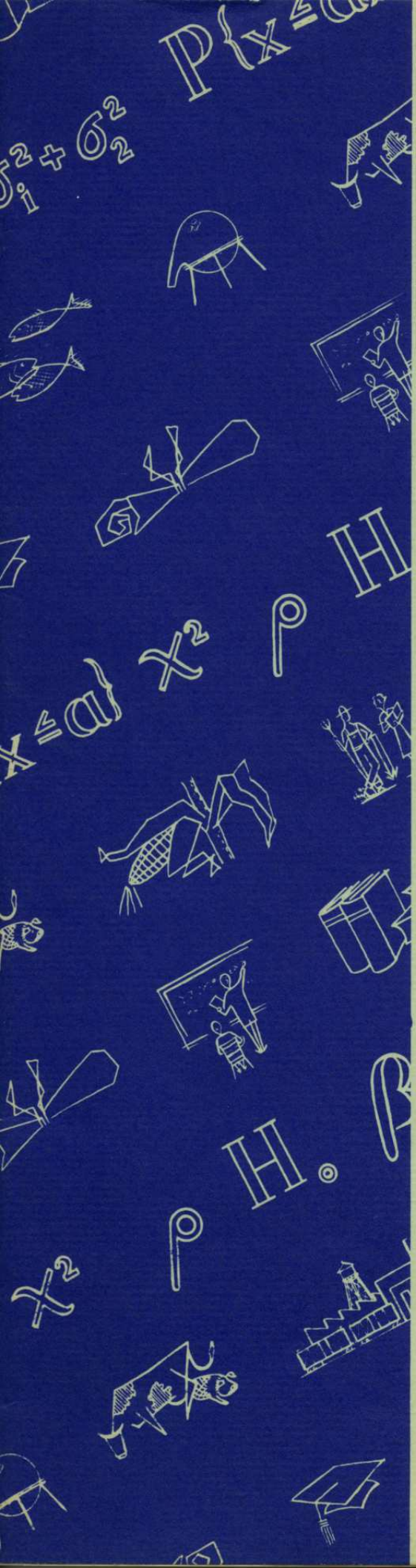

IOWA STATE UNIVERSITY BULLETIN

STATISTICAL LABORATORY

ESTABLISHED 1933

ANNUAL REPORT

July 1, 1966 to June 30, 1967

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, 1966, through June 30, 1967. 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 Agricultural and Home Economics Experiment Station;

(4) The statistics participant in the Sciences and Humanities Research Institute and the Engineering Research Institute; and

(5) The research field office of the Statistical Standards Division, Statistical Reporting Service, United States Department of Agriculture, which is located in the Statistical Laboratory.

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,
Agricultural and Home Economics
Experiment Station

THE STATISTICAL LABORATORY

Iowa State University

ANNUAL REPORT 1966-1967

IOWA STATE UNIVERSITY BULLETIN
Ames, Iowa

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Personnel

The various components of the statistical center have a single director and share personnel. In fiscal terms, this means that a staff member's salary may be provided from several sources: the Department of Statistics in the College of Sciences and Humanities; the Statistical Laboratory, an institute under the president's office; a statistical project of the Iowa Agricultural and Home Economics Experiment Station or the Engineering Research Institute; or a research contract by the Statistical Laboratory and the Sciences and Humanities Research Institute. The director of the Statistical Laboratory reports to the president of the university through the vice president for research.

The laboratory also has a number of research grants and contracts with federal agencies which provide funds for research for both staff and graduate students at all levels.

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

THE STATISTICAL LABORATORY STAFF FOR THE FISCAL YEAR 1966-67

Under the administrative direction of

W. Robert Parks, Ph.D.....President of the University

J. Boyd Page, Ph.D. .....Vice President for Research; Dean of the Graduate College

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 Agricultural and Home Economics Experiment Station

Theodore A. Bancroft, Ph.D.....Director, Statistical Laboratory; Head, Department of Statistics; Head, Statistics Department, Iowa Agricultural and Home Economics Experiment Station

Professors

T. A. Bancroft
C. Philip Cox
Herbert T. David
Wayne A. Fuller
David V. Huntsberger
Oscar Kempthorne—Distinguished Professor, College of Sciences and Humanities
George W. Snedecor—Professor Emeritus—in absentia
Norman V. Strand
Leroy Wolins—joint appointment with Department of Psychology

Associate Professors

Om P. Aggarwal—through fall quarter
Foster B. Cady—on assignment in Mexico
Donald K. Hotchkiss
Howard W. Jespersen—joint appointment with Computation Center
B. K. Kale—visiting
Akio Kudô—visiting, through fall quarter
C. C. Mosier—joint appointment with Computation Center
J. H. Sedransk
J. K. Sengupta—joint appointment with Department of Economics
B. V. Sukhatme—beginning spring quarter
James Walsh—joint appointment with Department of Psychology
George Zyskind

Assistant Professors

Barry Arnold—joint appointment with Department of Mathematics
Harold Baker
Edward J. Carney
Carol Edwards Fuchs
Chien-pai Han—beginning spring quarter
Roy Hickman
David Jowett
Edward Pollak
S. R. Srivastava—visiting, 1966 summer session
David Thomas
Richard D. Warren—joint appointment with Department of Sociology

Visiting Lecturer

Henry Tucker—on assignment in Mexico

Postdoctoral Fellows

Richard Kleber
Hans Peter Thöni
Frances Ward

Visiting Scholar

A. F. dos Santos

Instructors and Associates

Patricia Conn
James S. DeGracie
Irving Hall—beginning winter quarter
William Kennedy
Richard Lund—beginning spring quarter
Frank B. Martin
Richard Mensing
Martin Rosenzweig
Donald Soults

Graduate Assistants

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

Joe Atkinson
Nell Bruner
Leon Burmeister
Richard Chamberlain
Gregory Fawcett
Thomas Fears
Ralph Folsom
Richard Frauendorfer
Charles K. Graham
Irving Hall
James Immordino
Carey Isaki
Louis Jensen
Paul A. Johnson
Leon Jordan
John Lake
Richard Lund
Mark Malone
Ronald Mead
James Mellon
Esmat Nouri
Peter O'Brien
James Olin
P. Papaioannou
David Pyne
Mary Ann Smith
V. B. Solomon
Douglas Splitstone
Vincent Sposito
James Veale
Eric West
Ing-Tzer Wey
James Wigton

Other Graduate Students

NIH Trainees:

Patricia Conn
James Gebert
John Johnson
Roland Loup
Peter O'Brien
Donna J. Ruhl
Charles Sampson

NASA Fellows:

Sharon Earley
John Meyer
Kenneth Mount

NSF Fellows:

Gordon Booth
Justus Seely

Supported Students:

Joseph Abbey, AID, Ghana
Munir Ahmad, AID, Census Bureau, Pakistan
Sorachai Bhisalbutra, AID, Thailand
John Buche, USDA Trainee
Alfonso Carrillo, Ford Foundation
K. T. deGraft-Johnson, United Nations, Ghana
John W. Hazard (joint statistics-forestry), U. S. Forest Service
Omar Henriquez, Rockefeller Foundation, Chile
Khadija Khatun, AID, Pakistan
Donald McElhone, Ames Laboratory
Ahmed Memon, AID, Pakistan
Abel Mexas, Statistical Laboratory
Mallika Mokkhaves, AID, Thailand
Lindsey Murdah, Industrial Engineering Department
Syed T. M. Naqvi, AID, Census Bureau, Pakistan
Bonnie Roberts, Statistical Laboratory
Carl Z. Roux, Government of Union of South Africa
Ahmed Salem, Government of UAR
Hans Schreuder (joint statistics-forestry), Forestry Department
Nimnual Sriplung, Government of Thailand
Arlette Urguelles, AID, Venezuela
Hermann Wiedenhofer, Government of Venezuela
Franklin Wolf, Department of Industrial Engineering
Mia Mohammed Yusuf, AID, Census Bureau, Pakistan

Unsupported Students:

Farrukh Ahmad
Forrest Aspengren
James Blinn
Leroy E. Carver
Robert Gray
Sue Rowe Johnson
Esmat Nouri
C. M. Patel

Special Students

Erol Farouk Karaglou, AID, Census Bureau, Turkey
G. S. Mebrautu, AID, Census Bureau, Ethiopia
Charles K. B. Tachie-Menson, FAO, Ghana

Student Assistants (Undergraduate)

Dennis Askvig
Dean Harvey
Jan Shoemaker

General Office Staff

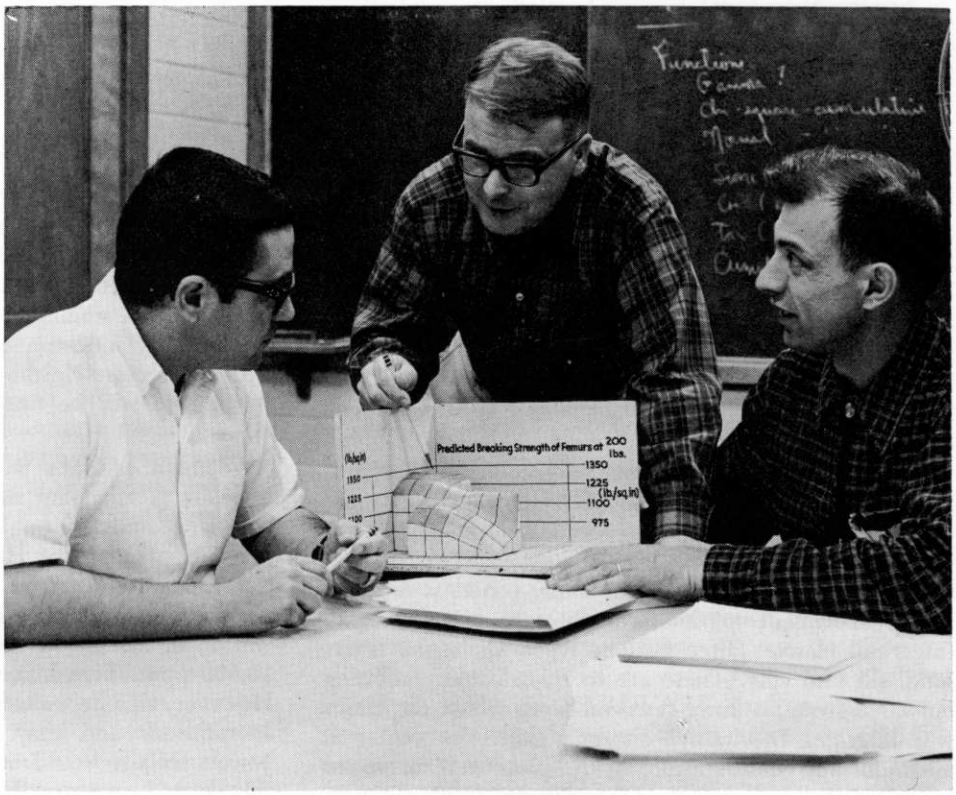
Margaret G. Kirwin, Administrative Assistant
Kathleen Ringgenberg, Accountant
Susan Alice Brown, Technical Writer-Editor
Carolyn Mindham, Secretary—through winter quarter
Marlene Sposito, Secretary—beginning winter quarter
Jan Bates, Secretary
Marian Bender, Secretary—through winter quarter
Norma Christian, Secretary—beginning spring quarter
Judy Donald, Secretary
Avonelle Jacobson, Secretary, Teaching Group
Iveta Zeliadt, Secretary, Experimental Design Group

Numerical Analysis-Programming Group

Shirley Saveraid, Secretary
Patricia Barnett, Technician
Mary Ann Carney, Technician
Gretchen Snowden, Technician—through fall quarter

Survey Group

Anne Leicht, Secretary
Helen Ayres, Survey Supervisor
Marjorie Mason, Clerical Supervisor
Clerks:
Hazel Cook
Ava Klopf
Mabel Matthews
Anna B. Woodrow



Dr. David Jowett, center, and Dr. Donald Hotchkiss, right, spend many hours consulting, under the auspices of Agricultural Experiment Station Project 101, Statistical Services in the Plant and Animal Sciences. Here they are discussing response surfaces with graduate student Alfonso Carrillo from Chapingo, Mexico, who is studying at Iowa State as part of the cooperative agreement with the Ford Foundation.

