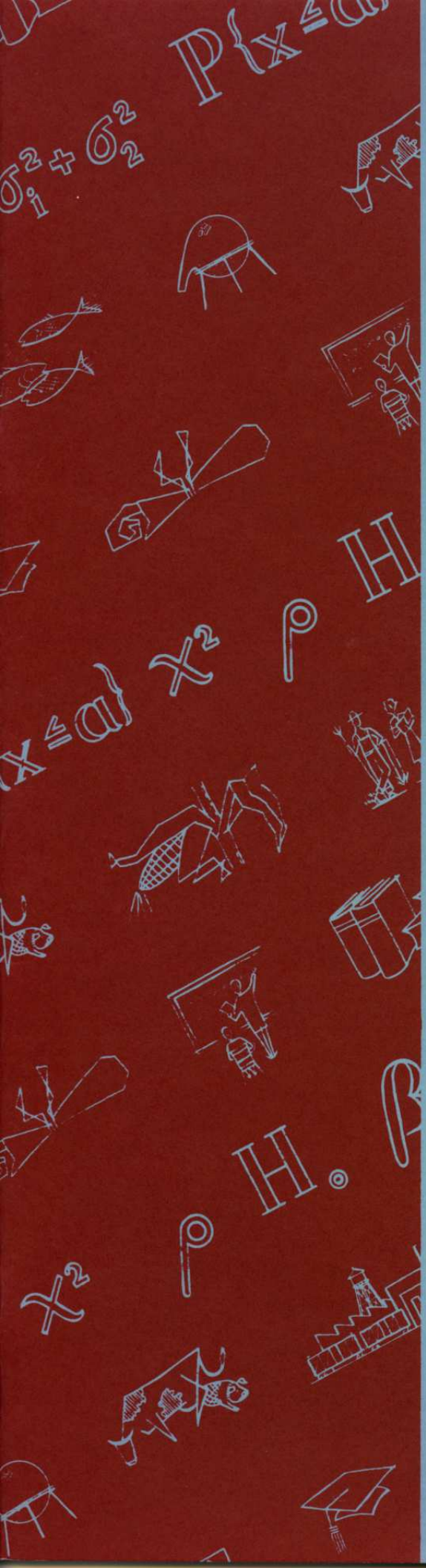

STATISTICAL LABORATORY

ESTABLISHED 1933

ANNUAL REPORT

July 1, 1970 to June 30, 1971

IOWA STATE UNIVERSITY

Ames, Iowa

President W.R. Parks
Iowa State University of
Science and Technology
Ames, Iowa

Dear President Parks:

This is the annual report of the Statistical Laboratory at Iowa State University for the fiscal year July 1, 1970, through June 30, 1971. It reports on the research, consulting, teaching and operational work of the staff of the university statistical center.

The statistical center is composed of:

(1) The Statistical Laboratory, a research and service institute under the president's office;
(2) The teaching Department of Statistics in the College of Sciences and Humanities;
(3) The statistics department of the Agriculture and Home Economics Experiment Station; and
(4) The statistics participant in the Sciences and Humanities Research Institute and the Engineering Research Institute.

The staff members of the Statistical Laboratory work in cooperation with many institutions and departments of Iowa State University. This annual report is a review of these activities as well as a record of the activities carried on solely by the Statistical Laboratory.

Respectfully submitted on behalf
of the Statistical Laboratory staff,

T.A. Bancroft

T.A. Bancroft
Director, Statistical Laboratory;
Head, Department of Statistics;
Head, Statistics Department,
Agriculture and Home Economics
Experiment Station

THE STATISTICAL LABORATORY

ANNUAL REPORT 1970-1971

Personnel

The statistical complex at Iowa State University includes all the components of a complete statistical center: the Statistical Laboratory, an institute under the president's office; the Department of Statistics in the College of Sciences and Humanities; the Statistics Department of the Agriculture and Home Economics Experiment Station; and the statistics participants in the Sciences and Humanities Research Institute and the Engineering Research Institute.

The director of the Statistical Laboratory reports to the president of the university through the vice president for research. He also serves as head of the Department of Statistics and Statistics Department, and in these capacities reports to the respective dean and director.

The various components of the statistical center share personnel, which means that a staff member's salary may be budgeted from several sources, depending on the emphasis of his work. In addition, a number of cooperative agreements with federal agencies provide research funds for both staff and graduate students.

The members of the statistical center, including its affiliated fellows and graduate students, are listed below:

THE STATISTICAL LABORATORY STAFF FOR THE FISCAL YEAR 1970-71

Under the administrative direction of

W. Robert Parks, Ph.D. .....President of the University
Kenneth J. Frey, Ph.D. .....Acting Vice President for Research; Acting Dean of the Graduate College, through March 14
Daniel J. Zaffarano, Ph.D. .....Vice President for Research; Dean of the Graduate College, beginning March 15
Chalmer J. Roy, Ph.D. .....Dean, College of Sciences and Humanities; Director, Sciences and Humanities Research Institute
Floyd Andre, Ph.D. .....Dean, College of Agriculture; Director, Iowa Agriculture and Home Economics Experiment Station
Theodore A. Bancroft, Ph.D. .....Director, Statistical Laboratory; Head, Department of Statistics; Head, Statistics Department, Iowa Agriculture and Home Economics Experiment Station

Professors

T. A. Bancroft
C. Philip Cox
David Cox
Herbert T. David
Wayne A. Fuller—faculty status in economics as well as statistics
Donald K. Hotchkiss
David V. Huntsberger
Oscar Kempthorne—Distinguished Professor, College of Sciences and Humanities
J. K. Sengupta—faculty status in statistics as well as economics
George W. Snedecor—Professor Emeritus—in absentia
Norman V. Strand
B. V. Sukhatme
James Walsh—joint appointment with Department of Psychology—on leave
Leroy Wolins
George Zyskind

Professor of Mathematics

James L. Cornette—summer 1971

Associate Professors

Barry Arnold—joint appointment with Department of Mathematics
Richard Groeneveld
Chien-Pai Han
C. C. Mosier—joint appointment with Computation Center
Edward Pollak—joint appointment with Department of Genetics
Richard D. Warren—joint appointment with Department of Sociology and Anthropology

Assistant Professors

Harold Baker
Terry Dickinson—joint appointment with Department of Psychology
Jon Geadelmann—beginning winter quarter
Roy Hickman
Paul Hinz
James L. Hutter—joint appointment with Department of Political Science
Dean Isaacson—joint appointment with Department of Mathematics
William Kennedy
Glen Meeden
Richard Mensing
Abel Mexas—on assignment in Mexico, through winter quarter
Vincent Sposito
Shashikala Sukhatme

Postdoctoral Associate

Sunardi Wirjosudirdjo

Instructors and Associates

George Battese
Mary Ann Chamberlain
G. L. Ghai
Louis Jensen
John Kinney
John Lin
Roland Loup—beginning winter quarter
Jeff Meeker
John Schmid
Wendell Smith
Richard Stein
Mauritz VanAarde
James Veale

Graduate Assistants

(The status of graduate students often changes. Students who have held the title of graduate assistant during the year are listed here.)

Guillermo Adames-Suari
Chaturvedula Asok
Richard Chamberlain
Mohamed El-Sabbagh
Ron Gallant
Linda Gorman
Earl Haynes
M. A. Hidiroglou
Patricia Howard
Elizabeth Huang
Her Tzai Huang
Cary Isaki
J. D. Jobson
Kazimierz Karpinski
Henry Kelker
Geung Ho Kim
G. Nick Lauer
Robert Mason
James Mellon
Kenneth Merritt
Roger Mrachek
Martin J. O'Connell
David Pyne
William Warde
Kirk Wolter

NIH Trainees

Pamela Doctor
Kenneth Offord
Lonnie Vance
James Whipple

NDEA Fellows

Richard Dorsch
John Goebel
Nancy Heath
Joan Keller

NSF Fellows

Thomas Keefe
Richard Madsen

Supported Graduate Students

Lal Chand, USAID
Isidoro David, Rockefeller Foundation, Philippines
Mohamed El-Sabbagh (joint statistics-industrial engineering), Department of Industrial Engineering
Joseph Grimes, Department of Mathematics
Norman Hoesly, Department of Mathematics
Jairoj Jayavadhanangkur, AID, Census Bureau, Thailand
Muhammad Malik, USDA, Pakistan
Omar Martinez, Centro de Investigaciones Agronomicas, Venezuela
Nimmagadda Murthy, AID, India
Preecha Sakarindr, Rockefeller Foundation, Thailand
A. Shawki Salem, Government of UAR
V. B. Solomon, Drake University
Malte Sund, Volkswagen Foundation
Jose Villasenor, Ford Foundation, Mexico
George Wang (joint statistics-economics), Department of Economics

Unsupported Graduate Students

Thomas Aiuppa
Michael Althaus
Claude Angers
Ray Bailey
Robert Centner
Kuo-Ming Chien
Richard Chung
Linda Costea
Peampan Davivongs
Modesto Freites
Harold Keplinger
Haeja Chung Kim
Charles MacIsaac
Yupha Onthuam
Dennis Tsai
Wai Wo Wong
Tetsuo Yamada

Statistical Data Processing Service

Bud J. Meador, Supervisor
Charlotte Bentley
Nancy Owens—spring quarter

General Office Staff

Margaret G. Kirwin, Administrative Assistant
Kathleen Ringgenberg, Accountant
Susan Alice Brown, Technical Writer-Editor
Avonelle Jacobson, Supervisor, Teaching Section
Shirley Saveraid, Secretary, Statistical Numerical Analysis and Data Processing Section—fall and winter quarters
Kristie Whitaker, Secretary, Statistical Numerical Analysis and Data Processing Section—beginning spring quarter
Iveta Zeliadt, Secretary, Experimental Design-Genetic Statistics Section
Jan Bates, Secretary—fall and winter quarters
Norma Christian Elwick, Secretary
Cheryl Huss, Secretary
Hilda Merritt, Secretary—beginning winter quarter
Donna Cooper Millang, Secretary

Survey Section

Sandi Partlow, Secretary
Marjorie Mason, Office Manager
Hazel Cook, Survey Supervisor
Anna B. Woodrow, Survey Supervisor
Betty Fell Price, Programmer—through spring quarter
Duane Lande, Programmer—beginning summer 1971
Statistical Clerks:
Evelyn Green
Ava Klopf
Margaret Nichols
Florence Osam

Consulting and Cooperative Research

The main objective of statistical consulting and cooperative research is to assist research workers in the efficient analysis and interpretation of data represented by probabilistic models. The data may be obtained from designed experiments and surveys or result from operational type investigations.

The needs of research workers in substantive fields for statistical consulting services may vary in complexity and creative statistical methodology input requirements from fairly routine assistance using known statistical techniques, through an innovative and sophisticated application or the modification and adaptation of known statistical methodology, to the creation of some new statistical theory or methodology, specifically designed to provide a solution to an important problem in some scientific investigation.

With the rapid advances in statistical methodology, it's difficult for a research worker from a substantive area to keep current with statistics as well as his own field. Therefore a skilled consulting statistician is able to help the research worker examine his objectives in view of his proposed investigation, to ensure that it will answer his questions.

The Iowa Agriculture and Home Economics Experiment Station (IAHEES) supports statistical consulting services for many staff members and graduate students in substantive areas. The Experiment Station budget also provides some funds for statistics research and the development of new statistical methods.

Statistical Services in the Animal Sciences and Plant Sciences, IAHEES Project 101, has supported the consulting services of Dr. D. F. Cox, Dr. Jon Geadelmann, Dr. Paul Hinz, Dr. D. K. Hotchkiss and several advanced graduate students. These staff members assist faculty and graduate students of IAHEES departments in experimental design and data analysis and in improving the methods used in the research conducted by these departments. New methods in design and data analysis are being continually explored in order to continue an adequate consulting service. Computer programs for unbalanced data have been made accessible; work with OMNITAB continues to expand in both research and teaching, and typewriter terminals are now under investigation to determine if they would be useful.

IAHEES Project 1448, Consultation and Research in Mathematical and Statistical Genetics, has permitted project director Dr. Edward Pollak to work with personnel from animal and poultry science and from the USDA Regional Swine Laboratory. Project 113, Statistical Services for Sampling Investigations, provides consultation and statistical survey services for all IAHEES departments. The project is directed by Professor N. V. Strand and Harold Baker. Arrangements with the Engineering Research Institute, similar to that with IAHEES, support some of the consulting done by Dr. H. T. David.

This report is intended only to give an indication of the consulting done by Statistical Laboratory personnel. It is neither possible nor practical to report every consulting project, but this condensation will give an indication of the type of projects with which staff members assist. Some projects require only a few minutes of a consultant's time, while others require many hours over a period of many months. Two or more staff members often will be consulted, independently or jointly, on a single project. The project may involve individual students, faculty members or a group of researchers. The results may appear in a thesis, be presented as a paper at a meeting, or be published. Sometimes the consultant's contribution will result in his recognition as a paper's co-author.

About half of the consulting involves assistance with analysis of data. Regression analysis was used for an industrial engineering study of the cost of operating fleet cars which was designed to determine the best disposal time. Path analysis was chosen for industrial administration research on the selection of eating places, and typal analysis was the statistical method selected to assist sociologists with a study of smoking behavior. An economics study of alternative manpower training programs required the use of a programming revision of benefit cost analysis. Error analysis of the

Fourier transformation of a regression function, plus model building based on distribution of chi-square for Poisson counts, was used for a nuclear engineering study of the space-dependent characteristics of a reactor.

Cluster analysis was chosen to interpret data from stroke patients in a study for Mercy Hospital in Des Moines to classify individuals into groups with similar characteristics. Analysis of variance and factor analysis were selected for a longitudinal study of managerial effectiveness for the Owens-Illinois Glass Co. Such off-campus consulting projects are accepted when time permits and when the work is considered mutually beneficial to the parties involved. Another consultant helped faculty members from the Department of Agronomy at the University of Nebraska interpret formulae on correlations between relatives when there is a parent-offspring mating system. Wayne Fuller made two trips to Peru to consult with personnel of the Ministry of Agriculture on conduct of a survey of household consumption. The trips were a part of the Iowa Universities Technical Assistance Program to Peru conducted under a United States Agency for International Development contract.

A split-split plot experiment was designed for an entomological study of the effect of chemicals and rate of application on corn borer damage. Analysis of variance, analysis of covariance and orthogonal polynomials were used to determine the effect of soil moisture and soil texture on the growth of Scotch pine seedlings and the production of photosynthetic materials for forestry research. Principal components analysis was used to identify plant communities and associations in a virgin prairie for a plant ecology study.

Data was organized for an analysis of unweighted means in a study for food technology of the effect of concentration of flavor on judges' scoring of fat products. The AARDVARK program was recommended for a veterinary physiological study of the effect of diets on the blood constituents of dogs, which involved factorial analysis and split plot. A rectangular balance incomplete block was designed for a fisheries study of the effect of drug injection v.s. oral intake on the growth characteristics of fish.

Bioassay was the statistical method used for animal science research on the prolactin assay of pig pituitary glands at various stages of pregnancy and lactation, and the influence of hysterectomy on prolactin production. An agricultural engineer was assisted with the design and analysis of studies of the activities (sleeping, standing, eating, etc.) of pigs subjected to different treatments such as temperature, lighting and air movement. Time-lapse films of the pig pens resulted in records of percentage of time in various activities which are studied as well as patterns of activity, such as sleeping-waking patterns. The OMNITAB regression program with plots was used for a study in the Department of Entomology of optimum methods for controlling soybean insect pests. The research included measuring the economic feasibility of pesticide control by examining yield loss after various degrees of defoliation at various stages in the life cycle.

The Survey Section and the Statistical Numerical Analysis and Data Processing Section of the Statistical Laboratory both provide extensive consulting services to staff members, graduate students, and when time permits, off-campus personnel.

Survey Section

Staff members of the Survey Section are able to adapt the services of the Section to the needs and resources of the individual researcher. These services include both consulting and direct operational services on all aspects of sampling, surveys and census-type studies. Staff members may design surveys, draw samples, construct questionnaires, train and supervise field workers, collect data by personal interview or mail questionnaires, code and edit data for IBM processing, analyze data and maintain liaison with programmers and the Computation Center on machine manipulations of data coded. Any or all of these services may be required on any particular project. The enumeration which follows indicates the type of work done by the Survey Section this year but is not a complete record of its activities for the year.

