristics by G. P. Patil, A. K. Sinha, and C. Taillie
- 92-1103 A general framework for ranked set sampling with application to encounter sampling and weighted distributions by G. P. Patil, A. K. Sinha, and C. Taillie
- 92-1202 Technical reports, reprints, and published books by Barbara Freed
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