Consulting and Joint Research

Providing consulting services to campus and off-campus personnel is an important activity of the Statistical Laboratory. Through this consulting, staff members of the Statistical Laboratory participate in research being conducted in many departments of the university. This consulting service is made possible by the budgetary allowance of the Statistical Laboratory and the financial support provided to some staff members by the Agricultural and Home Economics Experiment Station and the Engineering Research Institute. Some staff members are budgeted to devote a great deal of their time to consulting activities while others are budgeted primarily on research projects or to fulfill teaching assignments.

Consulting services are available for statistical design of experiments, statistical design of surveys, statistical analysis and interpretation of data, numerical analysis and programming of a statistical nature, and the development and extension of new statistical methods and techniques.

Consulting problems vary, not only in the technical nature of the problem, but also in the amount of assistance needed by the investigator. Some problems may be fairly routine while others need modification of existing statistical methods and/or the development of new statistical theory and methodology. Often one important service performed by the consulting statistician is to encourage a research worker to examine his objectives carefully in view of his proposed experiment to ensure that it will answer his questions.

Staff members who have provided consulting services during the year were asked to select the most interesting or significant projects on which they worked to report here. This gives an indication of the consulting activities being carried out through the Statistical Laboratory but is not meant as a complete record of the work of each staff member involved in consulting.

Frequently, two or more staff members will be consulted, independently or jointly, on a single project, which may involve individual students, staff members or a group of researchers. The results may appear in a thesis, or are presented as a paper at a meeting, or are published. Sometimes the consultant's contribution is such that he is recognized as a paper's co-author.

Dr. David V. Huntsberger has consulted during the year with a number of students and staff members in the area of collection and analysis of experimental data. Personnel seeking this advice have been from the departments of agricultural engineering, botany, chemical engineering and zoology.

Consulting in the Plant Sciences

Dr. David Jowett has continued to provide consulting services in the plant sciences, as co-leader of Agricultural Experiment Station Project 101, Statisti-

cal Services in the Animal Sciences and Plant Sciences. He reports that workers in plant and animal ecology have again presented interesting statistical problems.

Dr. R. W. Bachmann, Department of Zoology and Entomology, has continued his survey of the invertebrates of Clear Lake, Iowa. In order to sample the bottom fauna, the lake was divided into seven unequal areas on the basis of gross ecological characteristics, and six random samples were obtained by dredging in each area at weekly intervals. Analysis of variance showed substantial differences in quantity and composition of bottom fauna among areas, and lesser differences over time. The total standing crop in the lake was estimated and found to be about typical for this type of lake.

Dr. Jowett's assistance was sought on another project of this type, initiated by Dr. R. J. Muncy, also of the Department of Zoology and Entomology, to investigate fingernail clams on the Mississippi. A particularly interesting part of the study concerns a laboratory experiment to determine bottom preferences of fingernail clams. Three bottom types are to be used: sand, silt and clay. These are to be arranged radiating outwards from an inner reservoir from which the clams will migrate. Inevitably, distance from the center is an important consideration, so the plots were arranged as a 3 x 3 latin square in each quadrant, with distance from the center acting as rows. In addition, it was felt there may be some carry-over effect, the number of clams available for settling a plot being influenced partly by their preference for the plot over which they have just traveled. Hence, the latin square was so arranged as to provide a crossover design with estimation of residual effects.

Dr. R. Q. Landers of the Department of Botany and Plant Pathology has asked for assistance with ecological studies of relict areas of woodland in Iowa. Some analyses have been performed on data obtained in an area about to be flooded. Plans have now been made for a survey of a large number of woods. It has been suggested that initially species lists be obtained and a computer program prepared to attempt a hierarchical classification of Iowa woodlands, as a guide to more intensive study, using statistical techniques recently developed elsewhere.

Dr. Jowett is developing an interest in the application of non-parametric statistical techniques to problems of agricultural scientists. Dr. L. R. Frederick, Department of Agronomy, collected data of the amount of different sera groups of the symbiotic nodule bacterium *Rhizobium* in Iowa soils. Amounts of the differing sera groups present were correlated using rank correlation, because the large number of zero or very low entries made hazardous the distributional assumptions necessary for the Pearson product-moment coefficient. The rank correlation program available proved unable to cope with this amount of data, and was improved by graduate student R. L. Chamberlain.

Dr. C. H. Sherwood, Department of Horticulture, is interested in consumer preferences for chrysanthemums. A scoring technique suggested by Dr. Leroy Wolins has been used successfully insofar as consumer preferences for certain types could be demonstrated on artificially constructed plastic plants. Currently, Dr. Jowett is helping to investigate the substitution of photographs for plants, for ease of handling. Rankings have been obtained for the original plants, for Polaroid color pictures and stereoscopic black and white pictures. Kendall's coefficient of concordance will be used to test agreement. A similar problem has been raised by workers in dairy industry, where cheese is to be produced by the processes forming a 2 x 2 factorial. Ultimately, the cheese will be ranked for consumer taste, preference.

Sometimes data is obtained which is scalar, but the data is such that the usual distributional properties of the residuals are unlikely to be met. Dr. Eliot C. Roberts, Departments of Horticulture and Agronomy, produced such data from analyses of grasses grown in water culture at various levels of arsenic. The concentration of arsenic in the plants varied from 0 ppm to 18,500 ppm. The data were analyzed on the log scale. However, this necessitates a change in the usual model assumptions and may not be effective anyway. Dr. Jowett feels it would be interesting to examine the residuals and compare the results with those obtained by non-parametric methods, if methods can be found which permit the necessary linear comparisons. Graduate student J. I. Mellon has begun an investigation of some possible non-parametric tests as a thesis problem. He will be studying the power of rank tests in two-way classifications by Monte Carlo techniques, and will also examine the relevance of such tests to actual research problems as previously described.

Chamberlain has adapted a program for probit analysis for use on the 360 computer. A graduate student in botany produced data of percentage death of pondweed (*Lemma minor*) in response to levels of surfactants and herbicides, both alone and in combination. The probit analyses gave informative results, but there were indications that the data was not entirely appropriate for such analysis, largely due to technical problems in collecting the data. Another study in which probit analysis was very effective was undertaken for Dr. James Gourlay of the Animal Disease Laboratory. The analysis was of the relative efficacy of vaccines against rabies in dogs. Differences were shown among vaccine sources, and graphs prepared.

Chamberlain has also worked on adapting the OMNITAB program of the National Bureau of Standards. A great advantage of this programming system is that instructions for the computer can be written in English rather than FORTRAN, and it opens up the possibility of using the computer for simple but time consuming operations which now must be handled by desk calculators. The program also handles stepwise regression.

A series of 2^6 experiments on corn in single reps

confounded in blocks of 16, performed in Kenya by A. Y. Allen, was analyzed by Dr. Jowett at the request of Dr. S. A. Eberhardt, a USDA collaborator from Iowa State currently working with the USDA/AID mission in Kitale, Kenya. The results demonstrated the importance of good husbandry rather than fertilizers in improving maize yields in this area of the world.

Dr. J. A. Browning, Department of Botany and Plant Pathology, produced data on the development of induced crown rust (*Puccinia coronata*) epiphytotics in pure line and multiline strains of oats. The development of the epiphytotic was clearly less in the multilines. The growth of the epidemic was measured by spore counts obtained from adjacent spore traps. These daily counts were treated as a measure of the increment of growth achieved by the fungus on the experimental plot, and accumulated to give a characteristic sigmoid curve of growth against time. Dr. Jowett analyzed this data by transforming the daily accumulated growth to a proportion of the growth at the end of the experiment and transformed to $\ln \frac{x}{1-x}$. If the growth was following a logistic curve, this should produce a straight line when plotted against time, but it did not. Further investigation is needed, for the total growth achieved may not reflect the total potential of the epidemic, so this should be estimated from the curves. Moreover, it would be desirable to develop a model for the increase of an epiphytotic in multiline strains which takes account of the presence of resistant plants in these strains.

Response surface methodology continued to be popular. Graduate student Leon F. Burmeister assisted Dr. R. E. Phares, Department of Forestry, in reducing to canonical form a five-factor second order polynomial obtained as the response of cottonwoods to nutrient levels. The absence of a maximum within the range studied was indicated. Allied with a significant lack of fit term, this made the experiment extremely difficult to interpret. The inferential problems associated with large experiments of this type are considerable, and often underestimated by researchers. Another trial involving NPK in which the whole plots were split for a three-line corn diallel was analyzed for Dr. J. R. Webb, Department of Agronomy. Initial work has been directed toward determining whether an interaction exists between general and specific combining ability and fertilizer response.

An interesting diallel type analysis was carried out by Dr. Jowett for Dr. D. F. Grabe, Department of Botany and Plant Pathology. He had three lines of corn of low, medium and high seed vitality grown in competition with each other as a diallel set. However, each of the two competing lines in whole plots was harvested separately, which provided a novel type of split-plot experiment. With the assistance of Dr. Oscar Kempthorne, an analysis was obtained into general and specific competing ability, and meaningful linear comparisons of subplots within whole plots.

Professor C. Philip Cox and Dr. Jowett advised on the application of probit analysis techniques in studies of the comparative toxicities of surfactants. Professor Cox also consulted with a graduate student in agronomy on the use and precision of ratio estimators arising from studies of the effects of drainage and soil association types on the ratio of organic calcium to organic phosphorous.

Dr. Oscar Kempthorne consulted with staff members in agricultural engineering on two projects. The first concerned methods of sampling and data interpretation in connection with estimating amount of damage in stored corn. The other involved methods of interpreting multivariate data and "spurious" correlations.