A sample was designed and data processed and analyzed for a grain transportation study conducted by agricultural economics; a sample was drawn and interview forms were tested for a textiles and clothing inventory of household linens; a sample was drawn for family environment studies of poverty in southwest Iowa and family living patterns in selected areas of Missouri, Iowa, Nebraska and Kansas; a study was made of water-based recreation patterns in six north-central Iowa counties for the Department of Sociology, and another study made of Iowa outdoor recreation patterns for the Department of Forestry and the Iowa Conservation Commission.

A sample was designed and a questionnaire prepared for a veterinary medicine study of farm practices related to health, and a sample was drawn for an entomological study of the incidence of mange in Iowa hogs. A questionnaire was prepared and field work completed for research conducted by agricultural economics on city agencies and the attraction of industries to communities. The Des Moines Model Cities program was assisted with sample design and data collection

techniques for a study of community attitudes in the Model Cities area.

Construction of an area sampling frame in Missouri was completed for the United States Department of Agriculture. The College of Education received help with studies of education intentions of junior college students, counselor defense mechanisms and their relation to counselling outcome, and evaluation of the audio-tutorial approach to instruction and audio-visual materials centers. Data was processed for a study of woodland production potentials for a number of southern and southeastern states. Data was analyzed for a study of farm operators who quit farming, and work was started on a study of on-farm grain storage and crop dryer facilities for the Department of Agricultural Economics.

Statistical Numerical Analysis and Data Processing Section

The Statistical Numerical Analysis and Data Processing Section of the Statistical Laboratory provides support in the area of computer applications of statistics to research workers who use statistics as a research tool. The Section is organized into two closely allied groups: Statistical Data Processing and Statistical Numerical Analysis.

Members of the Statistical Data Processing group devote their time to the actual processing of data through the computer and to consulting on problems in statistical data processing. During the year the group handled over 200 research projects, nearly doubling its activities of the previous year. The extent of service rendered in each case varied considerably. Many projects required that extensive project-oriented computer procedures be developed to satisfy special computations or data handling in the analysis. Others called for more routine processing using existing software and procedures, usually with large data sets.

The Statistical Numerical Analysis group includes personnel who conduct research, consult on computer applications of statistics, and develop general-purpose computer programs for statistical applications. This group provides the general programming support available within the section, thus allowing the data processing group to avoid programming which is not immediately applicable to a data processing problem on hand.

Research in computer applications of statistics by members of the Section has produced several new algorithms, each capable of solving general classes of problems in statistics. Subsequent computer program development based upon these algorithms has provided a library of statistical programs which has been used extensively on campus and made available, upon request, to off-campus organizations. Programs from the Section's library are now being used at a great many computer installations in the United States and several foreign countries. ZORILLA, a quadratic programming routine, has been modified to handle multiple right hand sides. A student version of OMNITAB has been developed which greatly reduces the cost of running student jobs on the computer. A new analysis of variance package has been developed. The new program utilizes algorithms similar to those in AARDVARK, has an associated keyword language, and performs univariate as well as multivariate analysis of variance and covariance.

The Statistical Laboratory now uses communications terminals which make possible an interactive mode of computer operation. The new time sharing option (TSO) available in the computer operating system is expected to be of great value in statistical applications. TSO makes it possible to write new programs, enter the origrim statements, and find out immediately if any errors need correction. This results in more rapid development of software packages. The terminal also can be effectively used to reduce turnaround time on many types of statistical data processing jobs.

During the year an information retrieval program for terminals was written to assist agronomists in the analysis of some plant mutation experiments. A multiple section and session course grading and analysis system was developed at the request of the chemistry department. A special computer program was developed for an agronomy erosion study of the Iowa Great Lakes shoreline, and a program was modified for food and nutrition research on nutrients in the human diet.

Examples of other consulting done during the year, which is in no way a complete report of the work of the Section, follows. Regression model building was used for a sociology study of personality changes in children, a farm income study for agricultural economics, and economics research on farmer equipment preference. An economics study of the international distribution of grain using the trans-shipment method of solution required linear programming, as did research on the numerical solution of a nonlinear minimum fuel problem for aerospace engineering. The Section is cooperating with the Computation Center on a joint project between Iowa State and the University of Iowa to provide information on population and housing from the 1970 census to interested researchers. These census data, and software for use in report generation, are available on magnetic tapes.

Current Research

Statistical research by staff members is supported by a variety of sources. The Statistical Laboratory budget supports research projects which are of specific interest to regular university research programs. Other research is part of a continuing cooperative program with other campus research institutes and experiment stations. Grants and contracts with off-campus agencies provide for supervised graduate research on statistical problems of common interest. Collectively, this research produces many fundamental techniques which are of value to a great number of research workers.

Dr. B. V. Sukhatme has been concerned with research on the use of auxiliary data in design and analysis of survey data, supported in part by the Statistical Reporting Service, U. S. Department of Agriculture.

One of the designs used frequently in surveys is multi-stage sampling in which selection at each stage is carried out with equal probabilities and without replacement. If, however, the units vary considerably in size as is often the case, the simple mean estimator does not provide the most efficient estimator of the population mean. If auxiliary data on the size of the unit is available, it is natural to use it to provide a more efficient estimator of the population mean. Data on auxiliary variables may or may not be available at all stages. Also, it may not be possible to collect it at all stages. It may, however, be possible to collect data for certain auxiliary variables at certain stages and for other variables at other stages.

Depending on the availability of auxiliary data at different stages of sampling, several ratio-type estimators have been proposed and their bias and efficiency investigated. Results of this investigation have been obtained by graduate students N. S. Murthy and C. Asok under Dr. Sukhatme's direction. Some of these results will constitute Murthy's M.S. thesis.

Dr. Dah-yinn Lee, Department of Civil Engineering, Dr. H. T. David and Dr. Richard W. Mensing are the senior research personnel of a project, "Evaluation of Gap-graded Asphalt Concrete Mixtures," of the Engineering Research Institute for the Iowa Highway Commission. Dr. Lee is the principal investigator.

The purpose of the project is to conduct a comparative study between well-graded and gap-graded aggregates used in asphalt concrete paving mixtures made of Iowa Type A gradings, Fuller's curve gradings, and gap-gradings involving different aggregate types, different maximum aggregate sizes and gaps, and different grades of asphalt cements at various asphalt contents. Physical properties evaluated will include stability, cohesion, density, voids, and resistance to water action in terms of Marshall and Hveem design methods.

T. A. Bancroft and Chien-Pai Han are investigating the pooling of mean squares in incompletely specified fixed models. Power of the sometimes pool procedure was obtained for certain specific degrees of freedom. Comparisons with the never pool procedure are being made and the selection of significance level of the preliminary test will be recommended.

Research by C. P. Cox and Dr. Han considers the hypothesis testing for correlation coefficient of bivariate normal distribution under the assumption of equal variances. It is shown that the likelihood ratio test is equivalent to an F test. Power of the test and confidence intervals for ρ are also investigated.

Dr. Han is testing the equality of covariance matrices under intraclass models. The likelihood ratio test and the asymptotic distribution of the test statistic are obtained. This test is being compared with other existing tests.

NIH Research

Two students who had been supported by the National Institutes of Health biometry training grant during the past fiscal year received doctorates in August: Peter O'Brien joined the staff of the Mayo Clinic and Roland Loup accepted an instructorship with the Statistical Laboratory after serving as a 1st lieutenant in the U.S. Army. He has now accepted a position with the Commission for Professional and Hospital Activities in Ann Arbor, Michigan. Tom Fears expects to complete requirements for his doctorate early in the coming fiscal year.

Four trainees received support during the year. Pamela Doctor worked with the Statistical Laboratory's Statistical Data Processing group during the summer. She helped researchers organize data for computer computation and gained programming and consulting experience. She has been attending classes during the year. Her major professor is Barry Arnold.

Kenneth Offord worked during the summer at the Mayo Clinic under the NIH work experience program which makes it possible for trainees to get experience on actual statistical problems while supervised by senior consultants at cooperating institutions. Offord assisted Dr. William F. Taylor with the analysis of several experiments. He also worked with Dr. Joseph Berkson in researching articles, and presented three seminars on various topics. He completed requirements for his M.S. degree, which he received in February, and continued course work toward his doctorate. His research was supervised by C. P. Cox. While at Iowa State he assisted in the analysis of an experiment designed to study the effects of exercise on cholesterol levels in blood serum of rats, and assisted with a parallel line assay of

growth hormone on crop sac of pigeons. OMNITAB programming was involved in both cases. Offord terminated his traineeship at the end of spring quarter to accept a consulting position at the Mayo Clinic.

Lonnie Vance and James Whipple have been students during the entire year. Vance has begun research on his dissertation topic which is expected to deal with regression analysis and discriminatory analysis with variances and co-variances unequal. His work is directed by C. P. Han. Whipple, whose major professor is C. P. Cox, has been getting teaching experience as a laboratory instructor with the Statistical Laboratory during winter quarter.

Research in Mathematical and Statistical Genetics

This research project in mathematical and statistical genetics is jointly supported by the National Institutes of Health and Agriculture Experiment Station Project 1669. Dr. Oscar Kempthorne and Dr. Edward Pollak continued as principal investigators.

Continuing research on the mathematical theory of the dynamics of Mendelian populations with overlapping generations that are under selection for viability and fecundity indicates that the number of each genotype increases geometrically in the long run, although there are exceptions. These geometric rates of increase are called the malthusian parameters. It has been found that the long run rate of increase in the population mean of these parameters is approximately equal to the total genetic variance if these parameters are small.

Work has continued on theoretical models for diploid populations under mixtures of inbreeding systems and under assortative mating. Both the dynamics of the population and the behavior of variance and covariances between relatives for quantitative attributes have been studied.

Research on the theory of culling selection for a quantitative attribute in a population with one or two loci also was continued. Theory of population growth in sexually reproducing populations has been developed. The emphasis is on fecundity of couples. This is different from current theories in which a child is attributed solely to one or the other of two parents. General theory of quantitative inheritance has been advanced in regard to threshold characters and genetic control of variability and in regard to centripetal selection in finite populations with multiple alleles. Results have been obtained for the probability of fixation of genes in populations of variable size. Some developments have been obtained on statistical aspects of estimation of heritability by realized heritability methods.

The first of several papers on the theory of genetic loads has been prepared. Abstracts of other papers resulting from this research are found in the publications section of this report.

Use of Preliminary Test(s) of Significance in Designing Surveys and Analysis of Survey Data

Research activities in the field of design and analysis of sample surveys supported by the U.S. Office of Education under Contract OEC-0-70-3655 continued with Dr. B. V. Sukhatme as the principal investigator. The main objective of the research was to extend and develop the theory and methodology of sampling involving the use of preliminary test(s) of significance to problems in the designing of sample surveys and analysis of survey data.

One of the important problems in designing surveys is the allocation of sample sizes to the different strata. It is well known that if the cost per unit is the same from stratum to stratum, Neyman allocation is optimum in the sense that the population mean can be estimated with maximum precision. Neyman allocation, however, depends on strata variances which are generally not known. The usual practice is to estimate the variances from a preliminary sample and use them to estimate sample sizes to be allocated to different strata according to Neyman allocation. The allocation so determined may not, however, be more efficient than proportional allocation unless the strata variances are heterogeneous. A new allocation based on a preliminary test of significance of the homogeneity of strata variances has been proposed and its efficiency investigated.

Results of this investigation have been obtained by Victor K. T. Tang, working under Dr. Sukhatme's direction, and are reported in Dr. Tang's Ph.D. thesis. An abstract appears in the publications section of this report.

Analysis of Variance and Experimental Design Research Procedures

Dr. George Zyskind and Dr. Oscar Kempthorne directed research sponsored by the Aerospace Research Laboratories, United States Air Force, which was terminated December 31. Most recently, the contract supported the thesis research of Abel Mexas, P. C. Papaioannou and Justus Seely; these theses have been abstracted in previous Annual Reports.

A substantial portion of recent research on this project has been devoted to related aspects of research in linear model theory. Part of the development is directed toward the further integration of finite derived randomization models, following directly from the way in which experiments are actually performed, with more conventional linear model theory. Illustrations of this have been presented in some examples developed by Dr. Zyskind. In addition, he has examined relationships between covariance matrices, design matrices and parametric augmentations under which usual simple least squares and analysis of variance procedures are also best.

The nature, logic and role of processes of statistical inference recently have been under extensive con-

troversy. Dr. Kempthorne has presented a reaction to this situation with a discussion of the relevance of theories of probability and statistical inference to the interpretation of data and the accumulation of knowledge.

Papers published by Basson, Papaioannou and Kempthorne, Seely, Seely and Zyskind, and White, which are abstracted in the publications section of this report, detail further research supported by this project. A final report on the project is in press.

Linear Models and Analysis of Variance Research Procedures

A new contract for research supported by the National Science Foundation became effective January 1, with Oscar Kempthorne and George Zyskind as principal investigators. The expected substantive significance of the research is in the theory of applications of statistical methods to comparative experiments and to general statistical data analysis. Six areas of study are being emphasized:

1. Continuation of the development of general linear model theory, with emphasis on formulation and unification in both fixed and mixed models, and general randomization theory.
2. Expansion of approaches to and results in the theory of models of finite experiments which take account of the physical act of randomization.
3. Characterizations of estimable parametric functions of variance components, etc., and of the characterization and computation of functions which within a specified class estimate their expectation with minimum variance.
4. Consideration of effective uses of a minimal sufficient set of statistics.
5. Development of theory of residual analysis and of data transformation.
6. Questions of basis of and comparisons among alternative modes of statistical reasoning.

This contract makes possible the continuation of research previously supported by the Aerospace Research Laboratories.

USDC, Bureau of the Census Research Project

A continuing cooperative program between the Statistical Laboratory and the U.S. Bureau of the Census is directed by Dr. Wayne Fuller. Investigations in the area of survey design and estimation in the presence of imperfect prior information continued and are reported in Cary Isaki's doctoral thesis. An abstract appears in the publications section of this report.

Estimators for a simple random sampling from two frames are being studied. An estimator for the total has been developed which has smaller bias and M.S.E. (to the order of approximation employed) than the estimators which have been suggested in the literature.

The estimation and testing of models for response error is under study. In this connection procedures are being developed for combining determinations subject to response error.

Research in Mathematical Statistics and Probability

Co-investigators of a project concerned with research in mathematical statistics and probability include Dr. Barry Arnold; Dr. H. T. David, the project coordinator; Dr. Dean Isaacson; Dr. Glen Meeden and Dr. Richard Mensing.

During the year research continued in a number of areas, including exponential distributions, random walk, the interface between mathematical programming and statistics, variance estimators in nonlinear problems and hypothesis testing. Details of the research have been reported in a number of papers which have been published. Abstracts of papers by Abbey and David, Arnold, Meeden, Mensing and David and Soults and David appear in the publications section of this report.

One piece of work by Dean Isaacson, accepted for publication, involves determining whether or not the stochastic integral has a property analogous to the Fundamental Theorem of Calculus. That is, if

$$N(t, \omega) = \int_0^t \Phi\ (s, \omega)dM(s, \omega) \text{ does}$$

$$\frac{N(t + \Delta t, \omega) - N(t, \omega)}{M(t + \Delta t, \omega) - M(t, \omega)} \xrightarrow{P} \Phi\ (t, \omega)$$

where the P denotes convergence in probability.

In a previous paper it was shown that in the case where the integrator, $M(t, \omega)$, is Brownian motion it has been shown that the desired convergence is achieved. It was also shown that if $M(t, \omega)$ is a continuous, nowhere constant, square integrable, martingale of the form

$$M(t, \omega) = \int_0^t \Phi\ (s, \omega)dX(s, \omega) \text{ where } p[\Phi\ (s, \omega) = 0] = 0$$

for each s and $X(s, \omega)$ is a Brownian motion, the convergence again holds. This most recent work shows, however, that it is not possible to get convergence for all martingales of this type. That is, a continuous, nowhere constant, square integrable, martingale has been constructed such that $P\ [M(1/2^k) = 0] \geq 3/4$ for $k \geq 4$. This construction is used to show that in general,

$$\lim_{t \to o} \int_0^t \Phi\ (s)dM(s, \omega)/M(t, \omega) \neq \Phi\ (0) \text{ where}$$

$\Phi\ (s)$ is non-random and right continuous, $M(t, \omega)$ is a continuous, nowhere constant, square integrable, martingale, and the limit is a limit in probability.