Dr. Donald K. Hotchkiss assisted with the analysis of a three-year study of corn root rot. Observations were made at three periods during the year on several varieties with and without combinations of nitrogen and phosphate fertilizer. Measurements were taken on stalk strength, yield and other performance attributes. Because of a decided heterogeniety of variance observed at each of the three periods, each period was analyzed separately using the AARDVARK and general regression programs. Partial correlations among several responses were calculated after adjustment for the treatment classifications.

Consulting in the Animal Sciences

Much of the consulting in the area of animal biology, related areas of animal and human nutrition, and food technology is done by Dr. D. K. Hotchkiss, under the support of Agricultural Experiment Station Project 101, Statistical Services in the Animal Sciences and Plant Sciences. This consulting has been varied in the nature of the statistical approach, the complexity of the statistical treatment, and the subject matter involved. This record concentrates on the more interesting statistical problems and does not report the numerous consultations which are little more than confirming the appropriateness of the chosen statistical design or the selection of the proper statistical analysis which results in routine statistical calculations and interpretation.

In the general area of animal biology, researchers have been interested in determining any relationship that might exist between two responses, after several other factors have been considered—partial regression coefficients frequently expressed in terms of partial correlation coefficients. Frequently, these studies involve a set of treatment variables imposed on the experimental units. Several related responses are measured and the agreement that these responses have within the treatment classes is of interest. The effect of treatments on these responses is usually evaluated. As an example, the Veterinary Physiology Department wanted to look at the partial correlation among the levels of several blood characteristics and the growth responses of offspring resulting after differing levels

of vitamins E and A had been administered to male and female parents (rats). Using a special computer routine, the within treatment sum of squares and cross products were used to calculate partial correlation coefficients as well as to evaluate the treatment effects on each response.

The dairy bacteriology group members were interested in determining which of several incubation temperatures and holding periods of milk samples was the best combination for evaluating milk quality. Selective counts on several types of bacteria were made. These results were then compared with an inspection score made on the farm at the time the milk was produced. By relating the several bacterial counts, described above, to the farm scores, the researchers attempted to indicate which laboratory technique would correlate highest with what is considered ideal and poor farm production practices.

The meat processing section of the Animal Science Department measured several characteristics of processed meat to determine the effect of breed of animal, length of aging and aging temperature. The AARDVARK ANOV program was used to measure the effect of the imposed variables on pH, color, tenderness of selected muscles, etc. The AARDVARK program was then modified by the Numerical Analysis-Programming staff so sum of squares and cross products could be obtained on the error line for use in calculating the partial correlation of the responses.

Dr. Hotchkiss has frequently been asked for assistance in determining the optimum model for describing a set of data. In a series of studies for the Veterinary Physiology Department, the residual effect of dosage of powdered metalic dust in the air of monkeys and dogs, on the blood and tissue characteristics, was evaluated using the multiple regression program. Many of the responses required a two-segment curve: a period of response due to reaction to the exposure and a recovery period. The nature of these curves varied according to the length of exposure of the animals to the dust. This interaction resulted in a series of curves that described the general response with a quadratic function.

The Fisheries Research Unit worked with Dr. E. J. Carney, Dr. Wayne Fuller and Dr. Hotchkiss on determining the effect of previous environmental temperature on water temperature and the resulting effect on fish population characteristics in Clear Lake. Using the equations for predicting water temperature, the relationship of air temperature and water conditions for fish survival and growth are being explored.

Another fisheries study measured the effect of several environmental factors on the abundance of fish in the three western Iowa reservoirs. Multiple regression was used to select the most important variables for describing abundance of fish.

A more unusual use of curve fitting was requested by the Dairy Science Department. They wanted to measure the blood flow rate by injecting a metabolizable dye in the blood stream and measuring the recovery by sampling blood at a measured distance from the point of injection. Because of the normal diffusion of the dye in the blood, the quantitative recovery was in the form of a distribution. The initial front increased in concentration linearly, while the declining phase followed an exponential curve. The Numerical Analysis-Programming staff assisted in developing a program that would optimally fit the two curves to the data and integrate the area under the curve. This information was then used to solve for blood flow rate.

The Poultry Science Department, in cooperation with the Iowa and Minnesota Turkey Federation and the United States Department of Agriculture, collected data on water uptake of turkeys during the chilling process. The data subjected to the regression analysis suggested that water intake is a function of bird weight and that this function is continuous in nature rather than a step function which is currently used by USDA. With the assistance of Dr. Carney, a quality control sampling procedure was prepared for consideration.

Flavors in butter oil develop at different rates, depending on storage temperature. The Dairy Chemistry Department stored butter oil at temperatures from $-27°$ to $50°$, had a taste panel score the level of oxidation and rancidity that had occurred, and chemically measured the degree of oxidation. A series of equations for the change in flavors with storage time were fitted, using a polynomial fit of quadratic degree, exponential and logarithmic functions to attempt to describe the development of the various flavors. A decided interaction of storage temperature and length of storage existed, therefore individual equations were necessary.

A study of nutritional adequacy of diets of pregnant young women was designed and analyzed by Dr. Hotchkiss for the Department of Food and Nutrition. Considerable disproportion in the number of married and unmarried girls of the various age groups resulted. Therefore, the regression analysis was used to detect diet differences due to the above factors at different intervals during and following pregnancy.

Numerous sets of data in several studies for the Department of Food and Nutrition resulted in unequal numbers of observations in one or more of the subclasses, or one or more entire treatment missing from a factorial set. With unequal subclass numbers, the approximate analysis of unweighted means was run using the AARDVARK ANOV computer routine. Three studies were handled in this way. Subsequently, the error estimate was used to make a series of planned, though not orthogonal comparisons. These studies involved placing rats on diets deficient in energy, followed by different length periods of feeding energy (fat or carbohydrate) supplemental diets.

The Dairy Chemistry Department obtained data in which different numbers of collections of each of two types of milk were obtained. This resulted in unequal numbers in the whole plot. The data were analyzed using the multiple regression program to measure the

effect of interactions and main effects (in the absence of interaction). A factorial set of comparisons was evaluated on the subplot treatments.

A dairy bacteriology study on which Dr. Hotchkiss was consulted effectively illustrated the problems that can be encountered by an arbitrary subdivision of a set of treatments after inspecting the results of the study. In an initial study, several strains of bacteria were examined before and after sharp freezing for the microbial activity. An increasing activity group and decreasing activity group, when compared in a subsequent study, were not able to demonstrate significant group responses. Considerable overlapping of results occurred.

Professor C. Philip Cox consulted with Dr. Emerson Bird and a graduate student in the Department of Dairy and Food Industry on the assessment of a proposed new method for the determination of sulfur in milk. As compared with the currently standard gravimetric method, attention is being directed to the study of the bias and precision of the new method.

Professor Cox consulted with Dr. D. D. Gillette of veterinary medicine on the possibilities of applying multivariate analysis techniques to detect the onset of diseases in animals. Two doctors from the National Animal Disease Laboratory sought advice on statistical methods in vaccine testing with particular reference to the determination of 90 percent protection doses. Professor Cox prepared an evaluative review of currently available statistical methods.

Dr. H. T. David helped a graduate student in veterinary medicine with cell counting techniques involved in quantifying the degradation of the pituitary gland of the dog with age.

Dr. Oscar Kempthorne consulted with staff members in veterinary medicine on the interpretation of disease data, and with staff in animal breeding on the interpretation of swine data on gastric ulcers.

A graduate student in poultry science asked Dr. E. J. Carney for assistance with analysis of covariance for a study of the influence of egg size on rate of growth during incubation.

Consulting in Genetics and Breeding Research

During the year, Dr. Edward Pollak provided assistance to personnel in the agronomy, animal science and genetics departments, on statistical aspects of genetics and breeding research. This was done under the support of Agricultural Experiment Station Project 1448.

Dr. Pollak consulted with a staff member in animal science, showing that if there are two alleles at each of K unlinked loci, N individuals in a population and inbreeding coefficient F, then the variance in the number of heterozygous loci in the population is maximized when $F = 0$. He helped a staff member in agronomy check computations concerning the mathematical theory of inbreeding in tetraploids, and consulted with a graduate student in genetics on the analysis of enumeration data occurring in a cytological study.

Dr. E. J. Carney assisted Dr. Pollak with programs for the calculation of the limiting probability of survival of a line descended from a new gene entering a population.

Dr. Oscar Kempthorne consulted with staff members in bacteriology on methods of experimentation and data interpretation. The project involved a study of life and reproduction tables of lymphocytes in culture in relation to cultural medium and technique factors. He assisted staff members in poultry science with methods of interpreting breed data on reactions to blood type sera.

Consulting in Engineering and the Physical Sciences

Much of the consulting in the area of engineering and the physical sciences is done by Dr. H. T. David, who holds a joint appointment in statistics and engineering, and his associates. The problems listed here are typical of the questions which arise in this area.

Dr. David consulted with a staff member from sanitary engineering on the statistical techniques for deciding between two regression models, neither of which specializes to the other. An interesting aspect of this investigation was an attempt to quantify apparent fit bias discovered in the repeated fitting of one of the two models to successive data sets. A graduate student in sanitary engineering sought advice about statistical criteria required to verify the superiority of a new process over an established one, and a staff member from mathematics sought criteria for the inclusion of independent variables in regression equations.

The problem of predicting campus parking requirements resulted in a discussion, with a staff member from transportation engineering, on the combination of two predictive models. A graduate student in the same department asked assistance on statistical questions arising in the testing of the hypothesis that high power-to-weight ratios are associated with fatal highway accidents.

A staff member and graduate student in industrial engineering were helped with the incorporation of the statistical properties of empirical retirement ratios into the fitting of industrial property life curves. In this connection, Monte Carlo studies were conducted to determine the effect on power of using certain coefficient sets alternate to those proposed by Shapiro and Wilk in the construction of the W statistic.

Dr. David Thomas consulted with a graduate student in industrial engineering on estimation procedures for the Weibull distribution. Dr. Thomas also consulted with a graduate student in electrical engineering on the application of multiple regression techniques for predicting peak loads. Dr. David discussed a signal detection problem for normal noise superimposed on a transmission of Markov type, also with a graduate student in electrical engineering.

Dr. David consulted with a graduate student in chemical engineering on the problem of determining optimal operating conditions for a non-quadratic response surface over a polygonal region in factor space. Another chemical engineering graduate student sought advice on the design of an experiment for determining optimal solvent ratios for a certain chemical process.

Staff members and graduate students from civil engineering discussed with Dr. David the statistical problems involved in the setting up of standards and ensuing quality control for certain water purification materials. A graduate student in nuclear engineering sought advice on a problem in the characterization of distributions by their moments.

Dr. David consulted with a staff member and graduate student in industrial administration on the combination of subjective probabilities for various economic contingencies in the computation of expected industrial production levels. A graduate student in physics asked for help with an occupancy problem arising in quantum mechanics.