Analysis of Data and Design of Surveys

The procedure for selecting non-replacement unequal probability samples, which was developed under the support of this Agriculture Experiment Station

Project, 1806, has been shown to yield a smaller expected variance for the variance estimator under a super-population model.

Currently researchers are investigating the asymptotic properties of estimators for the errors in variables model. Dr. Wayne Fuller is project director. It has been demonstrated that the maximum likelihood estimator is superior to the moment estimator. For both estimators the statistic for testing "goodness of fit" is approximately distributed as Snedecor's F.

Design of Experiments and Analysis of the Data

With the support of Agriculture Experiment Station Project 890, work has continued on the logic of statistical inference, the nature and role of probability, the nature of statistical methods, and aspects of the design and analysis of experiments. Dr. Oscar Kempthorne directs the research.

Research to Formulate Techniques for Estimating Farm and Related Characteristics by Sample Surveys

Research in four areas was administered by Agriculture Experiment Station Project 1753, directed by Professor Norman V. Strand.

Summary tables were completed for 52 states and territories in the soil and water conservation inventory. Soil, slope, erosion and land capability runs have been made for a majority of the states and will be completed during the next fiscal year. Data on file have been corrected and updated and soil series names have been placed on tapes. Resource area, resource region and river basin tabulations have been made for each state and for the continental United States.

In a second study administered through Project 1753, a response error study is being conducted in selected Iowa counties to estimate the interviewer effect on errors of observation. Selected items of the USDA acreage, livestock and labor enumeration survey of June 1970 are being studied. The field interviewing has been completed and analysis of the data is underway.

A third project has resulted in library research on the development of methods for using auxiliary data in the design and analysis of surveys. Work will continue in the coming year.

Finally, Project 1753 is engaged in revision of the area frames made originally for the Master Sample of Agriculture. Materials are being updated by restratification of areas and the formation of count units suitable for drawing samples of agricultural interest.

Publications and Professional Activities

Research conducted by the staff members of the Statistical Laboratory is reported at professional meetings, and the findings frequently are published in professional journals. Staff members also participate in the various professional societies and assist with the publication of the journals. A record of these activities for the past fiscal year follows.

Editorial collaborators for the Journal of the American Statistical Association included T. A. Bancroft, C. P. Cox, H. T. David, Wayne A. Fuller, G. L. Ghai, Chien-Pai Han, Oscar Kempthorne, Richard Lund, Glen Meeden, B. V. Sukhatme and George Zyskind.

Barry Arnold refereed papers for Technometrics and the Journal of Mathematical Psychology and Dr. Sukhatme did the same for Technometrics and the Journal of the Indian Society of Agricultural Statistics. Biometrics referees included Professor Cox, Thomas Keefe, Dr. Kempthorne, Edward Pollak and Dr. Zyskind. Dr. Kempthorne also refereed for Genetics and the American Journal of Human Genetics; Dr. Pollak for Genetics; and Dr. David and Dr. Zyskind for Technometrics and Annals of Mathematical Statistics.

Vincent Sposito refereed for the Journal of Operations Research and George Battese refereed for the American Journal of Agricultural Economics, which Dr. Fuller continues to serve as a member of the editorial council. Dr. Fuller refereed for the International Economics Review.

Dr. Bancroft and Dr. Kempthorne have been named to the editorial advisory board of the Journal of Statistical Computation and Simulation.

RECORD OF PUBLISHED RESEARCH

This is a record of articles published by staff members and graduate students during the past fiscal year. When the research was conducted at Iowa State but the author has since accepted a new position, his current location is listed in parenthesis after his name. Some of these publications are included in the Statistical Laboratory's Reprint Series and copies are available upon request. These are indicated by an asterisk (*).

*J. L. Abbey (University of Ghana) and H. T. David: "The Construction of Uniformly Minimum Variance Unbiased Estimators for Exponential Distributions." Annals of Mathematical Statistics, 41: 4, 1217-1226. August 1970. Reprint Series No. 261, Statistical Laboratory, Iowa State University.

In this paper the authors consider the Koopman-Darmois class of exponential densities and develop a method for obtaining the unique minimum variance unbiased estimator (U. M. V. U. E.), t_g, of $g(\Theta)$ without explicit knowledge of any unbiased estimator of $g(\Theta)$. The U. M. V. U. E. t_g is given as the limit in the mean (l. i. m.) of a series and a convergent series is also given for the variance. An explicit construction of t_g and criteria for the pointwise convergence of the series for t_g are also given. The authors illustrate the use of the method and discuss some related results.

*Barry C. Arnold: "An Alternative Derivation of a Result Due to Srivastava and Bancroft." Journal of the Royal Statistical Society, Series B, 32:2 265-267. 1970. Reprint Series No. 267, Statistical Laboratory, Iowa State University.

An alternative simple proof is presented of the inadmissibility (m. s. e.) of the usual unbiased estimate of the mean in a bivariate normal with known diagonal covariance matrix when the mean vector is restricted.

*Barry C. Arnold: "Inadmissibility of the Usual Scale Estimate for a Shifted Exponential Distribution." Journal of the American Statistical Association, 65:330, 1260-1264. September 1970. Reprint Series No. 265, Statistical Laboratory, Iowa State University.

Let $X_{(1)}, X_{(2)}, \ldots, X_{(n)}$ be the order statistics of a sample size n from the density $f(x; \mu, \sigma) = \sigma^{-1}e^{-(x-\mu)/\sigma}$, $x > \mu$. The statistic

$$\frac{1}{n} \sum_{i=2}^{n} (X_{(i)} - X_{(1)}) ,$$

which is the best invariant estimate of the scale parameter σ, is shown to be inadmissible under squared error loss. It is shown to be strictly dominated by an estimate that is not translation invariant. Similarity between this estimation problem and the normal scale estimation problem treated by Stein (1964) is discussed.

*Barry C. Arnold: "Hypothesis Testing Incorporating a Preliminary Test of Significance." Journal of the American Statistical Association, 65:332, 1590-1596. December 1970. Reprint Series, Statistical Laboratory, Iowa State University.

Suppose that independent samples are available from two normal populations with means μ_1 and μ_2 and known variances. It is desired to test H: $\mu_1 = 0$. A possible preliminary test procedure in this case consists of first testing $\mu_1 = \mu_2$ and then testing H using either the sample mean from the first population or the pooled sample mean, depending on the outcome of the test regarding equality of μ_1 and μ_2. This procedure is shown to be biased. A power comparison of this procedure with the generalized likelihood ratio test of H indicates that the latter test is more powerful in a fairly extensive parametric region. It is noted that biasedness is frequently encountered in preliminary test procedures. In light of the example, it is recommended that power comparisons be made between such procedures and any available unbiased tests to ascertain whether extensive power loss regions exist or not.

*T. A. Bancroft: "What Rewards May a Statistician Expect?" American Statistician, 24:5, 8-10. December 1970. Reprint Series No. 268, Statistical Laboratory, Iowa State University.

In this paper monetary and non-monetary rewards are discussed which may affect the vocational choice of statisticians or potential statisticians. One section of the paper focuses on monetary rewards for women.

*T. A. Bancroft: "The American Statistical Association: A Single Scientific and Educational Community." Journal of the American Statistical Association, 66:333, 7-12. March 1971. Reprint Series, Statistical Laboratory, Iowa State University.

A multitude of constantly changing problems must be faced and successfully resolved by an umbrella-type organization such as the American Statistical Association with its broad objectives, diverse activities and heterogeneous membership. However, the fact that the Association is broad based undoubtedly accounts for its strength (over 10,000 members) and endurance (established in 1839). The multiple-faceted aspect of the Association should be considered an important asset resulting in the opportunity for healthy interactions of differing kinds of people and ideas.

The author contends that, even in the face of dislocations and accelerated change in many areas of modern life, the membership has the leadership qualities to make any needed adjustments and continue the development of the Association as a viable and vigorous organization, provided members cooperate with mutual respect and tolerance, despite differences, and continually remold themselves, subsequent to such adjustments, as a diversified but single scientific and educational community.

Rodney P. Basson (Norwich Pharmacal Company, Norwich, New York): "A Comparison of Variances of Some Estimators in the Balanced Incomplete Block (BIB) Variance Components Model." Biometrics, 26:4, 657-669. December 1970.

A way is described of obtaining the variances of Henderson's (1953) Methods 1 and 3 estimates in a BIB with random effects, when normality is assumed.

The method is illustrated by an example, showing that an estimator indicated by the minimal sufficient but not complete set of statistics given by Weeks and Graybill (1961) has variance which can exceed that of another estimator, and so is not MV. Tentative conclusions are given regarding the choice of estimator in practice.

***Wayne A. Fuller:** "Sampling with Random Stratum Boundaries. "Journal of the Royal Statistical Society, Series B, 32:2, 209-226. 1970. Reprint Series No. 266, Statistical Laboratory, Iowa State University.

Sampling designs are presented which admit unbiased estimators of the variance of the mean and which possess efficiency for the mean approximately equal to that of sampling one per stratum. The designs are developed for unequal as well as equal probability sampling. Improved estimators of the variance of the estimated mean are considered.

R. E. Voss, J. J. Hanway and **W. A. Fuller:** "Influence of Soil, Management, and Climatic Factors on the Yield Response by Corn (*Zea mays L.*) to N, P and K Fertilizer." Agronomy Journal 62, 736-740. November-December 1970. Journal Paper No. J-6442, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1190.

Quantitative evaluations of applied fertility, indigenous soil properties, management, and weather variables in field experiments were all necessary to develop a satisfactory relationship between corn grain yield and the responsible factors. Experimental sites were selected that provided a sufficiently wide range in each uncontrolled variable to permit inferences concerning the entire Marshall and Monona soil areas. At each site, 19 different N-P-K fertilizer combinations were applied in a composite type design, with 6 of the treatments replicated. Each plot was characterized for soil test N, P, K and pH, stand level, and barrenness. Variables evaluated on a site basis were past cropping, subsoil fertility, planting date, soil yield potential, and soil moisture stress.

The necessity for this type of field experimentation is discussed. Methods of interpretation and practical applications of yield prediction equations are suggested and exemplified.

***Richard A. Groeneveld:** "A Note on the Sequential Sign Test." American Statistician, 25:2, 15-16. April 1971. Reprint Series, Statistical Laboratory, Iowa State University.

The efficiency of the sequential sign test in relation to the sequential probability ratio test is considered for the location problem. An expression for this efficiency, analogous to that of the sign test for tests based on a fixed sample size, is obtained. The sense in which the sequential sign test is nonparametric is considered.

Paul Hinz and John Gurland: "A Test of Fit for the Negative Binomial and Other Contagious Distributions." Journal of the American Statistical Association, 65:330, 887-903. June 1970.

A test of fit for the negative binomial and other contagious distributions is presented in this paper. The test is free of certain disadvantages of the Pearson chi-square test ordinarily used. The proposed test statistics, here called X_F^2, is constructed from estimators given by Hinz and Gurland (1967) which are obtainable through weighted least squares and which were shown to be highly efficient in wide regions of the parameter space. The power of the proposed test procedure is given for some alternatives and a comparison is made with the corresponding power of the Pearson chi-square test.

David V. Huntsberger and Paul E. Leaverton: *Statistical Inference in the Biomedical Sciences.* 269 pp., Allyn and Bacon, Inc., Boston. 1970.

This book is meant to be used as a text for introductory courses in statistical concepts and methods for medical and dental students as well as for others in the biomedical sciences; it is hoped it also will be useful as an elementary reference source of statistical techniques of interest to research workers in the biomedical sciences.

Sufficient material is included for a one-semester course. Mathematical prerequisites have been kept to a minimum; a knowledge of elementary algebra is sufficient. Summation notation is used throughout but a detailed exposition of this notation is given immediately following its introduction.

The authors' primary consideration is the interpretation of the results obtained when statistical methods are applied to problems in the biomedical sciences; therefore the problems and concepts of statistical inference are discussed in detail. Special attention has been given to the role of statistical inference in both experimental and non-experimental studies in medicine. Examples and problems have been selected to illustrate real-world problems in the biomedical sciences. However, few are actual sets of data. The numbers have been selected or adjusted to keep the necessary computations at a reasonably low level. Accessibility to a desk calculator would be desirable.

The first five chapters are concerned with empirical distributions, descriptive measures, elementary probability, and the population sample concept. The remainder of the book is concerned with inductive statistics. Methods of estimation and of testing hypotheses are presented for both discrete and continuous data. Included is a general discussion of the interpretation of significance tests in which the concept of the power of a test is introduced. An introduction to linear regression and correlation is followed by the fundamental ideas of experimental design. Special reference is made

to clinical trials. The last chapter is a brief discussion of epidemiology and data analysis.

*Oscar Kempthorne and Edward Pollak: "Concepts of Fitness in Mendelian Populations." Genetics 64, 125-145. 1970. Journal Paper No. J-5486, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1669. Reprint Series No. 258, Statistical Laboratory, Iowa State University.

The purpose of this paper is to examine the relationship between certain widely quoted definitions of fitness and purported mathematical consequences of these definitions. Calculations are carried out for a simple model for selection. A population in which the members have two life phases, infancy and adulthood, is considered. The probability of survival of an individual from infancy to adulthood depends only on its genotype. Mating takes place at random amongst adults. The fecundity of a mating is a product of two factors, one corresponding to each parent. These depend solely on the genotype of a parent and not on sex. It is shown that, under this model, different reasonable measures of fitness lead to different versions of the relation of the change in mean fitness to population attributes. In only very special cases does a form like Fisher's Fundamental Theorem hold. It is possible, for example, for the mean fitness to decrease after a generation of selection if the fitness of an infant is defined to be one-half the expected number of infant offspring of the infant.

*B. D. H. Latter (Division of Plant Industry, CSIRO, Australia): "Selection for a Threshold Character in Drosophila. III. Genetic Control of Variability in Plateaued Populations." Genetics Research, Cambridge, 15, 285-300. 1970. Journal Paper No. J-6223, Iowa Agriculture and Home Economics Experiment Station, Ames. Reprint Series No. 262, Statistical Laboratory, Iowa State University.

An analysis of populations of *Drosophila melanogaster* which had ceased to respond to selection for increased scutellar bristle number has disclosed the existence of an overall negative genetic correlation between replicate lines in the frequency of the two major component bristle types: anteriors and posteriors. Negative phenotypic correlations among component bristle sites have also been detected within populations. A model involving competition among sites for the available resources of a particular limiting substrate is therefore proposed. Genetic changes have been effected in exceptional populations which lead either to an increase in the rate of production of the limiting substrate, or to a lowering of the concentration of the substrate necessary for bristle initiation. The allelic substitutions concerned are recessive, and have been described as decanalizing alleles in view of their effects on both bristle number variability and a measure of developmental regulation at individual anterior sites. Genetic variation has also been demonstrated for the mean allocation of resources to each of the four component bristle types: anteriors, interstitials, posteriors and apicals. A brief discussion is given of the implications of the model for breeding practice in domestic species.

*B. D. H. Latter (Division of Plant Industry, CSIRO, Australia): "Selection in Finite Populations with Multiple Alleles. II. Centripetal Selection, Mutation, and Isoallelic Variation." Genetics 66, 165-186. September 1970. Journal Paper No. J-6589, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1669. Reprint Series No. 263, Statistical Laboratory, Iowa State University.

In this series of papers the behavior of multiple allelic systems in populations subject to selection, genetic sampling, and mutation is systematically explored. The first paper (Latter and Novitski 1969) dealt with the effects of directional selection for a quantitative character in small populations, given an infinite base population with multiallelic variation similar to that described by Kimura (1965). In this paper computer simulation techniques are used to extend Kimura's model to populations of finite size, where the expected number of alleles segregating per locus is not necessarily large.

Richard W. Madsen: "A Note on Some Ergodic Theorems of A. Paz." Annals of Mathematical Statistics, 42:1, 405-408. February 1971.

In a paper entitled "Ergodic theorems for infinite probabilistic tables," Paz studies the ergodic properties of non-homogeneous Markov chains with countably infinite state space. This note is to draw attention to the fact that Paz's theory is easily extended to arbitrary state spaces.

*Glen Meeden: "Finding Best Tests Approximately for Testing Hypotheses about a Random Parameter." Annals of Mathematical Statistics, 42. 1971. Reprint Series, Statistical Laboratory, Iowa State University.

In an earlier paper the author proved the existence of a best test for testing hypothesis about a random parameter with unknown distribution. This paper gives a result which helps one find the best test approximately for several of the examples considered in the previous paper.

Ahmed Zogo Memon (West Pakistan Agricultural University, Pakistan) and Masashi Okamoto (Osaka University, Japan): "The Classification Statistic W in Covariate Discriminant Analysis." Annals of Mathematical Statistics, 41:5, 1491-1499. October 1970. Reprint Series No. 264, Statistical Laboratory, Iowa State University.

This paper deals with the classification statistic W* which is a generalization of the Anderson statistic W

into the situation considered by Cochran and Bliss (1948) where covariates are available besides discriminators. As a generalization of the result of Okamoto (1963), an asymptotic expansion of the distribution of W* as well as the associated probability of misclassification with respect to the numbers of degrees of freedom is given. It is shown numerically that the covariate method reduces the probability of misclassification and also that the reduction becomes larger along with the number of the covariates.

*Richard W. Mensing and H. T. David: "Absorption Probabilities for Certain Two-Dimensional Random Walks." Annals of Mathematical Statistics, 42:1, 304-314. February 1971. Reprint Series No. 270, Statistical Laboratory, Iowa State University.

In this paper the authors consider absorption of certain finite random walks on three boundaries amenable to a method of images. Each of the three boundaries determines a class of walks to which the method is applicable. For each of these boundary-walk combinations, it is possible to compute certain "untied" and "tied" probabilities.

Limits of expressions derived in this paper provide asymptotic absorption probabilities not only for the few cases examined but also, through the invariance principle, for rather large classes of walks, both "untied" and "tied". These are detailed. The invariance principle simultaneously provides probabilities of absorption of two-dimensional untied and tied Wiener processes within cylinders based on triangles, and hence the corresponding distributions of the time to absorption.

Kenneth S. Mount (University of Manitoba, Winnipeg, Canada) and H. T. David: "An Asymptotic Minimax Property of Certain Likelihood Ratio Tests." Pp. 479-485 in *Nonparametric Techniques in Statistical Inference,* edited by Madan Lal Puri, Cambridge University Press. 1970.

The authors show that a certain likelihood ratio test is "asymptotically logarithmically minimax" for deciding between two "separated" composite hypotheses concerning an exponential family. The two hypotheses remain fixed as sample size increases, and the minimax property refers to a risk that sums the errors of both kinds. The analysis involves first going to the limit with sample size, and then performing the minimax operation.

T. Papaioannou (University of Georgia) and O. Kempthorne: "Parallel Tangents and Steepest Descent Optimization Algorithm—a Computer Implementation with Application to Partially Linear Models." Technical Documentary Report 70-0117, Aerospace Research Laboratories, United States Air Force. July 1970.

This report presents a computer implementation of the PARTAN and steepest descent optimization algorithms. Some research in fitting partially linear models is also reported. Chapter I gives an introduction to the PARTAN and steepest descent optimization algorithms. Chapter II describes the problems solvable by the present routine. Chapter III presents an analysis of the program. Input-output considerations, data preparation and limitations of the program are given in Chapter IV. Results of test problems and a list of error messages are given in Chapters V and VI, respectively. The fitting of nonlinear models is discussed in Chapter VII. Finally, a listing of the computer program is given in the Appendix.

*Edward Pollak and Oscar Kempthorne: "Malthusian Parameters in Genetic Populations. I. Haploid and Selfing Models." Theoretical Population Biology, 1:3, 315-345. November 1970. Journal Paper No. J-6620, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1669. Reprint Series No. 273, Statistical Laboratory, Iowa State University.

The discrete time model for a single type population originally proposed by Leslie is treated by the calculus of finite differences and a continuous time model obtained by a limiting process. With several types each producing offspring of its own type, the number of individuals of any type has a long run steady rate of geometric increase, which is called the Malthusian parameter of the type. If the population size changes slowly, the rate of change in the mean of the Malthusian parameter tends to the variance of the parameter in the overall population. Mutation is incorporated also, and it then happens that if mutations of all kinds are possible there is only one Malthusian parameter. The dynamics of Mendelian populations reproducing by self-fertilization is considered, and it is seen that there is only one Malthusian parameter under reasonable conditions. Relations to prior work by Haldane are discussed.

*Justus Seely (Oregon State University, Corvallis): "Linear Spaces and Unbiased Estimation-Application to the Mixed Linear Model." Annals of Mathematical Statistics, 41:5, 1735-1748. October 1970. Reprint Series, Statistical Laboratory, Iowa State University.

In this paper the author exemplifies theory presented in his earlier (1970) Annals paper using a linear space of random variables for unbiased estimation of the parameters of a mixed linear model using quadratic estimators. Two forms of parametric functions are considered. One particular method for obtaining unbiased estimators for linear combinations of variance components is given that is computationally simpler than the widely used Henderson Method III. The method described has the added advantage of giving necessary and sufficient conditions for the existence of unbiased quadratic estimators, which is not always the case with the Henderson Method III.

*Justus Seely (Oregon State University, Corvallis): "Linear Spaces and Unbiased Estimation." Annals of Mathematical Statistics, 41:5, 1725-1734. October 1970. Reprint Series, Statistical Laboratory, Iowa State University.

In this paper some general results are obtained on unbiased estimation when the choice of estimators is restricted to a finite-dimensional linear space $\overline{a}$. The results are mainly concerned with necessary and sufficient conditions for existence of unbiased estimators within $\overline{a}$ and procedures for obtaining such estimators when they exist.

*Justus Seely (Oregon State University, Corvallis) and George Zyskind: "Linear Spaces and Minimum Variance Unbiased Estimation." Annals of Mathematical Statistics, 42:2, 691-703. April 1971. Reprint Series, Statistical Laboratory, Iowa State University.

Consideration is given to minimum variance unbiased estimation when the choice of estimators is restricted to a finite-dimensional linear space. The discussion gives generalizations and minor extensions of known results in linear model theory utilizing both the coordinate-free approach of Kruskal and the usual parametric representations. Included are: a restatement of a theorem on minimum variance unbiased estimation by Lehmann and Scheffe; a minor extension of a theorem by Zyskind on best linear unbiased estimation; a generalization of the covariance adjustment procedure described by Rao; a generalization of the normal equations; and criteria for existence of minimum variance unbiased estimators by means of invariant subspaces. Illustrative examples are included.

J. K. Sengupta: "Stochastic Linear Programming with Chance Constraints." International Economic Review, 11:1, 101-116. 1970.

This paper attempts to analyze a class of stochastic linear programming (SLP) problems under the additional restrictions of a chance-constrained type. The analysis of the distribution of the optimal solution under the SLP approach with chance constraints has several implications for economic models of production and investment allocation, and for the linear dynamic models of economic policy.

First, the formulation of alternative deterministic equivalents for a given stochastic LP problem suggests the need for a sensitivity analysis in some detail before any particular criteria, such as maximizing the expected value or minimizing the overall variance, etc., are selected. Second, the conventional analysis of risk in economic models has not generally incorporated the need for considering the coefficients of skewness and kurtosis characterized by the third and higher moments, presumably because of the belief in the invisible hand of the central limit theorem; however in small samples and particularly in the theory of extreme value distribution, a departure from normality is usually the rule rather than an exception, and such extreme value distributions have significant degrees of skewness and kurtosis.

J. K. Sengupta: "A Generalization of Some Distribution Aspects of Chance-Constrained Linear Programming." International Economic Review, 11:2, 287-304. 1970.

The objective in this paper is to analyze the implications of a non-normal distribution of the random elements (A, b, c) of a linear program in the framework of probabilistic linear programming, where only the two approaches of chance-constrained programming (CCP) and stochastic linear programming (SLP) are considered. In this approach the assumption of normality is replaced by a chi-square distribution, which has a nonnegative range and hence has more applicability to economic models of production and investment.

*Donald J. Soults (Boeing Aircraft Company, Renton, Washington) and H. T. David: "The Distribution of 2xn Game Values and Program Optima." SIAM Journal of Control, 9:1, 135-141. February 1971. Reprint Series No. 269, Statistical Laboratory, Iowa State University.

In this paper the authors derive an expression for the distribution of the value V of a 2xn game when the n columns of the game matrix are distributed independently, each according to a bivariate distribution satisfying certain continuity conditions.

*M. S. Avadhani and B. V. Sukhatme: "A Comparison of Two Sampling Procedures with an Application to Successive Sampling." Journal of the Royal Statistical Society, Series C (Applied Statistics), 19:3, 251-259. 1970. Reprint Series No. 271, Statistical Laboratory, Iowa State University.

In this paper two methods are considered for solving the problem of estimating the population mean $\bar{y}_N$ of a finite population of size N of the characteristic Y under study when data on an auxiliary variate X correlated with Y is available for all the units in the population. One is a method proposed by Rao, Hartley and Cochran (1962) where the units are selected with probabiilty proportional to the value of the auxiliary variate and without replacement. The other is simple random sampling without replacement and the data on the auxiliary variate X is used in the form of ratio estimate to estimate the population mean $\bar{y}_N$.

The authors have proposed a model applicable to sampling from finite populations and used it to compare the two sampling procedures. They have also investigated the applicability of these methods to successive sampling.

P. V. Sukhatme and **B. V. Sukhatme:** *Sampling Theory of Surveys with Applications,* Second Edition. 452 pp., Iowa State University Press, Ames. 1970.

This book, which was abstracted in last year's Annual Report when it was published by Asia Publishing House, London, was issued this year by the Iowa State University Press. It contains comprehensive and systematic accounts of sampling theory and its applications including recent developments, and current methods of obtaining accurate agricultural statistics in the developing countries.

George M. Beal, **Richard D. Warren** and John L. Tait: "A Training Program for Managers." 1970 Cooperation, American Institute of Cooperation, 220-225. 1970. Journal Paper No. J-6781, Iowa Agriculture and Home Economics Experiment Station, Ames, Project 1469.

This paper reports the findings of an exploratory study to determine the influence of an intensive training program for general managers of local retail farm supply businesses. An attempt was made to measure changes in: 1) general managers' knowledge, 2) general managers' attitudes, 3) general managers' performance, 4) internal environment and activities of the business firm, and 5) economic returns to the business. The training program and research design are briefly described. A summary of findings for hypotheses concerning variables in the five change areas is presented.

Robert F. White (Hoffman-LaRoche, Inc.): "Randomization Analysis of the General Experiment." Technical Documentary Report 70-0239, Aerospace Research Laboratories, United States Air Force. October 1970.

General consideration has been given to the expectation of quadratic functions, and in particular of analysis of variance components, of random samples drawn from structured populations of elements called "responses." A systematic approach to three general notions: the structure of the population, the structure of the sample and the scheme for drawing the random sample, is presented.

The primary result of this report, Theorem 1, is obtained under just two requirements: that the inference structure be balanced and complete and that the random sampling scheme be of a form called "symmetric uniform probability." Theorem 1 gives a general form for the expectation of the product of any two of the responses obtained in the experiment. Theorem 2, a specialization of Theorem 1, gives a simple expression for the expectation of the square of any partial mean in the sample. Together the two theorems are of great utility in finding, under general conditions, the expectations of mean squares for a wide class of experimental situations.

The report concludes with a number of examples for experiments with a balanced but not necessarily complete observation structure.

Robert F. Boruch, John D. Larkin, **Leroy Wolins** and Arthur C. MacKinney: "Alternative Methods of Analysis: Multitrait-Multimethod Data." Educational and Psychological Measurement, 30:4, 833-853. Winter 1970.

Both experimental and factor analytic models provide succinct, albeit imperfect, description of the multitrait-multimethod data. The inferences made, conditional on the use of either model, are consistent with those made on the basis of the Campbell-Fiske prescription for examination of the correlation matrices. A noteworthy feature of either assessment is the emphasis on the "methods" aspect of the measures virtually ignored in previous research on this data. The authors conclude that relations among the various techniques of assessing multitrait-multimethod matrices and their efficacy needs to be investigated.

Leroy Wolins and Arthur C. MacKinney: "Methodological Considerations for Analyzing Accident Data Conditional on Psychological Test Scores." Chartered Property and Casualty Underwriters Annals, 121-128. 1970.

The research on which this methodological paper is based represents a five-year effort which some believe to be as near to a definitive piece of research as has been attempted in this broad area. It leads to the conclusion that selective attrition in longitudinal research is as serious a methodological flaw as is sampling bias in cross-sectional research. Also longitudinal research automatically results in little data since most sampling units are not accident involved.

Michael J. Kavanagh, Arthur C. MacKinney and **Leroy Wolins:** "Issues in Managerial Performance: Multitrait-Multimethod Analyses of Ratings." Psychological Bulletin, 75:1, 34-49. January 1971.

Three general issues of dimensionality, validity and content of ratings of managerial performance are examined in terms of "relevance to the ultimate criterion." It is argued that the multitrait-multimethod design yields the best evidence for investigating these issues.

An analysis of variance model with computational formulas for the sums of squares and variance components based on the correlation matrix is proposed for the multitrait-multimethod situation. Using this method, data from two studies are examined and compared, relative to convergent and discriminant validity, method bias (halo), and error variance. It appears that this model and the indexes derived from it provide a more simplified and interpretable technique for analyzing and summarizing multitrait-multimethod data.

In addition, a procedure to improve performance ratings based on partitioning the original matrix is illustrated with an example from a large data set.

Robert Boruch and **Leroy Wolins:** "A Procedure for Estimation of Trait, Method and Error Variance

Attributable to a Measure." Educational and Psychological Measurement, 30:3, 547-574. 1970.

A computational procedure devised by Jöreskog (1967) was applied to multimethod-multitrait data and conditionally evaluated. The procedure described in this paper is based on explicit models for multitrait-multimethod data. The formal models are related to models implicit in the classical Campbell and Fiske (1959) presentation. The procedure is based also on previous research conducted by Wolins (1964) and by Stanley (1961). Another relevant procedure, using a different class of models, is given by Bock and Bargmann (1966).

The results of this procedure seem somewhat less equivocal than conventional factor analysis procedure since the rotation is uniquely specified by the design. It shares with the conventional procedures problems of nonuniqueness, convergence to local minimum and under determination of factors. To the extent that the various criteria proposed earlier can be used, the solutions appear to be adequate summarizations of the data.

Leroy Wolins: "Selecting a Representative Sample of Test Questions." Didakta Medica, 3, 80-83. 1970.

Having exposed a group of students to an educational program, it is then necessary to determine how much of the knowledge in that program has been learned by each student. Generally, an educational program has a defined structure. The subject matter is allocated to specific courses and each course has a course outline. This structure forms the basis of selecting test questions by means of stratification rather than randomness. A stratified basis for sampling is more likely to result in a good representation of the total program in a test than a random basis.

Depending on the educational program, the stratification of content could be made according to one or more dimensions. For each dimension, the content might be organized according to major areas and subareas. For illustrative purposes a stratification according to two dimensions, each further divided into subareas, is considered in this paper.

Report

Paul N. Hinz: "Undergraduate Program in Biometry at Iowa State," pp. 47-51, and "Graduate Programs in Natural Resources—Biometry and Statistics at Iowa State," pp. 52-56 in Proceedings of the Symposium on the Development and Implementation of Courses and Curricula in Natural Resources Biometry, a report to the National Science Foundation. 1970.

Problem Solution

R. A. Groeneveld: "A Comparison of Integrals," solution to problem E2216, p. 1114, American Mathematical Monthly, 77:10. December 1970.

Discussion

H. T. David. Discussion on Puri and Shane's Paper, pp. 154-155; Oscar Kempthorne: Discussion on B. Durbin's Paper, pp. 450-451; and Oscar Kempthorne: Discussion on Mount and David's Paper, pp. 486-488, all in *Nonparametric Techniques in Statistical Inference,* edited by Madan Lal Puri. Cambridge University Press. 1970.

Book Reviews

David V. Huntsberger: Review of *Introductory Statistical Procedures: with Computer Exercises* by Paul J. Lohnes and William W. Cooley. Journal of the American Statistical Association, 65:330, 997-998. 1970.

Dean Isaacson: Review of *Stochastic Convergence* by Eugene Lukacs. Biometrics, 26:4, 870. December 1970.

Oscar Kempthorne: Review of *Joint Statistical Papers* by J. Neyman and E. S. Pearson. Econometrics, 575-582. 1970.

Glen Meeden: Review of *Introduction to Probability Theory and Statistical Inference* by Harold J. Larson. Biometrics, 26:4, 870. December 1970.