Consulting in the Behavioral and Social Sciences

Much of the consulting in the area of behavioral and social sciences is done by staff members who hold joint appointments in statistics and one of these substantive fields. Dr. Leroy Wolins, who has a joint appointment in statistics and psychology, continues to consult with a great many psychology graduate students on statistical problems related to their theses research.

Dr. Wolins worked with a graduate student in psychology on factor analyzing 288 of the items in the Strong Vocational Interest Blank. The full intercorrelation matrix among these 288 items was obtained and the factors were extracted by Thurstone's multiple group method. The programs for performing this analysis were written by Howard Jespersen. Robert Boruch, Department of Psychology, is preparing a manual for this group of programs and modifying them for input-output compatibility and for the IBM 360 operating system.

Dr. Richard D. Warren, who holds a joint appointment in statistics and sociology, continues to consult with graduate students and faculty on problems involving design and analysis of investigations in sociology and other social sciences.

Annual requests for assistance occur in the area of adoption-diffusion research. Dr. Warren's activities in this area include assistance in constructing interview schedules, developing codes for the data, constructing scales and indexes, discussing statistical techniques and their application, and analyzing and interpreting data. This year researchers requested assistance in two separate studies which attempted to determine whether there can be a cross-cultural application of some of the concepts from adoption-diffusion research which has been developed in the United States.

The general objective of one study was to determine some of the variables related to the speed and intensity of adoption of agricultural technology among a sample of Indians in Guatemala. Level of adoption of farm practices was the dependent variable and independent variables included were: (1) predispositional factors-attitudes, knowledge levels, personal characteristics, and past behavior; (2) immediate environmental variables—farm firm characteristics; and (3) perceptions—of specific attributes of inputs, markets, credit and transportation.

The other study sought to determine the relationship between value orientations of Indian cultivators and their adoption behavior. Cultivators of Delhi, India, were used as the sample. Independent variables included areas of general value orientations, occupational value orientations, situational factors and personal characteristics.

With a graduate student in sociology, Dr. Warren consulted on statistical problems in analyzing the relationship of social and psychological variables to agricultural marketing practices for farmers in Guatemala. Some of the variables included were age, education, farm size, information sources, adoption behavior, perception of marketing system and marketing behavior. He consulted with another graduate student on the selection of appropriate statistical tests for analyzing the variables related to the role performance of Gram Sevoks in South India.

Dr. Warren consulted with staff members in sociology and education on a study of the nature and scope of school bond elections requesting funds for vocational and technical educational purposes. All Iowa school districts engaged in school bond elections during a five-year period were included in the study. Information was obtained about the characteristics of the district prior to election, the characteristics of the bond proposal, election strategy, the timing of the election, communications techniques used and the perceived reasons for passage or failure. Statistical techniques, chi-square correlation, regression and analysis of variance were used to test the relationship of these factors to the passage or failure of the bond issues. This study was an exploratory attempt to establish and quantify the problem and to provide a basis for more rigorous conceptualization and methods for later studies.

With a sociology staff member and graduate student, Dr. Warren worked on the selection of independent variables for predicting college attendance for high school students. On another sociology project, he was consulted about constructing interview schedules for studies in social power, support of community activities, impact of a training program and college plans of high school students.

Other projects and studies, typical of Dr. Warren's consulting activities include: assistance with data analysis and interpretation for a study on the social psychological factors related to adoption of public fallout shelters; selection of appropriate statistical tests in research on the relationship between the personal and social characteristics of farmers and their positions

on farm programs; the use of multiple regression and correlation in a study on the relation of certain variables to parental acceptance of children; statistical representations and assumptions for models on causal inference in sociological survey research; the use of multiple comparisons in a study on the attachment to a voluntary organization as related to conforming behavior; development of composite scores and indexes for a study on satisfaction with present housing.

Dr. H. T. David consulted with a graduate student in economics on the construction of a game model simulating farmer reaction to several alternative government policies. With another graduate student in economics, he discussed the implications on partial regression coefficients of relations among marginal regression coefficients for multivariate data. He helped a graduate student in education with the extension of the method of weighted means to the analysis of variance of unbalanced two and three way classifications.

Off-Campus Consulting and Advisory Assignments

As time permits, staff members may serve in an advisory capacity to off-campus professional groups in addition to their regular consulting duties for campus departments and individuals. Some of this consulting is done by mail, other projects require the statistician to travel to the project, or the group seeking advice may visit the campus.

Dr. James Walsh, who holds a joint appointment in statistics and psychology, has been assisting with a number of projects in the Northwest, all psychometric or computer-implementation in nature. A speech and hearing research project in the Seattle, Washington, public schools required advice on psychometrics, design of experiments, data coding and punching, and analysis and interpretation of results. Advice on questionnaire design, data coding and analysis of results was given for a poverty survey report of Hill County, Montana, Community Action, Inc. A third project involved consultations on vocational school planning in northern Montana.

Dr. Leroy Wolins, who also has a joint appointment in statistics and psychology, consulted with the Association of American Medical Colleges where he discovered some firm empirical support for a long suspected artifact in psychological testing. Namely, when measuring quantitative ability by means of multiple choice questions, there is a practice effect. This effect does not occur when measuring other performances. The procedure of equating a new form of a test to the form in use in any given year by administering the new form following the current form, led to the spurious conclusion that the populations from which medical students were selected were declining in quantitative ability over time. In fact, over the last ten years applicants to medical schools, like most other groups of students, have shown substantial increases in performance on standardized tests of quantitative ability. This research is reported in Technical Report M662 and M662A, Office of Basic Research, Division of Education, Association of American Medical Colleges, Evanston, Illinois.

Dr. T. A. Bancroft and Dr. D. V. Huntsberger were consulted by James Mayhew, assistant superintendent of biology, Iowa Conservation Commission, about statistical analysis of catfish data from a 20-mile section of the Des Moines river.

The study is concerned with four main problems: estimation of the number of channel catfish in the study section using capture-recapture and catch-effort data; estimation of mortality rates based on age-class distribution; study of the movement of catfish by means of tagging; and analysis of data concerning the influence of certain environmental factors on catch success.

Dr. Huntsberger reports that attempts to fit distributions to movement of tagged fish has been unsuccessful to date. He currently is investigating methods based on catch success and tagging data as possible alternative bases for population estimates. The catch curves are also being studied to obtain estimates of survival and mortality rates.

Professor C. Philip Cox consulted with Dr. D. E. O'Connell, Western Utilization Research and Development Division, USDA, California, on the analysis of a multiple slope-ratio assay experiment with unequal replication and unequal dose intervals, with particular attention to tests of model relevance at zero dose.

Dr. Wayne Fuller continued work with Dr. Raymond Beneke and Dr. Lehman Fletcher, Department of Economics, on a project of the design of a study of agricultural extension in Mexico. Dr. Fuller made two trips to Mexico as a consultant to the Ford Foundation on the three-year evaluation study of certain extension programs. A benchmark survey was completed in two states in December and January. Dr. Henry Tucker, on assignment in Mexico with the Ford Foundation cooperative project at Chapingo, assisted with the project, supervising the coding, punching and programming of data.

Dr. Tucker also was consulted on a Rockefeller Foundation project, and helped with the preparation of a generalized program for the analysis of International Wheat Trials.

Donald Soults continued consulting work for the Staley Manufacturing Company, Decatur, Illinois, in the area of mathematical programming.

Survey Group

The Survey Group of the Statistical Laboratory provides direct operational services to the rest of the campus on all aspects of sampling, surveys and census-type studies. Consulting services are combined with operational work through the financing of the Statistical Laboratory, the Statistics Department, the Iowa Agricultural and Home Economics Experiment Station and the Sciences and Humanities Research Institute.

The Survey Group annually participates in a number of studies administered jointly by the Statistical Laboratory and some other university, institute, state or federal agency. The United States Department of

Professor Norman Strand, center, points out an area selected for a sample survey to Survey Group personnel Harold Baker and Mrs. Helen Ayres.

Agriculture and the Bureau of the Census have had long-term agreements for survey and statistical services on a number of projects.

The Survey Group assisted sixteen departments of the university under Agricultural Experiment Station Project 113, Statistical Services for Sampling Investigations. Some of these departments sought advice and consultation on the design and analysis of as many as six studies. The project is directed by Professor Norman Strand and Dr. Wayne Fuller.

On some studies, samples were designed and drawn, field materials and instructions prepared, field work performed and data processed and analyzed; other projects required technical assistance with statistical problems.

The departments assisted during the year included agricultural economics, agricultural education, agricultural engineering, agricultural extension, agricultural journalism, animal science, dairy industry, food and nutrition, forestry, home management, household equipment, institution management, rural sociology, textiles and clothing, veterinary medicine and zoology.

One agricultural economics study involved the estimation of the production functions for a series of pork experiments, another required assistance with analysis of data on business firms in a six-county survey in southern Iowa.

Operational work was performed for a study of farm records and business analysis systems of Iowa farmers, for a study of the effects of noise on satisfaction with apartment house living, for a study of outdoor recreational activities in Iowa, and for a study of the dimensions of welfare problems in Iowa.

Examples of studies for which samples were drawn are: in home management, a sample for a study of the contributions of young urban wives to family economic development in Des Moines; in political science, a sample for a study of city and county governments; in education, a sample of industrial firms for a study of occupational skills. Data was collected for a rural sociology study of occupational change plans for a sample of persons representing five occupations in Iowa. A lag model was constructed and estimated for lake water temperature, for a zoology project.

A survey of the outdoor recreation activities and preferences of Iowans was conducted in the fall by the Survey Group for the Forestry Department, with Dr. Carl Stoltenberg of forestry as project leader, assisted by Glenn Manning. The project was financed by the Iowa Conservation Commission and the Iowa Agricultural Experiment Station.

The objectives of the survey were to quantitatively describe outdoor recreation participation of Iowa residents, 12 years of age and older, to provide a base for developing trend estimates from future surveys, and to provide estimates of the relative values Iowans place on various types of outdoor recreation.

Professor Norman Strand and Dr. Wayne Fuller were responsible for the sample design. Mrs. Helen Ayres and Dr. Roy Hickman supervised the field work, and Dr. Hickman the compilations. Field work was conducted in October and early November. A questionnaire was adapted from an earlier national survey, and expanded to collect data about backyard activities as well as away-from-home activities.

Preliminary results indicate that "driving for pleasure" is the most popular away-from-home outdoor recreational activity of Iowans (79 percent participation), followed closely by picnicking (78 percent participation). A detailed analysis of data collected in the study will be completed as publications are prepared.

The Survey Group has been involved this year with operational work for a dimensions of welfare project directed by Dr. Arnold Paulsen and Russell Pounds of the Department of Economics. Data collected will be used as background material for a public affairs adult education program sponsored by the Extension Service, one of a series planned to explain public issues to interested citizens. Many Iowans will be reached through statewide study groups and will have an opportunity to learn about areas of welfare programs and the people who are benefiting or potentially can benefit from them. A sample survey was drawn of 600 disadvantaged families and 300 not disadvantaged families, to collect data about the living levels and other conditions. The Survey Group recruited and trained interviewers, assisted in the preparation of the questionnaire and instructions for its use, supervised the collection of data and has begun editing and coding the data.