Leroy Wolins: Review of *Basic Statistical Methods* by N. M. Downie and R. W. Heath, *Statistics: The Essentials for Research* by Henry Klugh and *Fundamental Statistics for Psychology* by Robert McCall. Contemporary Psychology, XVI:5, 302-304. May 1971.

George Zyskind: Review of *Introduction to Matrices with Applications in Statistics* by Franklin A. Graybill. Technometrics, 12:4, 929-931. November 1970.

ABSTRACTS OF THESES

A. Ronald Gallant: "Statistical Inference for Nonlinear Regression Models." Ph.D. thesis. Iowa State University Library. May 1971.

This study considers estimation and hypothesis testing problems for regression models with the structure

$$y_t = f(x_t, \Theta) + e_t \quad (t=1, 2, \ldots, n)$$

$\Theta \in \Omega \subset \mathcal{R}^p$.

Given that Ω is not compact and that not all of the second order partial derivatives of f with respect to Θ exist, conditions are obtained such that the least squares estimator of Θ is measurable, converges almost surely to the true value of the parameter Θ, and is asymptotically normally distributed. A proof of the convergence of the modified Gauss-Newton method of computing least squares estimates is obtained when the second order partials of f do not exist. A segmented quadratic with estimated join point regression model is presented as an example where Ω is not compact, some second order partials of f do not exist, and the conditions obtained in the study are satisfied.

Hypothesis testing problems in the situation where the e_t are independent normal $(0, \sigma^2)$ with σ^2 known

are considered. For the hypothesis $\Theta = \Theta^o$ vs $\Theta \neq \Theta^o$ necessary and sufficient conditions for the existence of uniformly most powerful tests are obtained, the asymptotic null and non-null distributions of the likelihood ratio test are obtained, and the asymptotic null distribution of a test based on the asymptotic normality of the least squares estimator is obtained. A special case investigated is that where Θ can be written $\Theta = (\Theta_{(1)}, \Theta_{(2)})$, f is of the form $f(x, \Theta) = a_0(x, \Theta_{(2)}) + \sum_{i=1}^{q} \Theta_i a_i(x, \Theta_{(2)})$, Ω is of the form $\mathcal{R}^q x\ \Omega_{(2)}$, and the hypothesis is $\Theta \in \Omega_H = \{\Theta \in \Omega: \Theta_{(2)} = \Theta^o_{(2)}\}$ vs $\Theta \in \Omega \sim \Omega_H$. For this model necessary and sufficient conditions for the existence of uniformly most powerful tests are obtained, the asymptotic null distribution of the likelihood ratio test is obtained, and the asymptotic null distribution of a test based on the asymptotic normality of the least squares estimator is obtained.

The problem of testing hypotheses when σ^2 is unknown is considered briefly and asymptotic null distributions are obtained.

Amiri Gamshadzahi: "Application of Normal Plotting Technique in the Analysis of a Series of Singly Replicated Experiments." M.S. thesis. Iowa State University Library. August 1970.

This research was concerned with the analysis of a series of singly replicated experiments. A randomized block experiment where the blocks are not adjacent can be considered as a series of singly replicated experiments. When the treatments interact with the sites, then an independent estimate of the experimental error variance is needed to carry out different tests. A normal plotting technique was used to obtain an independent estimate. The theoretical and the applied aspects of the full normal and half normal plotting methods were discussed. The method developed was applied to the data of six different series of experiments.

Cary Tsuguo Isaki: "Survey Designs Utilizing Prior Information." Ph.D. thesis. Iowa State University Library. November 1970.

Using the criterion of anticipated variance, sampling designs and estimators possessing desirable properties for certain models are derived. The term anticipated variance is introduced to emphasize the subjective or personalistic nature of survey design. In practice, the determination of the sampling design and estimator is based on the survey designer's experience and intuition concerning a single finite population. The anticipated variance is the variance of the design and estimator computed on the basis of the survey designer's *a priori* personalistic information. The use of prior knowledge in the form of models specifying the anticipated means and covariances of the population units is investigated.

When the anticipated first and second order moments are constant for all population elements the sample mean together with simple random sampling without replacement minimize the anticipated variance over a large class of estimators and sampling designs.

Several miscellaneous topics concerning sampling designs and estimators are considered. A class of variable sample size designs is shown to be inferior to the class of without replacement designs of size n admitting a nonnegative estimator of variance. Consistency of the Horwitz-Thompson estimator in unequal probability sampling is established for a sequence of finite populations.

Stratified with replacement sampling is shown to have a smaller variance than the usual with replacement unequal probability design of size n. The order in probability of $\bar{x}_n - \bar{X}_N$ is established for a stratified sample with the number of strata proportional to n.

Louis Jensen: "Mathematical Models for the Growth of Diploid Populations with Overlapping Generations." Ph.D. thesis. Iowa State University Library. May 1971.

The currently used model which describes the growth of a population with overlapping generations is examined. The basic assumption for this model is that the population consists of only one type of individual, say females. The females in the population survive to different ages with known probabilities and produce offspring at known rates according to age. The offspring are identical to the parents. If the population contains males, all of the infants are credited to the adult females. It is shown that the females and males grow in numbers at the same asymptotic rate.

A model for population growth which incorporates the fact that females and males form couples before reproduction occurs is developed. The function used to describe the formation of couples is a quantitative measure of the maximum number of couples formed.

In one case it is possible to solve completely the equations which describe the growth of the population. This case is when couples are formed between females and males of the same age, and the ratio of the numbers of females to males at birth is a known constant. If couples are formed arbitrarily according to age, or if the ratio of the numbers of females to males at birth is not a known constant, it is only possible to construct upper bounds to the solution to the equations which describe the growth of the population.

Polygamy has been incorporated into the mating structure. If the number of mates that any male can have is sufficiently large, the equations which describe the production of offspring are identical to the equations for the growth of a population which credits both types of offspring to the females.

The stochastic models for the growth of populations with overlapping generations are the age-dependent branching processes. If a population consists of females, the equation which describes the generating function of the size of the population is derived. If couples are formed in a population consisting of females

and males, it is not possible to find the generating function for the size of the population explicitly. It is shown that the probability of extinction for a population which forms couples is at least the probability of extinction of a population which credits the offspring to either adult.

Haeja Chung Kim: "Allocation of the Sample in Stratified Sampling for Estimating Proportion." M.S. thesis. Iowa State University Library. May 1971.

Consider a population of size N. Let P denote the proportion of the units that fall in some definite class. One method of estimating unknown P is to use stratified sampling. Suppose the population is divided into k strata such that h-th stratum contains N_h elements. n_h, the number of units in the sample from the h-th stratum, can be chosen in many ways, e. g. one way is to choose n_h so that for fixed total sample size the variance p_{st}, the estimate of P, is minimum.

This thesis proposes a new method of allocating n_h so that the variance of the estimate of the variance of p_{st} is minimum. Under some mild assumptions it is possible to give a simple expression for n_h. This method of allocation is compared with optimum allocation that minimizes the variance of p_{st}. The allocation proposed here not only minimizes the variance of the estimated variance of p_{st}, but also keeps the variance of p_{st} close to its minimum.

G. Nicholas Lauer: "Power of Cochran's Test in Behrens-Fisher Problems." Ph.D. thesis. Iowa State University Library. May 1971.

No universally accepted testing procedure now exists for the Behrens-Fisher problem although certain exact procedures and simpler approximate procedures have been proposed. This thesis investigates an approximate test procedure which is called Cochran's test.

A form of the distribution function of the nominal level α Cochran's test statistic is written as a multiple integral and then transformed to an expression which facilitates numerical computations for specific values of n_1 and n_2. Size and power studies for several small sample combinations are then carried out to determine the behavior of the test for various values of $R = \sigma_1^2/\sigma_2^2$. Denote S(R) as the size function for fixed R. It is found that in a particular sense, the test is uniformly conservative for $\alpha = .05$ in that $\sup_R S(R) - \alpha <$ .0001 for the cases studied.

The univariate Behrens-Fisher problem is also considered when a preliminary F-test of level α_0 is used for H_{00}: $\sigma_1 = \sigma_2 = \sigma_0$. If $\overline{H}_{00}$ is accepted then s_1^2 and s_2^2 are pooled to estimate σ_0^2 and the standard t-test is used to make a final test of H_{10}: $\mu_1 = \mu_2$. If H_{00} is rejected Cochran's test for H_{10} is used. The distribution function of the statistic in the testing procedure is a natural extension of that for the single Cochran's test. Numerical computations are carried out for small samples and it is shown that for a proper choice of α_0 this procedure achieves a higher power than the single Cochran's test of the same size.

Finally, the multivariate extension of Cochran's test is examined. Monte Carlo techniques are employed to make an empirical analysis of the size and power behavior for the bivariate case. Results tend to be quite consistent with the findings in the univariate case.

Roland Joseph Loup: "A Generalization of the Mean Square Successive Difference Statistic with Applications." Ph.D. thesis. Iowa State University Library. August 1970.

This study presents a generalization of the mean square successive difference statistic, introduced into statistical literature by John von Neumann, together with some applications of the generalized statistic. A method for finding the positive integral moments of the generalized statistic is given and applied to find the mean and variance. The asymptotic distribution of the statistic is found under the assumption that the original observations are normally distributed. A test procedure for detecting the degree of polynomial which best fits a sequence of y-observations at equally spaced x-values is presented and several applications of this test procedure are discussed and exemplified. One of these applications is the use of the given test procedure, in conjunction with the simple least squares procedure for detecting polynomial trend, to gain additional information about the data such as the presence of negative serial correlation among adjacent observations. Theoretical results are given to indicate the situations in which the above-mentioned application of the test procedure can be usefully employed to test for negative serial correlation. Results are given for two Monte Carlo studies. The first was undertaken to study the distribution of two particular cases of the generalized statistic. The other was undertaken to compare the power of the given test procedure, incorporating the generalized statistic, with the simple least squares test procedure and with a test procedure incorporating the variate difference statistic in the two situations of detecting polynomial trend of degree 1 and degree 2.

Angel Martinez-Garza: "Estimators for the Errors in Variables Models." Ph.D. thesis. Iowa State University Library. August 1970.

Alternative estimators for the errors in variables problem are investigated. The moment estimator $\hat{\beta}$, and the estimator $\tilde{\beta}$ proposed by Fuller (1968) are investigated. $\tilde{\beta}$ is unbiased to $0_p(1/n)$. The general conditions under which $\tilde{\beta}$ has smaller mean square error than $\hat{\beta}$ to $0_p(1/n^2)$ are established. In the important case when β is a scalar, it is shown that $\tilde{\beta}$ has a smaller mean square error than $\hat{\beta}$. The expected values of the

estimators $\hat{\beta}$ and $\tilde{\beta}$ are not necessarily defined for finite samples. Modified estimators with finite moments are suggested. An application of the techniques to the estimation of a single equation in a system of equations is illustrated. The estimation of some functions of the parameters of a regression model, found frequently in economic studies, is also illustrated.

The asymptotic properties of the maximum likelihood estimator are studied. In particular, expressions for the asymptotic bias and mean square error of the maximum likelihood estimator in the one variable case, are presented. An immediate consequence of these results is the derivation of an estimator unbiased to $0(1/n)$ with smaller mean square error than the moment estimator.

A review and extension of DeGracie's (1968) work on a covariance model with errors in the covariates is presented. Using generalized inverses the methodology is extended to a nonfull rank covariance model. It is shown that the system of normal equations can be solved in a way completely analogous to the standard covariance model. It is observed that the maximum likelihood procedure can also be applied.

A sampling experiment was used to compare the properties of several estimators. This bias and relative efficiency of the estimators were a function of the parametric configuration. The modified maximum likelihood estimator unbiased to $0(1/n)$ was uniformly superior to the maximum likelihood estimator modified only to have finite variance. For the eight parametric configurations investigated the relative efficiency of the two stage least squares estimator (modified to have finite variance) to the maximum likelihood estimator (modified to be unbiased to $0(1/n)$) was 0.954.

Donald Hughes McElhone: "Estimation of the Mean of Skewed Distributions Using Systematic Statistics." Ph.D. thesis. Iowa State University Library. August 1970.

This thesis investigates the use of simple linear combinations of order statistics to estimate the mean of the Weibull distribution. Formulas for calculating the expected values, variances, and covariances of the order statistics of Weibull random variables with integer shape parameter are developed. The asymptotic values of the expectations and covariances are derived for the largest order statistics. These results are used to study estimators of the mean of the form $\hat{w} = (\sum_{i=1}^{n-r} y_{(i)} + ry_{(n-r)})/D$ where the $y_{(i)}$ are the ordered observations of a sample of size n and D is a suitably chosen denominator. This type of estimator replaces each of the r largest observations with the $(r+1)$–st largest observation. In particular the Winsorized mean is the estimate $\hat{w}$ with $D=n$. Two other forms of D are considered: $D = n-r$ and $D = n-r+1$. For the exponential $D = n-r$ gives an unbiased estimator and $D = n-r+1$ gives the minimum mean square error estimator. These three estimates are compared using mean square error as the criterion. The asymptotic results are used to show that the mean square error of the once censored estimate is less than the mean square error of $\bar{y}$ for Weibull distributions with shape parameter greater than one.

The maximum likelihood estimate for the mean is developed and compared with $\bar{y}$.

Tests of the null hypothesis that the shape parameter of the Weibull is one are investigated. A test suggested by Fuller, a test based on the log-Weibull estimator and likelihood ratio test are compared. Fuller's test has the advantage of having a known distribution, but the power of Fuller's test is somewhat less than that of the log-Weibull test. The likelihood ratio test was more powerful than either, but the likelihood test studied is a simple versus simple test while the other are simple versus composite tests.

A technique is also presented which allows the calculation of expected values and expected crossproducts of the order statistics of symmetric distributions using the expected values and crossproducts of the order statistics of the related half distribution.

Esmat Moustafa Nouri: "The Mathematical and Statistical Theory of Culling Selection." Ph.D. thesis. Iowa State University Library. February 1971.

The theory of the progress of infinite populations under the culling or truncation type of selection is examined in detail for the case of the one locus with two and three alleles and the case of two loci with two alleles at each locus. In the theory which is discussed in this study, the fraction of the population saved is the best $S(0 < S < 1)$ with regard to the attribute under selection. With this model of selection, the actual dependence of the selective values of genotypes are determined by the relative positions of the genotypes on a scale of merit and by the relative frequencies. The present work can therefore be regarded as a study of gene frequency dependent selection.

The main difficulty in the development arises because the degree of selection against any one genotype depends critically on the population structure at the time of selection. The purpose of the present work was to examine the dynamics of a genetic population under this type of selection, both with and without environmental variability in the expression on the scale of merit of genotypes.

In order to keep the mathematics workable, the following conditions are assumed: two life phases - infant and adult, non-overlapping generations, no differences between the two sexes in fitness, random mating, infinite population size, and no fecundity differences between the possible genetic types of mating. The validity of this type of simplifying approach derives from a feeling that in the advance of science it is not simplification that leads to error, but rather the absence of a rigorous and clear analysis of the problem at hand. A simplified approach, however, may also reveal

whether a given theory holds enough promise to warrant further investigation.

Under the assumptions, the progress of the population is completely determined by recursive equations which are generally nonlinear. The standard procedure in such problems is to replace the discrete process by a continuous one which yields a differential equation. In all cases, examples were developed exactly by a computer to obtain a check on the accuracy of the continuous approximation.

For the case of no variability, the progress of the population under selection proceeds in stages, with the number of stages depending on the number of distinct possible genotypes and on the proportion culled in relation to gene frequency. In some simple cases in which exact solutions are obtained, a comparison is made between the change in gene frequency obtained as a discrete process expressed in terms of difference equations and the change obtained using the continuous time analog. In most cases, functions of gene frequencies are obtained which change linearly with generations with slope depending on the parameters involved.

For the two-loci models, linkage may have a profound effect on the changes in the gametic frequencies.

Existing theory has in general failed to accommodate the fact that variance parameters change under selection, and an attempt is made to remedy this defect. Some results for the cases of one and two loci with variability are given. A completely general solution giving the long-term dynamics still eludes research.

Peter Charles O'Brien: "Procedures for Selecting the Best of Several Populations." Ph.D. thesis. Iowa State University Library. August 1970.

The problem of selecting the best of several populations with common known distribution function is considered. It is assumed that the experimenter specifies an indifference region and a probability of correct selection that is to hold outside the indifference region.