In November, ISU President W. Robert Parks established a university-wide Committee on International Programs, with John Timmons as chairman, to conduct a study of Iowa State's role in international affairs, and on the basis of this study, to make recommendations as to policy, guiding objectives, priorities,

administrative organization and procedure to be followed by the university in this area of activities. One activity of the committee was to initiate a questionnaire directed to all faculty members with the rank of instructor, assistant professor, associate professor or professor. The Survey Group assisted in the construction of the questionnaire, designed to obtain the views, interest and experiences of the staff relating to the university's role in international affairs, in such a way that data could be rapidly tabulated in the limited time available. Data was collected and coded from returned questionnaires, a comprehensive 87 percent. Machine runs were completed and preliminary tabulations prepared. The survey indicated that about 40 percent of the faculty would be interested in foreign assignments of three months or less, with fewer interested in longer assignments. Western Europe and Latin America were the regions of greatest interest.

In a study of the effect of noise on satisfaction with apartment house living, the Survey Group designed the survey, reviewed the questionnaire and performed the field work, trained interviewers and supervised data collection. The study involved 20 apartments in each of three apartment house complexes in three midwest cities: Des Moines, Detroit and St. Paul. The data is now being coded.

Work was continued on a number of projects initiated in previous years. Tables were prepared for the study investigating the characteristics of Iowa taxpayers and their attitudes toward the present tax structure in the state. This project was done in cooperation with the Department of Economics, which prepared an evaluation for the Iowa Legislative Research Committee.

An interesting by-product resulted from this year's work on the survey of factors relating to diets of preschool children. While evaluating the dietary intakes of children from 0 to 6 years of age, collected in the survey of the 12 north central states, Evelyn Fuller and Dorothy Albertson of the Survey Group obtained the nutrient characteristics of a number of foods not previously available. Data from this study, planned in cooperation with researchers from five land grant universities in the north central region, has been coded this year and some machine runs have been completed.

Data collected for a survey of Iowa food establishments, conducted in cooperation with the Department of Institution Management, is being used for three I. Mgt. master's theses. The Survey Group has processed data from the sample of 396 restaurants, 73 hospitals and 127 nursing homes, to be used as a basis for determining food service education programs. Tables were prepared for Virginia Aimone, whose thesis was "Characteristics of and Employment in Food Service Departments in Nursing Homes in Iowa," and for Barbara Bobeng, who researched "Characteristics of and Employment in Restaurants in Iowa." Janet Jolin is completing her thesis on food service as related to hospitals.

A pilot study of the completeness and accuracy of congenital malformation reporting on certificates of live birth in a high incidence area continued under the direction of Professor Norman Strand. The study is jointly sponsored by the Epidemiology Branch, Division of Dental Health, and the Division of Vital Statistics, National Center for Health Statistics.

The collection of data from birth records of every Iowa hospital continued. The information is being converted to an automatic data processing format and compared, through the use of a computer matching program, with birth certificate information obtained by the Dental Health Center.

Manuscripts have been prepared on two projects which were reported in the 1964-65 Annual Report. A farm building study was designed to make a physical inventory of farm buildings, their current and past use, and the extent of new building construction and remodeling, and to investigate the many factors affecting the use of present farm buildings and the construction of new ones. A food consumption study in Webster County was used for Richard Lund's doctoral thesis, and information will be published in an Agricultural Experment Station bulletin.

Coding and data processing were done for the study of clothing acquisition and use which is being directed by Dr. Geitel Winakor, Department of Textiles and Clothing. Data will be used to prepare better clothing budgets for extension programs and teaching.

The Survey Group has completed work on a project with the Bureau of the Census to help the government conduct a coverage check and related evaluation studies of the 1964 Census of Agriculture. Charles Graham's M.S. thesis describes in detail some experiments in gathering data in the second phase of the evaluation survey. An abstract of the thesis appears in the publications section of this report.

Sampling in Soil Surveys

A cooperative agreement between the Survey Group and the Soil Conservation Service, administered under Agricultural Experiment Station Project 1312, was continued under the direction of Professor Norman Strand with Mrs. Marjorie Mason as supervisor. The work included a continuation of the updating of land samples drawn to determine conservation needs.

The tabulations for use by economists in ERS-USDA of the states or parts of states in the Columbia River Basin neared completion. Additional samples were drawn in Alaska, Arizona, Idaho, New Mexico, Montana, Utah, the Virgin Islands and Wyoming, so that these areas can more nearly achieve desired accuracy in estimation.

Tally sheets were received for approximately 2150 counties in 42 states. Sheets for approximately 1300 counties were reviewed and edited. Information from approximately 1250 counties was submitted for punching and a 27-page tabulation for 950 counties was prepared. Before this work could be done, IBM 360 programs were written and tested to produce the tabulations.

Current Research

The research program of the Statistical Laboratory emphasizes both the development and extension of basic theory and its application to new statistical methods and techniques. The Laboratory cooperates with other research institutes and experiment stations on the campus to arrange programs of statistical research and obtain support through joint grants and projects. Many studies of a fundamental nature are supported by such grants and contracts with off-campus agencies. In most instances, they provide for supervised graduate research on topics proposed by the staff. The Statistical Laboratory budget, however, supports only projects which are of specific interest to regular university research programs.

Professor C. Philip Cox has conducted research on divergent lines in log-dose response assays with Hermann Wiedenhofer. As reported last year, research was initiated on the determination of equi-potent doses for log-dose response single subject assays when divergent rather than parallel lines are obtained for the standard and test preparations. This research has now been completed and resulted in Wiedenhofer's M.S. thesis. An abstract appears in the publications section of this report. The results show that if equipotent dose relationships are estimated separately for each of several subjects the quantities of interest are the contrasts $(\alpha_s - \alpha_T)$, β_s and β_T where α_s and α_T are intercepts for the standard and test preparations respectively, and β_s and β_T are the slopes of the two lines. It is shown that in some cases estimates of these qualities may be combined to achieve a more precise method for estimating equipotent doses. The procedure is illustrated by a numerical example. A report describing the procedure is being prepared for publication.

Professor Cox has also done research on log-dose bioassay experiments with unequal dose-ratios. The simplest bioassay experiments are those in which successive dose ratios are the same for both the standard and test preparations, an arrangement which leads to the well-known and simple analyses. This arrangement is not always convenient, especially in research assay situations. Simple analyses have been obtained for the case, intermediate between equal and completely general dose ratios, in which the successive dose ratios are constant within, but different between, preparations. The analysis includes the simplest form as a special case and provides operational flexibility in return for an only slight increase in computation. A somewhat easier method of computing interval estimates from bioassay ratio estimates using Fieller's theorem was also found.

Dr. Hans Peter Thöni has concluded a year as a postdoctoral fellow at the Statistical Laboratory, with Dr. T. A. Bancroft serving as sponsor and preceptor. Dr. Thöni, who was on leave from his position as head assistant at the Institute of Plant Physiology, University of Bern, Switzerland, was supported by the Swiss National Science Foundation and a U.S. Public Health Service International Fellowship.

During his stay, Dr. Thöni prepared a report on the use of transformations of variables in the statistical analysis of experimental data. The report contains a summary of the three main objectives of applying a transformation to data: (1) to normalize the distribution function, (2) to stabilize the variance, and (3) to achieve an additive (or linear) model. It considers also the problem of bias in estimation, when the mean of the transformed data is reconverted into the original scale. Dr. E. J. Carney assisted Dr. Thöni with the preparation of computer programs for the evaluation of a correction for bias in estimation with log transformed data.

In a second part of the report, the transformations generally used in biological sciences are presented and discussed: the logarithmic, square root, inverse sine, inverse hyperbolic sine, inverse hyperbolic tangent, log-log, probit, normit and logit, reciprocal, legit, ridit and rankit transformations. Each section contains a list of references relating to the respective transformations.

Dr. Thöni also did a special study on the bias-problem with the logarithmic transformation. Based on the results reported by Finney (1941) and Oldham (1965), corresponding expressions for correcting the bias in estimating the mean could be derived, when logarithms to the base 10 (or generally: to any base a) are used. A note on this problem is being prepared for publication. The complete manuscript will be made available through the Statistical Laboratory's mimeo-multilith series.

In continuation of earlier work (1963), Dr. Thöni showed how a nomogram can be constructed to test multiple comparisons, using Tukey's, Student-Newman-Keuls' or Dunnett's method. A note on the results has been submitted for publication.

Another postdoctoral fellow, Dr. Richard Kleber, is completing a year on sabbatical leave from his position as associate professor of mathematics at St. Olaf College, Northfield, Minnesota. His stay was partially supported by a faculty improvement fellowship from the American Lutheran Church.

During his year at Iowa State, Dr. Kleber concentrated on course work, mostly in applied statistics and computer science, to establish a firm foundation for his teaching responsibilities. In addition, he conducted research on the problem of duplication in sampling with replacement, and has submitted a paper for publication.

While formulas exist for working out the probability of duplication when given the sample size and population size, Dr. Kleber has worked out highly accurate asymptotic formulas for determining the sample size

when given the population size and probability, and for determining the population size when given the sample size and probability. The accuracy of these formulas was established by extensive tests run on the computer.

In related work, Dr. Kleber has prepared another paper describing his classroom illustration of non-intuitive probability. He first poses the "birthday problem" to his students: the probability that a single birthdate will be shared by two or more members of the class. He then has the members of the class write down integers between 1 and N where N is determined by a table he has prepared showing the probability of duplicate choices for classes of different sizes. The value of N which yields a probability of ½ is much larger than most students anticipate. This paper will be submitted to a teacher's journal for publication.

A third postdoctoral fellow, Frances Ward, is completing two years at Iowa State supported by the National Institutes of Health. Miss Ward came to Iowa State with a background in the biological sciences, and has spent considerable time in course work in mathematics and statistics, designed to supplement this background. Her previous research work was on the heredity of variability in mice. While at Iowa State, she has worked on the development and testing of genetic models, under the direction of Dr. Oscar Kempthorne, including the computer simulation of these models.

Aldo F. dos Santos joined the Statistical Laboratory in January as a visiting scholar under the sponsorship of the Committee on International Exchange of Persons. He is a professor of statistical methods, Faculty of Economic Studies, University of Espirito Santo, Brazil, who came to the United States on a Fulbright Travel Grant. He previously was at Iowa State during 1952-54, when he received an M.S. degree in soil fertility with a minor in statistics.

Professor dos Santos is conducting research on functional forms to describe the yield response of crops to nutrients and other environmental stimuli. A form frequently used in the past is the Mitscherlich function. Professor dos Santos, working under the direction of Dr. Oscar Kempthorne, is comparing this one with several others, using data from the so-called Great German Soil-Fertility Survey. He is also studying numerically some statistical properties of least-squares fitting of data of different origins, to determine the sensitivity of modes of choosing between possible forms.