Sequential screening procedures are introduced for this problem. In a screening procedure a subset of the population may be observed at any stage of sampling. However, unlike eliminating procedures, no population is permanently dropped from the experiment. Procedures are proposed for the multinomial, gamma, normal and certain incompletely specified populations. The screening procedures are shown empirically to provide a substantial reduction in average sample number related to existing single sample, sequential nonscreening and sequential eliminating procedures.

The empirical study also indicates that these sequential screening procedures also yield a higher level of probability of correct selection in some cases. However proof that these procedures maintain specifed levels of PRCS has been obtained only for certain parametric configurations.

A class of sequential screening procedures which may be used for any family of densities belonging to the Koopman-Darmois family is also proposed. An empirical study indicates that these procedures may provide a reduction in ASN relative to existing procedures. These procedures are proposed without proof that they maintain specified levels of PRCS.

Also developed are inverse sampling procedures for selecting the best multinomial category and a single sample procedure for selecting the best negative binomial population. The relationship between these procedures and the single sample procedures for selecting the best gamma population are investigated.

A sequential nonscreening procedure for selecting the best negative binomial population, procedures for modified selection problems which include a test for homogeneity (i. e., that all populations are identical), and a sequential procedure for the interval estimation of the shape parameter of the gamma distribution are considered.

Yupha Sirikiate Onthuam: "Comparing Clusters Formed by Two Cluster Analysis Techniques." M.S. thesis. Iowa State University Library. February 1971.

This thesis illustrates a development of attitude scales and measurement by using different cluster analysis techniques to select items. The data used resulted from the smoking and health project, a research study in the Department of Sociology and Anthropology, concerned with the relationship between cigarette smoking and health problems. The research design was a stratified random sample of adults.

The intercorrelation matrix was used to indicate the degree of interrelationship. The two methods of cluster analysis techniques, the method A and the elementary linkage analysis method, were used to construct the attitude scales. Each method was discussed with different significant levels of correlation coefficient. Criteria for comparing scales emphasizing additivity were stated.

The outcome of the two cluster analysis techniques supported the general hypotheses: (1) using different methods to construct scales will influence the scale developed and evaluation of attitude scales; and (2) the different significant levels of correlation coefficients will influence the analysis techniques to construct attitude scales and will influence item selection. The procedure of the method and the significance level have influence on attitude scales and measurement and the various conditions of additivity were influenced by the methods and their respective scales.

Comparison of the outcome of the two cluster methods indicated that the method A at the level .40 tends to produce scales which satisfy the conditions of additivity at a higher level in general than the elementary linkage method or method A using the level at .321.

David Albert Pyne: "Relationships Between Sets of Variables Found by Several Model Building Procedures." M.S. thesis. Iowa State University Library. November 1970.

In this thesis, the sets of independent variables found by stepwise procedures—backward, forward and Efroymson's—are characterized by F ratios. Use of the C_p statistic is shown to be equivalent to the use of an F test on the variables not in the regression equation. Conditions are given under which certain relationships hold between F ratios for the set of variables found by stepwise procedures, and the F ratio for sets found by the use of C_p statistic, so it is shown that under certain conditions use of a stepwise procedure will lead to a set of independent variables found by use of the C_p statistic.

A. Shawki Salem: "Investigation of Alternative Estimators of the Parameters of Autoregressive Processes." M.S. thesis. Iowa State University Library. February 1971.

This study investigated the estimation of the parameter ρ in the model $y_t = \rho y_{y-1} + u_t$, where $|\rho| < 1$ and $u_t \sim NID(0, \sigma^2)$.

Four estimators were studied analytically and investigated by use of the Monte Carlo technique. Two of these estimators were in the literature: $\hat{\rho}$, the least squares estimator, and $\hat{\rho}_{o-w} = \frac{(n-1)\hat{\rho} + 1}{n-4}$, a linear combination of $\hat{\rho}$ constructed to be approximately unbiased. The two estimators derived in this study were $\hat{\rho}_1$, a function of $\hat{\rho}$ which is approximately unbiased for $\rho=0$, and $\hat{\rho}_2$, a function of $\hat{\rho}$ which is approximately unbiased for all ρ.

The Monte Carlo estimator of bias agreed well with the approximate formulaes for all four estimators. The bias in $\hat{\rho}_1$ was smaller than the bias in $\hat{\rho}$ for all nonnegative values of ρ, and the estimator $\hat{\rho}_{o-w}$ has a smaller bias over a wider range of ρ than any other estimator for all values of n. For positive values of ρ, the estimated MSE for $\hat{\rho}_1$ was less than the estimated MSE of $\hat{\rho}$ for all values of n. This result was anticipated on the basis of the approximate theory which indicated that to order $\frac{1}{n}$, MSE $(\hat{\rho}_1)$ < MSE $(\hat{\rho})$ for $\rho > 0.14$. The estimator $\hat{\rho}_1$ had smaller observed MSE than either $\hat{\rho}_{o-w}$ or $\hat{\rho}_2$ when the true value of ρ was in the range -0.6 to 0.6.

The estimator of σ^2 multiplied by n-3 behaved much like a chi-square with n-3 degrees of freedom for all estimators.

On the basis of this study, the distribution of the statistics "t" $= \frac{\hat{\rho}_1 - \rho}{\sqrt{s^2_{\hat{\rho}}}}$ where $s^2_{\hat{\rho}}$ is the usual regression estimator of the variance $\hat{\rho}$, is well approximated by Student's t for ρ near zero ($|\rho| < 0.33$) and moderate sized samples ($n > 15$).

Ivan B. M. Sampaio: "A Comparison of the C_p Statistic and the Ridge Trace Method in Building Nonorthogonal Linear Models." M.S. thesis. Iowa State University Library. August 1970.

Dealing with nonorthogonal problems, overestimation of the regression coefficients may be caused either by the presence of correlated variables or by the nature of the X'X matrix which may be near singular itself. Adding small values to the diagonal elements of the correlation matrix seems to control satisfactorily this inflation without losing too much precision. The coefficients so obtained from the perturbed system are slightly biased, however their values tend to be closer to their actual values. The C_p statistic should not be used in such nonorthogonal problems of the inflation cited above. Even after the Ridge Trace is applied, the C_p statistic should be avoided since it requires unbiased estimates of the residual sum of squares.

Nancy Heath Shover: "A Method for Estimating the Variance in Nonlinear Estimation." M.S. thesis. Iowa State University Library. May 1971.

A method involving Monte Carlo sampling techniques was investigated for the problem of estimating the variance of maximum likelihood estimators for parameters in a nonlinear regression function. A study of the effect of several parameters on the model and a comparison with the asymptotic approximation of the variance was made for the case $y_i = \alpha^2 + e_i$, $i = 1, 2, \ldots, r$; $\alpha \geq 0$.

Vasantha Balan Solomon: "Some Contributions to the Mathematical Theory of Epidemics and Related Problems." Ph.D. thesis. Iowa State University Library. November 1970.

This dissertation is concerned with the discussion and exploration of some methods to study epidemics in which there are two kinds of susceptibles. The simple deterministic model has been studied at length and an approximate solution is obtained by solving a simple first order linear differential equation. The exact solution is obtained in the situation when the ratio of the rates of infection is equal to two. Bounds are obtained for the general situation and are presented for three distinct cases. The cases considered are (i) the number of susceptibles of the first kind is much larger than the number of susceptibles of the second kind, (ii) the susceptibles of the two kinds do not differ greatly in number, and (iii) the number of susceptibles of the second kind is much larger than the number of susceptibles of the first kind. A solution of the deterministic equation with removal or isolation of infectives is also presented.

The stochastic model is considered for the two kinds of susceptibles. The solution for a population of size

four is given when the time variable is discrete. The moments calculated are very complicated and simple interpretations are not possible. Probabilities are calculated for cases in which the reduction in susceptible population occurs only in one kind and two theorems are presented. Models involving both the rates of infection and removal by death or isolation are considered next and general cases in which the infectives alone are reduced are considered.

Immigration of both susceptibles and infectives into the population is also considered. The stationary solutions are obtained in the deterministic case. An approximate solution based on another approach is discussed. The procedure involves consideration of the stochastic model and the approximation of the true problem by a manageable one which yields a nonrandom solution. The solution obtained is equivalent to the stationary solution obtained earlier. Small deviations about these stationary values are considered and the general forms of the solutions of the deviations about these stationary values are presented.

Diseases of epidemic proportions do not occur only in human beings and animals, but also in the plant world. General epidemic situations in trees are discussed when infection is passed through the root system. A simulated study of the spread of a disease to its neighbors, immediate and once removed, with probabilities p_1 and p_2 is presented. A simple mathematical relationship connecting the infected population with the planting distance and velocity of propagation of the disease is derived. If the distances along either axis are not equal, then the resulting geographical spread over time is elliptical; and if the planting distances are equal along the x and y axes, then the resulting pattern is circular. A simple method of estimating the total number of trees diseased at some time T is also indicated.

Victor Tang: "Allocation in Stratified Sampling Based on Preliminary Tests of Significance." Ph.D. thesis. Iowa State University Library. May 1971.

The classical problem of allocation of sample sizes in stratified sampling is to determine a vector $n=(n_1 n_2, \ldots, n_k)$ of k nonnegative integers for which the variance $V(\bar{y}_w)$, of $\bar{y}_w$ the estimated population mean is minimum. The allocation so determined is known as Neyman allocation. This allocation depends upon strata variances σ_i^2 which are generally unknown. One way to overcome this difficulty is to draw a preliminary sample of fixed size from each stratum to estimate σ_i^2 which are used to estimate n_i. This allocation will be referred to as modified Neyman allocation. It is known that if the strata variances differ significantly among themselves, modified Neyman allocation is more efficient than proportional allocation. It is therefore proposed to carry out a preliminary test of significance concerning the homogeneity of strata variances.

Based on the result of the preliminary test, if the hypothesis of the homogeneity of strata variances is accepted, the sample sizes will be determined according to proportional allocation. Otherwise, they will be determined according to modified Neyman allocation. This allocation will be called sometimes proportional allocation. Variances under sometimes proportional allocation are derived for the cases of $k=2$ and 3. Efficiency of sometimes proportional allocation is studied with respect to proportional allocation and modified Neyman allocation.

Eric Neil West: "Some Aspects of Inference, with Particular Reference to Goodness of Fit." Ph.D. thesis. Iowa State University Library. November 1970.

A critical examination has been made of some aspects of the problem of statistical inference. These are studied from the point of view of testing the significance of an observed set of data. A strong emphasis is placed upon the use of modern high speed computing equipment in statistical evaluation of data. In particular, the Pearson chi-square and log likelihood ratio tests of goodness of fit are discussed in detail, with the emphasis on small sample properties. Additionally the Neyman-Pearson theory of testing hypotheses is compared with the theory of testing significance, when the desideratum is to measure the consonance of some class of models with observed data.

A test of significance is discussed as a procedure for computing a significance level which is a measure of the distance of the observed data from the candidate class of models. No reference to alternative models is required, in contrast to the theory of testing hypotheses as developed by Neyman and Pearson. A property required of significance tests is the reasonable one from the point of view of data analysis that data significant at level α must be significant at all levels α' with $\alpha' > \alpha$. The analogous property does not hold for tests hypotheses, and a simple example is presented to illustrate this fact.

The small sample distribution of the Pearson chi-square test statistic is studied, both when the hypothesized model is true, and when the alternative holds, for a large variety of multinomial models. Various approximations for the power of the test are compared and a new one is described. The new approximation, based on a two parameter gamma distribution, is judged to be much superior to the usual noncentral chi-square approximation.

Finally the chi-square and log likelihood ratio tests are compared using an heuristic technique. The new technique uses elements of the Neyman-Pearson concept of power of a test in conjunction with efficient computing and plotting techniques to compare the two tests. Contours of exact constant power are plotted and form the basis for the comparison. It is concluded that the chi-square test performs well in many situations, and that the procedure permits the identification of regions in the parameter space in which each of the tests out-performs the other.

Franklin Kreamer Wolf: "Markovian Decision Process with Uncertain Rewards." Ph.D. thesis. Iowa State University Library. August 1970.

Several decision models with uncertain rewards are discussed in this thesis. Suppose a system can be defined as a stochastic process whose realization is a series of transitions between a finite number of states. One or more alternatives are associated with each state, and prior to each transition one of the alternatives must be selected. The alternative selected will determine the probability of transition to the other states. Immediately after each transition a random reward is generated; the reward received due to the n^{th} transition is discounted by β^{n-1}, $0 \leq \beta < 1$. The distribution from which the reward is sampled is determined by the state of the system prior to the transition, the state of the system immediately after the transition and the alternative chosen to govern the transition. The class of each reward distribution is known, but the parameters of the distributions are uncertain; a prior distribution is specified for the parameter of each reward distribution. For a given number of state transitions, the expected value of the sum of discounted rewards is called the value of the system. A decision maker would like to determine a strategy which, given the past history of states and rewards, will specify the alternative to be chosen to govern the next transition in a manner which will maximize the value of the system.

A general decision process with uncertain rewards, which places few restrictions on the process which generates state transitions, and on the distributions of parameters and rewards, is defined. The maximum value of the system is expressed in terms of a set of simultaneous functional equations. Using this result and assuming the stochastic process governing the state transitions to be Markovian, an expression for the value of the system is obtained.

Special consideration is given the case when the rewards are generated by a Bernoulli process, and the parameters of the reward distributions are independently distributed according to beta distributions. A method of obtaining bounds for the value of a Markovian decision process with uncertain Bernoulli rewards, when the state transition horizon is infinite, is given, as well as a method for determining the optimum policy.

PAPERS AND SPEECHES

This is a record of papers and speeches that Statistical Laboratory staff members presented at scientific and professional meetings. Many of these papers will be published. In cases where abstracts already have been published, references are given.

T. A. Bancroft: "On Establishing a University-Wide Statistical Consulting and Cooperative Research Service," as part of a panel discussion on "Administrative and Budgetary Policies and Procedures to Maintain Effective Statistical Consulting Services at Universities," at the spring regional meeting of the Biometric Society (ENAR), Pennsylvania State University, April 21-23.

At the ASA annual meeting in Detroit, December 27-30:

T. A. Bancroft: "The American Statistical Association: A Single Scientific and Educational Community," the presidential address;

I. Lee and **C. P. Cox:** "The Analysis of a Quantal Response Bioassay as a Markov Process", abstract 1790, p. 483, Biometrics 27:2, June 1971;

G. L. Ghai: "Theoretical Quantitative Genetics with Assortative Mating" (also presented at the University of Minnesota, February 18);

Edward Pollak and **Oscar Kempthorne:** "Some Developments on the Dynamics of a Bisexual Population Under Selection"; and

B. V. Sukhatme and **Victor K. T. Tang:** "Allocation in Stratified Sampling Based on Preliminary Tests of Significance."

Alfonso Carrillo and **B. V. Sukhatme:** "Preliminary Test of Significance in Estimation of Variance," at the European regional meeting of the Institute of Mathematical Statistics, Hanover, West Germany, August 19-26.

H. T. David: "The Theory of Games" and "Two Problems in Applied Statistics," at the University of Minnesota, July 27-28; and "Sequential Decision Making," at the University of Oklahoma, January 25.

Wayne Fuller: "Least Squares and Grafted Quadratics," and "Practical Aspects of Survey Sampling," at Kansas Wesleyan University, March 23-24, University of North Dakota, April 1-3, and University of Northern Colorado, May 26; "Practical Aspects of Survey Sampling," at Metro State College, May 27, all as part of the visiting lecturer in statistics program.

Louis Jensen: "A New Model Describing the Growth of a Population Having Two Sexes," at Kansas State University, January 18; and "A New Model Describing the Growth of a Bisexual Population," at the University of Michigan, March 30.

W. J. Kennedy and **V. A. Sposito:** "Regression Model Building Techniques and Supporting Software," at the meeting of SHARE XXXVI in Los Angeles, March 11.

J. J. Kinney: "On the Formation of Polykays," at the symposium on Symmetric Functions in Statistics at the University of Windsor, Canada, March 13.

Richard W. Madsen: "Some Ergodic Theorems for Markov Chains Defined on an Arbitrary State Space," at the annual meeting of the American Mathematical Society, Atlantic City, January 22-24.