Dr. David Huntsberger has been working with J. R. Veale on problems associated with weighted estimation when spurious observations may be present. A paper on the results of this research is being prepared for publication.

Dr. James Walsh, who holds a joint appointment in statistics and psychology, has been researching the objective measurement of socialization in children. This work is sponsored by a research grant from the National Institutes of Health, administered through the Department of Psychology. Social desirability responses in children were tested by showing them nine stylized drawings of a woman's face. Dr. Walsh's research shows that children learn very early how society expects them to behave. He has concluded that almost everything a mother says or does registers in the child's mind together with either a positive or a negative sanction deduced from the mother's postural, facial and tonal expressions. Connections are thus built in the child's mind between concepts and social and behavioral connotations.

This research resulted in a master's thesis by a psychology graduate student, describing the development of a technique for obtaining social desirability scale values for young children, and illuminating both the process and the rate of acquisition of the childrens' social desirability response. The results were published and an abstract of the paper, "A Pictorial Technique for Obtaining Social Desirability Ratings from Young Children," appears in the publications section of this report.

Dr. Walsh has worked on other research concerning computer simulation of objective personality test behavior and of administrative decision making; factorial dimensions of original and reversed authoritarian scales and of ambiguity in the MMPI; and the effect of differential social influence on color perception.

Dr. H. T. David worked with graduate student Joe Abbey on series representation for UMVU estimates related to projection formulations of conditional expectations. This research will be used for Abbey's M.S. thesis. Dr. David also worked on research with Ahmed Memon. This concerned asymptotic distribution of multivariate join counts, based on earlier joint work on configuration counts with Dr. C. E. Fuchs.

Dr. Fuchs and Dr. Wayne Fuller completed work predicting alumni contributions for the next 50 years at five-year intervals for John Granson, director of the Alumni Achievement Fund. The predictions depended upon the models used. Thus a multiplicative model estimated total contributions in the year 2020 in current dollars at over three million, while a simple linear regression model estimated contributions for the same time at one-third of a million dollars. Current contributions are about one-tenth of a million dollars.

Under the direction of Dr. J. H. Sedransk and Dr. Kenneth Ware of the Forestry Department, Hans Schreuder completed his Ph.D. dissertation relating to unequal probability and double sampling designs appropriate for forestry applications. An abstract of his thesis appears in the publications section of this report. Subsequently, additional research has been carried out to investigate more thoroughly the "3-P" sampling technique. Moreover, some additional alternative sample designs have been suggested, and these are compared with the "3-P" procedure. A paper has been written on this research and submitted for publication.

Dr. David Thomas assisted with the master's research of Douglas Splitstone. A Monte Carlo study was conducted for comparing several methods of estimation for the Weibull and extreme-value distributions.

During 1966-67, Dr. Richard D. Warren participated

as co-leader of Agricultural Experiment Station Project 1469 with Dr. George M. Beal and Dr. Joe M. Bohlen in the Department of Sociology and Anthropology. This research project was designed to determine the effect of an experimental training program conducted for general managers of retail farm supply firms who sold fertilizer and agricultural chemicals as two of their product lines.

The educational phase consisted of planning, organizing and implementing an intensive training program for ten managers. The research phase included setting up the experimental design, developing measures to determine the influence of the training upon the manager, his business firm and his farmer customers, and analyzing the obtained data.

Dr. Warren used information from this project as an example for his paper presented at the 1966 Rural Sociological Society meetings, which is listed in the Papers and Speeches column of the publications section of this report. A publication, "The Experimental Dealer Training Program" was prepared, and an abstract appears in the publications section. Two more papers based on this project have been accepted for presentation at 1967 meetings.

Dr. Warren continued as co-leader of Agricultural Experiment Station Project 1626 with Drs. Beal and Bohlen. The project is an attempt to determine the characteristics of managers and local agribusiness firms that will permit prediction of their success and ability to adjust to innovations and change.

Specific empirical measures were developed for concepts in the theoretical model. Measures were developed in the following areas: knowledge, attitudes, managerial performance, selected personality characteristics, manager's background and experience, perceptions of factors relevant to business management, available resources, and economic returns. A sample of 100 managers of agribusiness firms was personally contacted during the sumer of 1966 to obtain data on the measures included in the study.

With the assistance of Dr. Leroy Wolins, a factor analysis was completed for the attitude scales. Factors or clusters formed by the attitude items included: economic motivation, general management orientation, managers' perception of their influence on outcomes for business, risk preference, independence, individualism, progressivism, and mental activity. Scales and indexes were developed in the various areas of performance. Plans for next year are to examine the interrelationships of the variables, and the relationship of the variables to managerial success and ability to adjust to innovations and change.

Design and Analysis of Sample Surveys

A new continuing contract between the Statistical Laboratory and the U. S. Office of Education, Number OEC-3-6-002041-2041, began July 1 under the direction of Dr. J. H. Sedransk. During this first year, research has been carried out in four major areas: combining information from two sample surveys; properties of ratio and ratio-type estimators; design of several factor analytical surveys; and formation of confidence intervals (appropriate to sample survey procedures).

Efficient methods of combining information from two data sources which are believed to measure the same quantity have been investigated by graduate student Donna Ruhl. The results of this research are summarized in the NIH research report in this research section.

An investigation has been undertaken by graduate student Richard Frauendorfer and Dr. Sedransk to ascertain the properties of the various ratio and ratio-type estimators when very small simple random samples are selected from specified finite populations. A computer program has been written which enumerates the $\binom{N}{n}$ possible samples, and evaluates each estimator for each sample. Thus, for each estimator, its complete frequency distribution is available and it is possible to calculate exact expected values, variances, etc. It is well known that the bias of the ordinary ratio estimator is negligible (and the ratio estimator is "efficient") if the relationship between the y and x variables is approximately linear through the origin. Hence, the populations used to compare the estimators should not exhibit this special relationship, but should be ones where an investigator would be likely to employ a ratio estimator. Thus far, forestry data exhibiting a quadratic relationship have been utilized.

It is planned that this investigation will be expanded to include stratified random sampling, and to utilize the various ratio-type estimators. This will entail the use of Monte Carlo sampling methods because a complete enumeration of all possible samples would be too costly.

In general, analytical surveys deal with comparisons among specified sectors of a population. In this investigation, it is assumed that several factors are to be studied, comparisons among the "levels" of the various factors are of greatest interest, and there is interaction between the factors. Attention is restricted to situations in which only two levels of each factor are to be compared.

The main problems considered by Gordon Booth, graduate student, and Dr. Sedransk are: (1) to suggest comparisons of interest, and appropriate estimators, and (2) to plan the survey so that specified precision for the estimates of the comparisons is attained at minimum cost.

Under (2), each type of estimator is considered separately. The optimal number of elements to be sampled from each sector is determined to minimize total cost of sampling subject to specified precision for each comparison of interest. In some cases, the optimal sample size allocation must be obtained from a convex programming algorithm. Hence, alternative, approximate, solutions are suggested. These approximate solutions are compared (numerically) with the exact results. Moreover, the exact results are contrasted with optimal allocations obtained by assuming other population models.

Such an analysis provides some evidence about the "robustness" of the models, estimators, and precision specifications being utilized.

Graduate student John Meyer and Dr. Sedransk have commenced an investigation of confidence intervals for the population mean when simple random sampling is employed. Many populations to which sampling methods are applied are non-normal and non-symmetrical. It is desired to devise *simple,* "small sample" confidence intervals without assuming the exact distribution of such underlying populations. In these situations, it is impossible to obtain exact $(1-\alpha)$ percent confidence intervals, but good approximations may be available. To place the preliminary work on a more concrete basis, the initial approach to the problem is to assume a definite distribution for the population. In particular, the gamma distribution is considered since its shape is typical of many commonly observed distributions, and previous numerical work has also utilized this family of distributions. Then the validity of the usual "t" statistics (and suitable modifications) to form confidence intervals have been investigated. In addition, the use of various order statistics has been studied.

USDC, Bureau of the Census Research Project

Project Cco-9165, the continuing cooperative program of basic research in sampling, response errors and other fields of joint interest, between the Statistical Laboratory and the U. S. Bureau of the Census, progressed under the direction of Dr. Wayne Fuller.

A small scale Monte Carlo experiment comparing alternative ratio and regression estimators for given models is being conducted. Higher order approximations to the variance will also be compared with the sampling results.

Some new methods of controlled selection have been developed and investigated. Part of this work is contained in the doctoral thesis of Mohammed Yusuf-Mia. An abstract appears in the publications section of this report.

Tests for skewness using order statistics are being developed in the study of estimators for skewed populations. It is planned to use such tests as the first step in a two-step estimating procedure.

Research continues on regression estimation and post stratification. Post-stratified estimators when boundaries are determined by the samples are discussed in Ing-Tzer Wey's Ph.D. thesis, which is abstracted in the publications section of this report.

NIH Research

This concluded the fourth year of the Statistical Laboratory's current, and second, five year National Institutes of Health graduate training grant program in biometry. The program, directed by Dr. T. A. Bancroft, provides financial support each year for up to six graduate students who expect to enter careers in biometry or medical statistics, and research time for one full professor and one associate or assistant professor. During 1966-67, research time for Professor C. P. Cox and Visiting Associate Professor B. K. Kale was budgeted on this project.

Patricia Conn, who has been supported under this grant, became an instructor in the Department of Statistics and left the program. Her research continues under the direction of Dr. H. T. David, and is reported elsewhere. During the year, six students were supported under the program.

James Gebert completed his doctoral research under Dr. B. K. Kale, and received his degree in February. An abstract of his thesis appears in the publications section of this report. Various spacings tests that had an information theoretic derivation were studied. Their asymptotic distributions were found and their power against a large family of alternatives was derived.

After graduation, Dr. Gebert remained at the Statistical Laboratory as a postdoctoral NIH fellow, continuing his thesis research and preparing it for publication. A joint paper by Dr. Gebert and Dr. Kale was presented at the IMS eastern regional meetings and is listed in the Papers and Speeches column in the publications section of this report.

John Johnson, a predoctoral student, continued his research on pooling regressions and an outlier methodology for regression lines. Dr. T. A. Bancroft has directed his research. During the year, Johnson has studied the bias and mean square error of estimation procedures for, and the size and power of test procedures about, a regression coefficient and a regression line after a preliminary test has been made to determine if N independent estimates should be pooled or if an outlying estimate is present. Johnson is currently generating tables of critical values for preliminary tests, and tables of the bias, mean square error, size and power for the estimation and test procedures. This is being done to permit recommendations as to what level the preliminary test should be made in order to control these measures of performance. The second part of Johnson's Ph.D. thesis is concerned with the development of an outlier methodology for lines considering the outlier test as a preliminary test, and subsequent inferences are made conditional on the outcome of the preliminary test.

Dr. Bancroft also is temporary advisor for Roland Loup, who entered the NIH program November 1 as a predoctoral student.

Also new to the program this year is Peter O'Brien, who began his master's research under Dr. David Thomas in September. O'Brien has developed several sequential selection procedures for gamma and Weibull populations. Assuming common, known values for the shape parameters of K Weibull (gamma) populations, the problem considered is that of selecting the population with the largest mean. A Monte Carlo study is planned for making average sample number comparisons among the selection procedures considered. O'Brien's thesis also will include a correction of some existing procedures for the case of Weibull variates which were found to be invalid.

Donna Ruhl's doctoral research for the year has been directed by Dr. J. H. Sedransk. Procedures for

pooling data from sample surveys have been investigated, with the problem approached from two points of view: the preliminary test approach and Bayesian approach.

Consider the random variable (X, Y) to have a bivariate normal distribution with parameters μ_x, μ_y, σ^2_x, σ^2_y, and ρ, of which σ^2_x, σ^2_y, and ρ are known. It is desired to estimate μ_y. Sample data $\bar{x}$ and $\bar{y}$ are collected and a size α preliminary test is made of $H_o: \mu_y = \mu_x$ versus $H_A: \mu_y \neq \mu_x$. If $H_o: \mu_y = \mu_x$ is accepted, there is the option of sampling more X variables and then combining all of the data on X and Y, with appropriate weights, to form a pooled estimator of μ_y. If $H_A: \mu_y \neq \mu_x$ is accepted, there is the option of sampling more Y variables and then using just the data on Y for the estimator of μ_y. The bias and mean square of this procedure have been derived and the effect of the various parameters upon them investigated. In another related procedure, using a pooled estimator is considered if $H_o: \mu_y = \mu_x$ is accepted, but using a regression estimator if $H_A: \mu_y \neq \mu_x$ is accepted.

In the Bayesian approach, $\Delta = \mu_y - \mu_x$ and μ_x are assumed to be random variables. Various prior distributions are assigned to them and then the Bayesian estimator is obtained by standard techniques. The most feasible prior on Δ seems to be $N(0, \alpha^2 \sigma^2)$, and several different priors have been considered on μ_x, such as normal, uniform, and precise measurement as defined by Savage.

There are plans to compare the Bayesian and preliminary test approaches to the estimation of μ_y through a Monte Carlo study.

The pooling problem for two independent sample proportions is also under consideration from a Bayesian viewpoint. The problem here is to obtain a feasible joint prior distribution on the population parameters p_1 and $-\Delta = p_1 - p_2$, where it is desired to estimate p_1. No sufficiently "general" distributions have appeared in the literature to date. A prior distribution (dependent upon three parameters) having several desirable properties has been derived. Currently, its affect on the Bayesian estimator of p_1 is being assessed.

A joint paper by Mrs. Ruhl and Dr. Sedransk was given at the IMS central regional meetings, and is listed in the Papers and Speeches column in the publications section of this report.

Predoctoral student Charles Sampson has begun his research under the direction of Professor C. Philip Cox. The work is generally concerned with developing sequential procedures for the comparison of two treatments utilizing concomitant information.

For the second year, Professor Cox taught Statistical Methods of Biological Assay, at the 1966 Graduate Summer Session of Statistics in the Health Sciences at Yale University, supported by NIH.

Goodness of Fit Procedures

A new National Science Foundation Grant, GP-5997, has been in effect this year with Dr. Oscar Kempthorne as chief investigator. This research concerns the general problem of testing goodness of fit of distributions in one or more dimensions.

The results of research to date are given in the master's thesis written by Joe Atkinson. An abstract of this thesis appears in the publications section of this report.

Another aspect of the research to be conducted is investigation of the joint role of errors of specification of the hypothesis and of errors of estimation of parameters in the assumed hypothesis. From a scientific point of view, the examination of errors of estimation assuming the hypothesis, e.g. normality, while ignoring the errors of specification of the hypothesis itself is highly questionable. Preliminary computations show that the effect of the latter is large, and in a true inference situation both must obviously be considered.

Some Problems in Multivariate Analysis; Symmetric Multiple Decision Problems

Dr. Akio Kudô continued as principal investigator of National Science Foundation Grant GP-6149. Dr. T. A. Bancroft became administrative director of the grant in December, when Dr. Kudô returned to Japan.

Research for the doctoral thesis of Irving Hall was supported by this grant. The thesis discusses slippage problems without assuming the usual condition of invariance, and an abstract appears in the publications section of this report.

Hall has investigated multiple decision problems as they apply to slippage problems. A generalization of the Neyman-Pearson lemma to slippage problems has been derived. Sufficient conditions for the monotonicity of power of certain test functions have also been examined.

The concept of similarity was used to derive a test for distributions belonging to the exponential family. A unified treatment for the derivation of optimal solutions in certain types of slippage problems has been achieved, and the derivation was accomplished without assuming invariance.

Problems in Random Walk and Sequential Decision-Making

Dr. Herbert T. David continued as director of National Science Foundation Grant GP-6013. Research progressed in the area of the application of a planar reflection principle to random walk in the plane. Absorption probabilities have been found for several sorts of two-dimensional constrained random walks. Wiener processes, tied-down Wiener processes, and certain discrete random walks have been considered, constrained by absorbing polygonal cylinders of various types.

Patricia Conn continued research in the area of the asymptotic behavior of unabsorbed paths of constrained random walks. She has worked principally on ergodic properties of random walk continuous in space, emphasizing the relatively unexplored non-stationary situation. Here the work recently has been concerned with establishing necessary and sufficient conditions for various sorts of ergodic behavior of non-stationary dissipative Markov chains. Contemplated applications of this

work include an approach to truncation for sequential analysis described earlier as "asymptotically exact truncation."

Research in the area of asymptotic value distributions for certain 2 x n and n-stage games of perfect information has resulted in the publication of two papers: "Game Value Distributions I" by David R. Thomas and Dr. David, and "Game Value Distributions II" by David R. Thomas. Abstracts of both appear in the publications section of this report. Pursuing work in this area, Donald J. Soults is working on asymptotic distributional problems arising in stochastic programming.

MaryAnn Smith completed research on the role of loss functions in determining whether sampling of finite lots is economical under control. This resulted in a master's thesis which is abstracted in the publications section of this report.

Another abstract which appears in the publications section is of a paper by W. D. Lawing and Dr. David, which reports earlier research done under this contract.

Inference Theory for Certain Incompletely Specified Models

Dr. T. A. Bancroft has continued as principal investigator of this National Science Foundation project, Grant GP-5688. Dr. B. K. Kale has served as a co-investigator, and S. R. Srivastava conducted research supported by the grant during the summer.

A paper by Dr. Kale and Dr. Bancroft, "Inference for Some Incompletely Specified Models Involving Discrete Data," was published in the June issue of Biometrics and an abstract appears in the publications section of this report. It discusses the inference problems concerning a population mean from a discrete distribution subsequent to a preliminary test of significance.

Two other papers discussing research conducted under this grant have been submitted for publication. "Inferences Concerning a Population Correlation Coefficient from One or Possibly Two Samples Subsequent to a Preliminary Test of Significance," by Srivastava and Dr. Bancroft, has been accepted for publication in the Journal of the Royal Statistical Society. "Inferences Concerning a Population Mean from a Single Sample Subsequent to an Outlier Test," by Dr. Bancroft and Dr. Florence Tetreault, has been submitted for possible publication.

Three papers discussing the research were presented at the IMS meetings in New Brunswick in August, and are listed in the Papers and Speeches column in the publications section of this report. A paper is being completed discussing the power of analysis of variance test procedures for an incompletely specified fixed linear model. Size and power tables are being calculated. Some of this work is being carried out by graduate student Ronald Mead as research for his M.S. thesis.

Graduate student Nell Bruner, under the guidance of Dr. Kale, investigated the problem of pooling of two sample means for her M.S. thesis. The primary interest was in the mean of the first population, and a class of priors was assumed on the population mean of the second sample. This class of priors is centered at the mean of the first population and has unknown variance.

Using empirical Bayes approach, the prior distribution was estimated on the basis of some past experience. The estimate of the mean of the first population was constructed using this information. It is shown that if the past experience is sufficiently large, the new estimator is uniformly better (in terms of mean squared error) than the mean of the sample from first population alone. Some numerical results have also been obtained to compare the advantage of the new estimator over the usual one. An abstract of the thesis appears in the publications section of this report.

During the year, Dr. Kale constructed an example where the use of preliminary test of significance in an incompletely specified model situation leads to a uniformly better estimator than the classical unbiased one. This has further led to problems dealing with the admissibility of the estimates obtained by using a preliminary test of significance. Purely viewed as an estimation problem, this leads to the problem of determining class of admissable estimates of a parameter θ, or a function thereof when nuisance parameters are present.

The Role of Errors of Parameter Estimation in Index Selection

This project, which originated July 1, 1961, was terminated on September 30. It was jointly supported by the National Science Foundation, Grant 18093, and the Agricultural Experiment Station, Project 1505, and directed by Dr. Oscar Kempthorne with Dr. Edward Pollak as co-leader.

During the project, some good information on the effects of errors of estimation of variances and covariances on the accuracy of a selection index were obtained. Errors of estimation of parameters lead to overestimation of progress of selection within a calculated index, and to poor prediction of expected gain.

A theoretical formula for genotypic covariances of inbred relatives in genetic populations was developed. After the departure of Dr. D. L. Harris, the project was changed to one on mathematical genetics.

Problems investigated included the effects of population subdivision on approach to homozygosity of a large finite population. If the average number of migrants per generation between any two parts of a subdivided population is at least as large as 1, the approach to homozygosity is essentially like that of an undivided population.

The progress of a simple theoretical Mendelian population under truncation selection was also investigated. The investigation showed that the mean performance of the population does not necessarily increase. If it does increase, then relaxation of selection may be followed by a decline. This would mimic what is to be expected if natural selection acts in a direction contrary to artificial selection.

Four papers were written on the research supported by this project. An abstract of "Some Effects of Fluctuating Offspring Distributions on the Survival of a

Gene" appears in the publications section of this annual report. The others were reported previously.

Analysis of Variance Procedures and Related Topics

Research continued on the Aerospace Research Laboratories contract under the direction of Dr. Oscar Kempthorne and Dr. George Zyskind.

Work has progressed on the exploration of linear models with arbitrary non-negative (possibly singular) covariance structure. An account of a geometric approach to the construction of best linear unbiased estimators (b.l.u.e.'s) in the general linear model with arbitrary covariance structure is being developed. The approach is formulated in a way which derives the least squares principle as a consequence of the overall geometry of the situation. In particular, another informative proof has been obtained of the fundamental fact, developed earlier in connection with this work, that the linear function $w'y$ is b.l.u.e. for its expectation if and only if the covariance matrix σ^2V transforms w into a vector belonging to the column space of the design matrix X, i.e., if and only if $Vw \epsilon \mathcal{C}(X)$.