At the IMS annual meeting in Laramie, August 25-28:

Glen Meeden: "Some Admissible Empirical Bayes Procedures," abstract 126-44, p. 1794, Annals of Mathematical Statistics, 41:5, October 1970;

Shashikala Sukhatme: "Fredholm Determinant of a Positive Definite Kernel of a Special Type and Its Application," abstract 126-24 in the October Annals; and

B. K. Kale and **J. R. Veale:** "Test of Hypotheses for Expected Life in the Presence of a Outlier Observation," abstract 126-37 in the October Annals.

Abel Mexas: "Analysis of Classificatory Data of Arbitrary Incidence," at the 7th International Biometric Conference in Hanover, Germany, August 16-21.

Vincent Sposito: "Solutions of Linear Programming Problems with M.P.S." and "The Use of READCOMM and other M.P.S. Procedures," at Computer Science seminars at ISU, March 23 and 25.

Richard Warren: "Utilization of Analytical Models in Empirical Research," at Texas A and M University, March 1.

George Zyskind: "Maximum Likelihood and Variance Component Estimation," at three Quantitative Animal Breeding open-ended seminars at ISU during March; and "Fixed Linear Model Theory," at the central regional meeting of IMS at the University of Missouri, May 4-8.

PARTICIPATION IN PROFESSIONAL ACTIVITIES

Dr. T. A. Bancroft completed his term as president of the American Statistical Association at the annual meeting in December; he continues on the Board of

Directors as past-president. During the December meetings he chaired sessions of the Board, the Council and of chapter presidents, secretaries and district representatives. He has been reappointed to the ASA Advisory Committee on Statistical Policy to the U. S. Office of Management and Budget, Executive Office of the President. He was elected a member of the International Statistical Institute.

Richard Chamberlain attended the 14th Annual Technical Conference in Rochester, New York, October 7-9. On November 20 he and Mary Ann Chamberlain presented a workshop for staff members of the University of Northern Iowa on the use of OMNITAB in consulting and teaching.

Professor C. P. Cox taught Statistical Methods for Biological Assays at the 1970 summer session of Statistics in the Health Sciences at the University of Washington, June 22-July 31. As chairman, he presided at a meeting of the ASA Biometrics Section during the December annual meeting.

Dr. H. T. David has been elected a Fellow of the Institute of Mathematical Statistics. He was named to the IMS 1971 Nominating Committee, and has been appointed to a three-year term on the Advisory Board of the ASA Section on Physical and Engineering Sciences. He continues serving on the IMS Committee on Summer Research Institutes, and will begin a three-year term on the executive committee of the Iowa State chapter of Sigma Xi. On April 12-13 he and David Pyne attended a conference on nonlinear functional analysis at the Mathematics Research Center, University of Wisconsin.

Dr. Wayne Fuller has been appointed to the Finances Task Force of the ASA study of future goals. August 9-14 he served as a discussant on a program on forecasting for the American Agricultural Economics Association meeting at the University of Missouri. He continues as a participating lecturer in the Visiting Lecturer Program in Statistics sponsored jointly by the principal statistical organizations in the United States. Dr. David continues as a member of the organizing committee for this program.

Dr. Richard Groeneveld was a panelist at the 1970 Conference on Computers in the Undergraduate Curricula which met at the University of Iowa, as reported in Proceedings of the Conference, published in September. The panel discussed the topic "Computing Facilities in the Small Institutions."

Dr. Chien-Pai Han served during the year as vice president of the Iowa Chapter, ASA, and has been elected president for 1971-72.

Dr. Paul Hinz has been appointed to the ISU Environtology Council.

Dr. D. K. Hotchkiss was a discussant at a session on Undergraduate Statistics Curricula during ASA meetings in December; Dr. Fuller served in the same capacity for the Econometrics Section.

Dr. D. V. Huntsberger was one of five ISU faculty members to receive an outstanding teacher award. The award, which consists of a plaque and $500, honors faculty, who spend more than 50 percent of their time in active teaching, for their excellence. Dr. Huntsberger is a member of the executive committee of the ASA Section on Training of Statisticians.

Dr. Oscar Kempthorne received one of the two Wilton Park Awards made to ISU faculty members to participate in Wilton Park Conferences in Sussex, England, during the 1971-72 academic year. Participants in the meetings are from nations comprising the Organization for Economic Cooperation and Development. The Conferences usually last two weeks and concentrate on such topics as the Atlantic Community and Integration of Europe; Aid and Technical Assistance; Trade, Credit and Investment; and Automation and Its Impact on Industry and Society.

In October Dr. Kempthorne represented the Statistical Laboratory at the dedication of a building on the North Carolina State University campus in honor of ISU's first graduate in statistics, Gertrude Cox. He then participated in the 16th Conference on Design Experiments in Army Research at Ft. Lee, Virginia, where he accepted, on behalf of Professor George Snedecor, the 1970 Samuel S. Wilks Memorial Medal. The medal was awarded to Professor Snedecor "for his pioneer contributions in the development and use of statistical methods, including applications of experimental design to research investigations, and for introducing several generations of statisticians and research workers to the subject of statistics through teaching and the six editions of his world-renowned book, *Statistical Methods.*" As chairman of the ASA R. A. Fisher Memorial Lecture committee, Dr. Kempthorne presided at the lecture during the ASA December meeting.

Dr. Glen Meeden attended a conference on Bayesian Inference at Oregon State University, July 27-31.

Professor emeritus George Snedecor was one of five members elected an honorary member of the Biometric Society.

Dr. V. A. Sposito was chairman of the Integer Programming and Optimization Systems sessions for IBM SHARE XXXVI, which met in Los Angeles in March. He has been appointed secretary for IBM's SHARE Mathematical Programming Projects.

Dr. Richard Warren continued as statistical-methodological consultant to members of the NC-90 committee working on the project, "Factors Affecting Patterns of Living in Disadvantaged Families." He assisted in planning data processing, analysis of data and publications at their annual meeting, and attended an executive committee meeting in May.

Dr. George Zyskind participated in a workshop on "Analysis of Variance and Data Structures" at the international workshop on analysis of variance sponsored by the International Institute of Statistical Computing at the University of Wisconsin, October 19-21. He gave a presentation on experimental structures in balanced experiments.

Teaching

In addition to the B.S., M.S. and Ph.D. degrees in statistics offered by the Department of Statistics through the College of Sciences and Humanities, a new B.S. program in biometry now is offered by the Department of Statistics through the College of Agriculture.

The biometry program specifically relates statistical methods to biology and agricultural subjects. Students who complete the program will be prepared to work with research scientists in agriculture, join agribusiness firms, enter government service or continue for graduate study in any field of agriculture or statistics.

All statistics programs are designed to emphasize the close relationship between sound application and modern statistical theory. Each statistics major is built around a common core of courses in both theory and methods, with supplementary courses which fit individual students' backgrounds and interests.

A number of course changes have been made during the year. Nonparametric Statistical Methods was offered fall quarter, the first time under its new number, 403. The information included in the course has been previously offered as 499X and 499A. A new advanced graduate course offering fall quarter, Sequential Statistical Decision Theory, drew an enrollment of 5. Class work focuses on several-source sequential analysis, optimal stop rules and Markovian sequential decision models.

Industrial Statistics: Design of Experiments was offered for the last time spring quarter with an enrollment of 3. Last offered in 1966, it is being dropped from the catalog because the course content is being included in other courses. It will be replaced by a new course, Industrial Statistics: Reliability, which will be offered fall quarter. Mathematical Programming was offered spring quarter as 599S and 37 students enrolled. The course now has been listed in the catalog and will continue to be offered under its new number, 549. It covers techniques for determining the optima of linear and nonlinear models including linear, integer, quadratic, convex, and geometric programming applied to economic, engineering and statistical problems.

COURSE OFFERINGS IN STATISTICS

The courses offered by the Department of Statistics during the 1970-71 academic year were:

Courses for Undergraduate Students Only

201,	Principles of Statistics	5	FWS*	Loup, Groeneveld, Schmid, Veale
201A,		3	WS,SS_1	Hotchkiss, Lin, Loup, Madsen, S. Sukhatme
201B		3	FS	M. Chamberlain, Groeneveld, Lin, Madsen, S. Sukhatme
327	Elementary Business Statistics	3	F	Battese
341,	Introduction to Theory of	3	FW	Groeneveld, Huntsberger
342,	Probability and Statistics	3	WS	Groeneveld, Huntsberger
343		3	S	Huntsberger
380	Statistical Applications of Digital Computers	3	FWS	Smith

Courses for Graduate Minors and Undergraduates

401	Statistical Methods for Research Workers	4	FW,SS_1	Battese, M. Chamberlain, C. P. Cox, D. Cox, Dickinson, Geadelmann, Groeneveld, Hickman, Hotchkiss, Hutter, Mensing, Warren, Wolins
402		4	SS_2WS	Battese, M. Chamberlain, D. Cox, Dickinson, Han, Hotchkiss, Hutter, Meeden, Mensing, Warren, Wolins
403	Nonparametric Statistical Methods	3	F	Groeneveld
411	Experimental Design for Research Workers	3	S,SS_1	D. Cox, Dickinson, Hotchkiss
421	Survey Design for Research Workers	3	SS_2S	B. Sukhatme
431	Elementary Statistical Quality Control	3	S	Mensing
436	Genetic Statistics for Research Workers	3	S	Geadelmann

*Because the fiscal year began July 1, 1970, and ended June 30, 1971, the courses taught in the second summer session of 1970 through the first summer session of 1971 are reported here. Symbols indicate the quarter each course was taught: SS_2—Second Summer Session, F—Fall, W—Winter, S—Spring, SS_1—First Summer Session.

446, 447,	Statistical Theory for Research Workers	3 3	F W,SS_1	Hinz Hinz
448		3	SS_2S	Hinz, Huntsberger
481, 482	Processing of Statistical Data	2 2	W S	Mosier Mosier
499	Special Problems	Arr.	SS_2S, SS_1	Bancroft, Hotchkiss
499X	Business Administation Statistics	5	FWS	Jobson

Courses Primarily for Graduate Students, Major and Minor

501	Intermediate Statistical Methods	3	F	Bancroft
505	Psychometrics	3	S	Wolins
506	Factor Analysis	3	F	Wolins
508	Sociometric Statistics	3	F	Warren
511, 512	Design of Experiments	3 3	W S	Kempthorne Zyskind
521, 522	Design of Surveys	3 3	W S	B. Sukhatme Han
531	Industrial Statistics: Sampling Inspection	3	F	David
532	Industrial Statistics: Design of Experiments	3	S	David
535	Biological Statistics	3	S	C. P. Cox
536, 537	Genetic Statistics	3 3	F W	Pollak Pollak
538	Econometric Statistics	3	F	Fuller
539	Operations Research	3	W	Mensing
541, 542, 543	Theory of Probability and Statistics	3 3 3	F W S	Arnold Meeden Arnold
545	Stochastic Processes	3	SS_2	Arnold
580	Computational Techniques in Statistics: Methods	3	W	Kennedy
581	Computational Techniques in Statistics: Theory	3	S	Kennedy
599	Special Topics	Arr.	SS_2FWS,SS_1	
	A. Theory			Arnold, Han, Meeden, S. Sukhatme, Wolins
	B. Methods			Bancroft, C. P. Cox, D. Cox, David, Dickinson, Fuller, Hickman, Hinz, Isaacson, Kennedy, Mensing Sposito, Wolins
	C. Design of Experiments			Zyskind
	D. Design of Surveys			Hickman, B. Sukhatme
599S	Mathematical Programming	3	S	Sposito
599X	Intermediate Statistical Methods in Education	4	FS	Hickman

Courses for Graduate Students, Major and Minor

601	Advanced Statistical Methods	3	F	C. P. Cox
608	Seminar on Statistical Methods	3	W	C. P. Cox
611, 612	Advanced Design of Experiments	3 3	W S	Zyskind Kempthorne
641	General Theory of Linear Hypothesis	3	F	Zyskind
642	Probability and Distribution Theory	3	W	Arnold
643	Theory of Estimation and Testing of Hypotheses	3	S	Meeden
644	Sequential Statistical Decision Theory	3	F	David
646	Time Series	3	S	Fuller
647	Multivariate Analysis	3	F	Han
648	Seminar on the Theory of Statistics and Probability	3	S,SS_1	Arnold, Isaacson, Meeden
699	Research	Arr.	SS_2FWS SS_1	Arnold, C. P. Cox, David, Fuller, Han, Isaacson, Kempthorne, Mensing, Pollak, B. Sukhatme, S. Sukhatme, Warren Zyskind

INSTITUTES

NSF Institute

"Basic Concepts of Probability and Statistics with Computer Applications," the second summer institute sponsored by the National Science Foundation, attracted 38 mathematics teachers from secondary schools in 17 states and the District of Columbia. It was planned to give the participants knowledge and competency in teaching statistics at the high school level. The institute met at the Statistical Laboratory June 29 through August 7.

Dr. D. K. Hotchkiss directed the institute and lectured on statistical methods. Dr. Roy D. Hickman, associate institute director, coordinated a special series of seminars. Dr. W. J. Kennedy discussed simple programming languages which have value for a remote computer terminal. Dr. Harold Larson, an ISU statistics graduate who is affiliated with the U.S. Naval Post-Graduate School in Monterey, California, was in Ames on special assignment for the institute. He lectured on the theory of probability and statistics.

The institute program focused on statistics at an introductory level, and used the computer to resolve statistical problems. Participants who completed the work earned ten graduate quarter hours of credit.

A survey to determine the impact of the institute indicated that participants are making good use of their training. Nearly two-thirds who replied to a questionnaire reported they have taught a high school course

which included statistical concepts, and 80% have included careers in statistics when counseling students interested in the mathematical sciences. Eight persons already have developed new courses at their schools in which at least half of the material is related to statistics or probability and more expect to do so. Institute participants also have been called on by colleagues to consult on the statistical evaluation of laboratory or experimental data.

Engineering and Management Institute

An institute on Quality Control met May 13 and 14 at Iowa State. R. W. Mensing assisted with plans for the institute, directed toward personnel from quality control and production who were concerned with quality. A large part of the program, designed to provide some direction and stimulation toward better quality, dealt with statistical techniques that have been helpful in controlling quality.

During the institute Dr. Mensing led a session on Control Charts for participants with some control chart experience, and discussed sampling inspection at two other sessions.

GRADUATE STUDENTS

Graduate students continue to take an active interest in departmental and university affairs. Dick Chamberlain represented the graduate students on the department's Curriculum Committee during the year, and Jeff Meeker has been elected vice president of the university Graduate Student Senate for the coming year.

Ph.D. Candidates

Thomas Aiuppa
Chaturuedula Asok
Ray Bailey
George Battese
Richard Chamberlain
Lal Chand
Richard Chung
Isidoro David
Pamela Doctor
Richard Dorsch*
Mohamed El-Sabbagh
A. Ronald Gallant
G. L. Ghai
John Goebel
Joseph Grimes
M. A. Hidiroglou
Elizabeth Hsu Huang*
Her Tzai Huang
Cary Isaki
Louis Jensen
J. D. Jobson
Kazimierz Karpinski
Thomas Keefe
John Kinney
Angel Martinez
Donald McElhone
Jeff Meeker
James Mellon
Kenneth Merritt
Nimmagadda Murthy
Esmat Nouri
Peter O'Brien
Martin J. O'Connell
Ken Offord*
David Pyne*
A. Shawki Salem*
J. R. Schmid
Preecha Sakarindr
Wendell Smith
V. B. Solomon
Richard Stein
Malte Sund
Victor Tang
Lonnie Vance
James Veale
Jose Villasenor
George Wang
William Warde
G. Nick Lauer
John Lin
Roland Loup
Richard Madsen
Eric West
James Whipple*
Franklin Wolf

*received M.S. during the year

M.S. Candidates

Guillermo Adames-Suari
Michael Althaus
Claude Angers
Forrest Aspengren
Robert Centner
Kuo Ming Chien
Eliahou Cohen
Linda Costea
Peampan Davivongs
Richard Dorsch
Modesto Freites
Amiri Gamshadzahi
Soner Gonen
Omer Gucelioglu
Earl Haynes
Norman Hoesly
Patricia Howard
Elizabeth Hsu Huang
Ronald Jacobson
Jairoj Jayavadhanangkur
J. D. Jobson
Henry Kelker
Joan Keller
Harold Keplinger
Geung Ho Kim
Haeja Chung Kim
Charles MacIsaac
Mohammad A. Malik
Omar Martinez
Robert Mason
Roger Mrachek
Kenneth Offord
Yupha Onthuam
David Pyne
A. Shawki Salem
Ivan Sampaio
Nancy Heath Shover
Dennis Tsai
Frederic Vogel
James Whipple
Kirk Wolter
Wai Wo Wong
Chartsee Xumsai
Tetsuo Yamada

Degrees Granted and Positions Taken

Students who received advanced degrees during the year and their location after graduation are listed here. Abstracts of their theses, written as partial fulfillment of the requirements for graduation, appear in the publications section of this report.

Recipients of the Ph.D. Degree

A. Ronald Gallant (May 1971, under W. A. Fuller) accepted a position as visiting assistant professor, Departments of Statistics and Economics, at North Carolina State University.

Cary Isaki (November 1970, under W. A. Fuller) joined the Statistical Research Division of the Bureau of the Census in Washington, D.C.

Louis Jensen (May 1971, under Edward Pollak) went to the University of Michigan as an assistant professor in the Department of Statistics.

G. Nick Lauer (May 1971, under C. P. Han) accepted a position as statistician with Owens-Illinois Glass Co.

Roland Loup (August 1970, under C. P. Cox) served as a 1st Lt. in the U.S. Army and then joined the Statistical Laboratory as an instructor.

Angel Martinez (August 1970, under W. A. Fuller) returned to Mexico and accepted a faculty appointment at the statistical center, National School of Agriculture, Chapingo.

Donald McElhone (August 1970, under W. A. Fuller) entered the U.S. Army as a 1st Lt.

Esmat Nouri (February 1971, joint statistics-agronomy, under Oscar Kempthorne, statistics and P. A. Peterson, agronomy) is an assistant professor in the Department of Mathematics, State University College, Oneonta, New York.

Peter O'Brien (August 1970, under W. A. Fuller) joined the staff of the Mayo Clinic.

V. B. Solomon (November 1970, under Edward Pollak) is an assistant professor at Drake University.

Victor Tang (May 1971, under B. V. Sukhatme) returned to his position with the Department of Mathematics at Humboldt State College in Arcata, California.

Eric West (November 1970, under Oscar Kempthorne) is an assistant professor in the Department of Computing Science at the University of Alberta in Canada.

Franklin Wolf (August 1970, joint statistics-industrial engineering, under H. T. David, statistics, and Harold Cowles, industrial engineering) is an associate professor of mechanical engineering at Western Michigan University in Kalamazoo.

Recipients of the M.S. Degree

Guillermo Adames-Suari (February 1971, non-thesis, under C. P. Han) continued course work at Iowa State during spring quarter before returning to Mexico.

Forrest Aspengren (August 1970, non-thesis, under Richard Mensing) joined Babcock and Wilcox Co. in Lynchburg, Virginia, as a statistician in the Quality Control Section, Naval Nuclear Fuel Division.

Eliahou Cohen (November 1970, non-thesis, under Edward Pollak) is a consulting statistician with Vogelback Computing Center at Northwestern University.

Richard Dorsch (May 1971, non-thesis, under Dean Isaacson) remains at Iowa State working toward a doctorate.

Amiri Gamshadzahi (August 1970, under David Jowett) returned to Iran and his position with the Soil Institute of Iran.

Soner Gonen (August 1970, non-thesis, under Roy Hickman) returned to his post at Hacettepe University, Turkey.

Omer Gucelioglu (August 1970, non-thesis, under Wayne Fuller) returned to Turkey and his position with the State Institute of Statistics.

Norman Hoesly (February 1971, non-thesis, under Dean Isaacson) continued course work at Iowa State during spring quarter.

Elizabeth Huang (May 1971, non-thesis, under Wayne Fuller) remains at Iowa State working toward a doctorate.

Ronald Jacobson (May 1971, non-thesis, under C. P. Cox) is employed by the University of Minnesota as a consultant in medical research.

Jairoj Jayavadhanangkur (November 1970, non-thesis, under Glen Meeden) returned to Thailand.

J. D. Jobson (August 1970, non-thesis, under Wayne Fuller) remains at Iowa State working toward a doctorate.

Haeja Chung Kim (May 1971, under S. Sukhatme) is employed by the Survey Section of the Statistical Laboratory while her husband completes his degree.

Charles MacIsaac (February 1971, non-thesis, under Dean Isaacson) remains at Iowa State, working toward a doctorate in education.

Kenneth Offord (February 1971, non-thesis, under C. P. Cox) remained at Iowa State working toward a doctorate spring quarter and has accepted a position with the Mayo Clinic.

Yupha Onthuam (February 1971, under R. D. Warren) returned to Thailand.

David Pyne (November 1970, under W. D. Lawing) remains at Iowa State working toward a doctorate.

A. Shawki Salem (February 1971, under Wayne Fuller) remains at Iowa State working toward a doctorate.

Ivan Sampaio (August 1970, under David Jowett) returned to Brazil where he is employed by the government in Brazilia.

Nancy Heath Shover (May 1971, under Richard Mensing) was married.

Frederic Vogel (February 1971, non-thesis, under Roy Hickman) continued his position with the United States Department of Agriculture in Washington, D.C.

James Whipple (November 1970, non-thesis, under C. P. Cox) remains at Iowa State working toward a doctorate.

Chartsee Xumsai (August 1970, non-thesis, under C. P. Han) returned to Thailand.

The George W. Snedecor Award in Statistics

Richard Madsen received the 1971 George W. Snedecor Award, consisting of a year's membership in the Institute of Mathematical Statistics, a subscription to the Institute's Annals and a cash gift. The Award, named in honor of the Statistical Laboratory's founder and first director, is presented annually to the most outstanding candidate for the Ph.D. degree in statistics at Iowa State, as selected by the graduate faculty. Madsen came to Iowa State in 1968 and has held a National Science Foundation fellowship.

UNDERGRADUATES

D. V. Huntsberger advised upper-class undergraduates, with D. K. Hotchkiss and Richard Groeneveld advising the underclassmen. The special freshman orientation program introducing new students to basic statistical topics was continued. Information on statistical methods, experimental design, sampling and statistical computing was presented by Dr. Hotchkiss, D. F. Cox, Roy D. Hickman and W. J. Kennedy, respectively.

A cooperative program is being developed which will provide undergraduates and students in the master's degree program with an opportunity for off-campus work experience in statistics during their educational program. It is anticipated the coordination of work experience, involving the application of statistical methods to real data, with the campus educational program, would provide a clear connection between statistical theory and practice. In addition, motivation toward academic work should increase as the coordination between vocation and education is made more apparent. The work experience should also contribute toward the development of a sense of responsibility and self-reliance on the student's part. Plans now are being made with ISU statistics graduates employed in industry to implement the program. It is hoped some students will begin cooperative employment in the summer of 1972.

Gary Kester received his degree in August, Linda Gorman was graduated in February, and Kirk Mattes in May. Also in May Joel Fuhrman and Michael O'Banion received B.S. degrees with joint majors in computer science and statistics.

Iowa State University Statistics Club

Kirk Mattes was awarded the IBM-Stat Club scholarship for 1970-71. The scholarship, which pays tuition costs for one school year, is jointly sponsored by the IBM Corporation and the Statistics Club. Mattes served as club president during the year and as chairman of the annual Veishea display.

The Statistics Club continued its program of informational meetings, with Dr. Leroy Wolins discussing "Application of Statistics to Educational Problems in Switzerland," and Kris Jones of the Dean of Student's office reporting on "Statistical Analysis of a Time Allocation Study." Scott Krane of Hallmark Cards, Inc. spoke to a joint meeting of the Statistics, Mathematics and Computer Science Clubs on "Mathematical Careers in a Greeting Card Industry." Club members visited the Armstrong Rubber plant in Des Moines for the annual field trip.

New officers elected are: David Lowe, president; Andrew Yam, vice president; Diane Pierick, secretary and Charles McCormick, treasurer.

Mu Sigma Rho

Wendell Smith has been elected president of the Iowa State chapter of Mu Sigma Rho, national statistical honor society. Other officers are Linda Gorman, vice president, and Nancy Allen, secretary-treasurer. The society will initiate new members in the fall.

SEMINARS

Statistical Laboratory—Department of Statistics Series

H. T. David, W. J. Kennedy and Edward Pollak composed the 1970-71 committee which planned the weekly seminars sponsored by the Statistical Laboratory and Department of Statistics for all students and faculty members. These non-credit seminars which frequently feature guest speakers from other institutions provide an opportunity to report current research in statistics and to explain and discuss statistical theory and methodology. Following is a list of topics and speakers presented during the year:

Fall Quarter 1970

September 9 What Rewards May a Statistician Expect? T. A. Bancroft.

September 16 Oblique Projections, Conditional and Generalized Inverses, and Least Squares Applications. George Zyskind.

September 23 Relationships Between Sets of Variables Found by Several Model Building Procedures. William D. Lawing, University of Rhode Island, and David A. Pyne.

September 30 Failures in Steel Structures and the Safety of Nuclear Reactor Power Stations. Monroe Wechsler, Department of Metallurgy, ISU.

October 7 Regression Estimation for Bivariate Normal Distributions. Chien-Pai Han.

October 14 The Application of Psychometrics in the Swiss Educational System. Leroy Wolins.

October 21 Some Admissible Empirical Bayes Procedures. Glen Meeden.

October 28 (joint Statistical Laboratory and Department of Economics) Defining Subjective Probability. Robert Buehler, University of Minnesota.

November 4 Simple Estimators for the Mean of Skewed Distributions. Wayne Fuller.

November 11 Duality Relationships for a Nonlinear Version of the Generalized Neyman-Pearson Problem. Howard Meeks, Department of Industrial Engineering, ISU.

Winter Quarter 1971

December 2 Ergodic Theorems for Kernels on an Arbitrary Space. Richard Madsen.

December 9 Theories of Population Growth, I: Currently Used Models and Their Limitations. Edward Pollak.

December 16 Theories of Population Growth, II: A New Model Describing the Growth of a Population Having Two Sexes. Louis Jensen.

January 6 Variations on the Birthday Theme. Barry Arnold.

January 13 Some Current Activities of the Survey Section. Norman Strand, Roy Hickman and Harold Baker.

January 20 Parsing Techniques for Compilers. Roy Keller, Department of Computer Science, ISU.

January 27 A Problem in the Estimation and Interpretation of the Intra-Class Correlation. D. F. Cox.

January 29 (joint Statistical Laboratory and Department of Political Science) Linkage Models of the Political System. John Sullivan, Yale University.

February 3 Estimation of Variance after Preliminary Tests of Significance. Alfonso Carrillo.

February 10 Least Squares Estimation for Nonlinear Regression Models. Ronald Gallant.

February 17 Examples of Bayesian Hypothesis Testing where the Uniform Prior Is Least Favorable. Glen Meeden.

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March 10 Continuous Martingales with Discrete Marginals. Dean Isaacson.

March 17 Signal Detection Problems—Tests Based on Percentiles. Richard Groeneveld.

March 24 The k Statistics. John Kinney.

March 31 Infinite Divisibility of Discrete Distributions. William Warde.

April 7	(joint Statistical Laboratory, Computation Center and Department of Mathematics) The Ill-Conditioned Generalized Eigenvalue Problem $Ax = \lambda Bx$. Richard Heiberger, Harvard University.
April 14	A Method for Solving Systems of Nonlinear Equations. Alexander MacEachern, Department of Computer Science, ISU.
April 28	(joint Statistical Laboratory and Iowa Chapter, ASA) Some Analyses of Variance of Biological Counts. C. I. Bliss, Yale University and Connecticut Agricultural Experiment Station.
May 3	Some Examples of Minimum Variance Unbiased Estimates. Barry Arnold.
May 12	Power of Cochran's Test in Behrens-Fisher Problems. G. Nicholas Lauer.
May 19	Random Sampling and the Forming of Opinion. Oscar Kempthorne.

Applied Statistics Series

Paul Hinz was chairman of the Applied Statistics seminar committee which included D. K. Hotchkiss and Dick Mensing. This series emphasizes the application of statistics to all fields and is especially planned for research workers who use statistics as a primary research tool. Programs for the year were:

September 21	Multiple Comparison Procedures. William Warde.
October 8	Psychological Scaling: Classical Models and Procedures. Leroy Wolins.
October 22	Sensory Measurements: Grading and Differences Versus Acceptability. A. F. Carlin, Department of Food and Nutrition, ISU.
November 5	Scaling of Sociological Data. Richard D. Warren and David Specht, Department of Sociology, ISU.
December 10	Scales Derived from Behavioral Descriptions of Infants by Judges. Damaris Pease, Department of Child Development, ISU.
January 14	Some Measurement Problems in Market and Consumer Testing. Scott Krane, Hallmark Cards, Inc.
January 28	Frequency Distributions in Hydrologic Data Analysis. Craig Beer, Department of Agricultural Engineering, ISU.
February 11	Prediction of Filter Performance Using a Chi-Square Model. John Cleasby, Department of Civil Engineering, ISU.
March 11	Applications of Statistics in Transportation Engineering. Robert Carstens, Department of Civil Engineering, ISU.
March 25	Probability Multiple Frame Sampling—USDA Applications to Improve Precision of Livestock Estimates. Galen Hart, Statistical Reporting Service, USDA.
April 29	A Choice Test by Two Panels of Young Trees. C. I. Bliss, Yale University and Connecticut Agricultural Experiment Station.
May 13	A Search Model for Evaluating Combinatorially Explosive Problems. Keith McRoberts, Department of Industrial Engineering, ISU.

Quantitative Genetics Series

The Quantitative Genetics seminars, planned by Oscar Kempthorne and Edward Pollak, are especially for staff members and graduate students in statistics, genetics, animal science, poultry science, agronomy and horticulture.

On December 15 Dr. Brian Charlesworth, University of Chicago, spoke on "Selection with Overlapping Generations." Dr. Pollak discussed "Malthusian Parameters in Genetic Populations. Part II. Random Mating Populations in Infinite Habitats" on March 30. The May 11 speaker was Cecilio Arboleda of the Department of Poultry Science. His topic was "The Economic Feasibility of Measuring Feed Consumption in Two Poultry Breeding Operations."

Operations Research Seminars

Under the guidance of H. T. David, Keith McRoberts from industrial engineering, and J. K. Sengupta, a new interdisciplinary seminar series was started fall quarter. It was organized to appeal to individuals concerned with mathematical modeling and optimization techniques often designated "Operations Research," many of which are applicable to current societal problems, and which are taught within a number of departmentally distinct disciplines. At monthly meetings the participants heard off-campus guests and speakers from a variety of departments. In December Dr. Sengupta spoke on "Simulation in Control Models Under Econometric Estimation." Richard Mensing discussed "A Review of Some Replacement Models in Reliability" for the April program.

FORD FOUNDATION MEXICAN PROJECT

This year saw the completion of the cooperative project with the Statistical Center at the National School of Agriculture in Chapingo, Mexico. This Ford Foundation-sponsored project, which was planned to strengthen the graduate program in statistics and develop a graduate program in agricultural economics, was a cooperative effort between Iowa State and two Mexican education institutions. It was jointly administered by T. A. Bancroft of the Statistical Laboratory, working with the Chapingo Statistical Center, and Earl Heady of the Department of Economics, working both with the Chapingo institution and the University of Nuevo Leon. Dr. J. B. Page, who was vice president for research and dean of the Graduate College at Iowa State coordinated the two programs.

A principal objective of the statistics part of the joint program was to provide Mexican nationals with graduate degrees obtained abroad to properly staff the

Statistical Center so it could develop and expand its teaching, research and consulting programs. During the project, five Mexican nationals completed Ph.D. degrees in the United States, three of them in statistics at Iowa State. Currently there are six Mexican national Ph.D.'s on the staff plus two visiting professors. It is planned that a Ph.D. program will be offered in 1972.

Dr. Abel Mexas finished his Statistical Laboratory assignment in Mexico during the year and then left the Laboratory to join the staff of the Ford Foundation and continue his assistance with the Chapingo statistical program.

As a part of his Iowa State assignment, Dr. Mexas continued backstop assistance to supplement and complement the work of Mexican national staff members in teaching, research and consulting. Assistance was provided to further strengthen the computing program, including computing services to on-campus users and Mexican federal agencies. Assistance also was provided on the statistical aspects of certain projects in Mexico of interest to the Mexican government and the Ford Foundation, but not directly related to the statistical program at Chapingo.

As a result of the assistance provided during the five-year project, it is expected that the Statistical Center will continue as a viable teaching, research and consulting center, with an increase in qualified Mexican national staff members resulting in an increase in students and programs offered.

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