Dr. Zyskind and Frank Martin have prepared a manuscript on "A General Gauss-Markoff Theorem in the Case of Any Non-Negative Covariance Matrix of Observations." For the general linear model $y = X\beta + e$ having the covariance matrix, σ^2V, of the errors, with $\sigma^2 > 0$, V known and non-negative (possibly singular), the complete non-empty class $\mathcal{Y}$ of conditional inverses of V is specified such that, for any estimable parametric function $\lambda'\beta$ and any V^* in $\mathcal{Y}$, a best linear unbiased estimator of $\lambda'\beta$ is given by $\lambda'\hat{\beta}$ where $\hat{\beta}$ is any solution to the general normal equations $X'V^*X\beta = X'V^*y$. Properties of the solutions $\hat{\beta}$ are presented. It is further verified that if y is distributed as a multivariate normal variable then $\lambda'\hat{\beta}$ is the maximum likelihood estimator of $\lambda'\beta$. A procedure for testing hypotheses, using solutions to the general normal equations, is also presented.

A description of the treatment of combinability of information from uncorrelated sources of information was published by Martin and Dr. Zyskind, and an abstract appears in the publications section of this report. This work has now been extended to cover the case of arbitrary non-negative covariance matrices. In addition, Martin has studied the problem of efficiency of linear estimators obtained by simple weighting. Extensive tables have been constructed, giving a narrow range for the minimum efficiency of simply weighted estimators based on the smallest and largest generalized eigenvalue ratios of the design matrices. A tabulation of actual efficiencies of simply weighted inter and intra block estimators for a large number of known P.B.I.B. design shows that the vast majority are efficient 95 percent or better in the case $\sigma^2 = \sigma^2_b$, but with notable exceptions. It is seen that the minimum efficiency is a monotone increasing function of the ratio σ^2_b / σ^2.

Dr. Zyskind and Paul Johnson have written a short manuscript, "A Note on a Zero Residual Sum." It is shown that a necessary and sufficient condition for the sum of the residuals $\sum_{i=1}^{n} (y_i - \sum_{j=1}^{p} x_{ij} \hat{\beta}_j)$ resulting from a best fit to the linear model $y = X\beta + e$, with $E(e) = 0$, $E(ee) = \sigma^2V$, to equal zero is that the vector $V\,1$ belong to $\mathcal{C}(X)$, where 1 is a column vector of unities, and $\mathcal{C}(X)$ is the vector space generated by the columns of the matrix X. The matrix σ^2V above may be any non-negative covariance matrix.

Dr. Zyskind has also done some further work on relations among methodologies in linear models partitioned in various ways. In particular, a new aspect considered is that of "A Covariance-Like Analysis for Incorporating Extra Observations." An abstract of the basic idea appears in the December 1966 issue of Annals of Mathematical Statistics. This abstract contains several typesetting errors, which are obvious.

With regard to randomization theory and cap sigmas, Σ's, occurring in connection with complex experimental structures, Dr. Zyskind and V. B. Solomon have been considering the definition of such quantities for arbitrary individual degrees of freedom. Definitions for particular instances have been formulated, and it is hoped that a general appropriate definition will also soon be obtained. Solomon has also been considering work on obtaining random fractions of factorial treatment structures. Interesting contrasts among several possible methods of procedure have been investigated.

Dr. Kempthorne and Leon Jordan have been working on procedures involving partially systematic samples for examining the behavior of an unknown function $f(x)$, over an interval of x. This work is judged to have relevance to the choice of experimental points in studying a response relationship, and to the examination of a real population distributed over a line or plane segment. Further work involved procedures for investigating the dependence of a yield variable on experimentally controlled variables, and some aspects of optimality of experiment design.

The research on computation of variances and covariances of mean squares by E. J. Carney under the direction of Dr. Kempthorne has culminated in a Ph.D. thesis which is abstracted in the publications section of this report. A technical report on this research is now in preparation.

Dr. Kempthorne presented two lectures connected with the general aims of the present research to the Department of Mathematics and Statistics at Colorado State University. Dr. Zyskind gave a paper at the IMS meeting at Rutgers, another (by Martin and Zyskind) at the 1966 meetings of European statisticians in London, two talks in Dayton and one formal talk and informal discussion at the University of Missouri, all based on recent research performed in connection with the present contract. All of these are listed in the Papers and Speeches column in the publications section of this report.

Research in Mathematical and Statistical Genetics

This research, supported by the National Institutes of

Health, Grant GM 13827, and the Agricultural Experiment Station, Project 1669, was in its first year of study under the direction of Dr. Oscar Kempthorne.

Considerable exploration has been made on the concept of fitness and the related mathematical theory which stems back to Fisher's work in the 1920's. It seems clear that the genetic progress of a population will be dependent on viabilities of types, the mating pattern, and the fecundity of matings. The attempt to summarize this complex of "forces," by a single measure for each genotype, the so-called Malthusian parameter is considered to be both misguided and misleading. It appears to be based on a Darwinian notion of fitness, in which the fitness of an individual is equal to half the number of offspring produced. This notion has no Mendelian content, for which one would not blame Darwin, of course. It, along with Malthusian parameters, seems to be appropriate only to what may be termed clonal propagation. The basic ideas in this case have been applied to a population growing in an indefinitely extensive environment, leading to exponential growth or decline. The relevance of such work to most natural populations seems highly tangential, at best.

As part of an examination of population subdivision, the progress of inbreeding in a subdivided population in which there is some possibility of migration from one part of the population to another has been calculated. In the case of an infinite number of subpopulations, it is assumed that the subpopulations are arranged on a line and that only migration to nearest neighbors is possible in one generation. Also, calculations have been made of some effects of two types of migration on the probability of extinction of a gene. Under one model, selection takes place before migration, while under the second, selection takes place afterwards. The case in which there are two subpopulations, such that a gene has an advantage in one and a disadvantage in the other, has been considered in detail.

A study has been made of the fate of a mutant gene. It is assumed that the mean number of mutant genes passed to the next generation by an individual carrying one such gene is less than one. An approximation is derived for the distribution of the number of descendants of the mutant gene in generation n, where n is large.

The influence of varying selective advantages of a gene on random genetic drift in a finite population is being studied. The probability of quasifixation in an infinite population, after a finite number of generations, is also being calculated.

Some study has been made of the theoretical dynamics of a simple Mendelian population with viability differences between genotypes, in which the mating system is selfing with a certain probability of random mating. The aim is to try to obtain some theory of a population in which there is some consanguineous mating. It had been shown that, with pure random mating, the mean viability increases. It appears that no simple theorem of this type holds with some consanguineous mating.

Some initial work has been done on the progress of simple Mendelian infinite populations with truncation selection, that is, one in which the best, say five percent, of a population is allowed to reproduce.

The ideas of genetic loads are being reviewed critically. A tentative conclusion is that, when all the semantic anthropomorphic irrevelant aspects are removed, the work in the literature is an attempt to relate observed viability differences to the coefficient of inbreeding, and to try to relate outcomes to competing models of causation. Logical aspects of the models which seem questionable are being explored.

Design of Experiments and Analysis of Data

Under the auspices of Agricultural Experiment Station Project 890, directed by Dr. Oscar Kempthorne, investigations have been continued on the logic of uncertain inference, particularly experimental inference; the testing of goodness of fit; the use of transformations and the interpretation of genetic experiments.

The theory of inference is commonly presented from a decision theory viewpoint with the concepts of point estimation, tests of hypotheses and confidence intervals. In contrast to this, the view is taken that the principal role of statistics is the condensation of data, and the determination of models which are consonant with the data. This point of view is being explored.

Necessarily associated with this view is the idea that one of the essential tasks, if not the essential one, of statistical methods is the problem of goodness of fit of models. Preliminary work has consisted of examination for unstructured data of the chi-square goodness of fit test with number of cells equal to the number of observations, and comparison of this procedure with other commonly used tests of significance for goodness of fit.

Also associated with this general outlook is the matter of transformation of experimental data, which is being considered from the point of view of goodness of fit of the transformed data. This work is in a preliminary stage.

Statistical and Economic Analysis for Long-Term (Rotational) Agronomic Experiments

Analyses of variance and estimates of yields for different rotation fertilization practices have been constructed for hay and oats on the Carrington-Clyde and Clarion Webster experiments. This work was done under Agricultural Experiment Station Project 1578, directed by Dr. Foster Cady and Dr. Wayne Fuller, with Dr. John Pesek and Dr. William Shrader as leaders in the Department of Agronomy.

For hay, these analyses indicated a very modest rotation effect. This appeared to be associated with the number of years the meadow had been seeded, with yields somewhat lower in the third year. There was large year to year variation but no apparent year treatment (rotation and nitrogen) interaction. The rate of nitrogen application on the corn crop had little effect upon the following hay yields.

Oat yields were higher on plots where the preceding corn had received more nitrogen fertilizer. The oat yields also exhibited considerable yearly variation with modest treatment by year interaction. Tentative investigation indicates that the oat yields can be fitted to a common response function in much the same manner as the corn yields.

A paper reporting the study of corn yield responses was published this year. An abstract of it, "Estimation of a Common Nitrogen Response Function for Corn (*Zea mays*) in Different Crop Rotations," appears in the publications section of this report.

Design of Surveys and Analysis of Data

Agricultural Experiment Station Project 1005 continued under the direction of Dr. Wayne Fuller.

Development of some response surface designs for three variables was undertaken. Some possible designs permitting the introduction of a fourth (0-1) variable were constructed. Two such designs will be used in field experimentation during the 1967 crop year.

Work on the bias and mean square error of regression estimators continued. A Monte Carlo study of such estimators under given model assumptions has been initiated.

Agricultural Estimates

A joint project between USDA and the Survey Group, administered under Agricultural Experiment Station Project 1207, Research in Sample Census Methods in Agriculture, continued with Professor Norman Strand, Dr. Wayne Fuller and Harold Baker as principal personnel. The research was divided into two areas.

The first work involved construction of sampling frames for list samples. To supply the need for a complete list from which to draw samples of farms having certain "rare" enterprises, it was necessary to initiate the compilation of such lists, since they are not available from public sources.

As a trial in the construction of such lists, three items were chosen: beekeepers, turkey raisers and sorghum growers. Incomplete lists exist and were obtained from various sources. Mail questionnaires were sent to these initial lists which requested the recipients to give names of persons they knew who kept bees, raised turkeys or grew sorghum. Then the new names given by these persons were asked to supply the names of others. This procedure was followed until no new names were forthcoming. Results of the study are being compiled.

In other research supported by this project, data was collected to use in investigating techniques for predicting and estimating hay yields. For this study, one alfalfa or alfalfa mix hay field was selected from each of ten farms in Story and Boone counties in Iowa. Within each field on each of three trips, ten plots, 30″ x 20′, were located at random and cut, the trips being made one month, two weeks and just before the expected harvest date. The forage from each plot was weighed in the field and a subsample dried and re-weighed in order to determine moisture content. At the time of harvest, a sample of bales was selected and weighed. This served as a check on the techniques devised for predicting and estimating yields on the basis of the plot cuttings.

Publications and Professional Activities

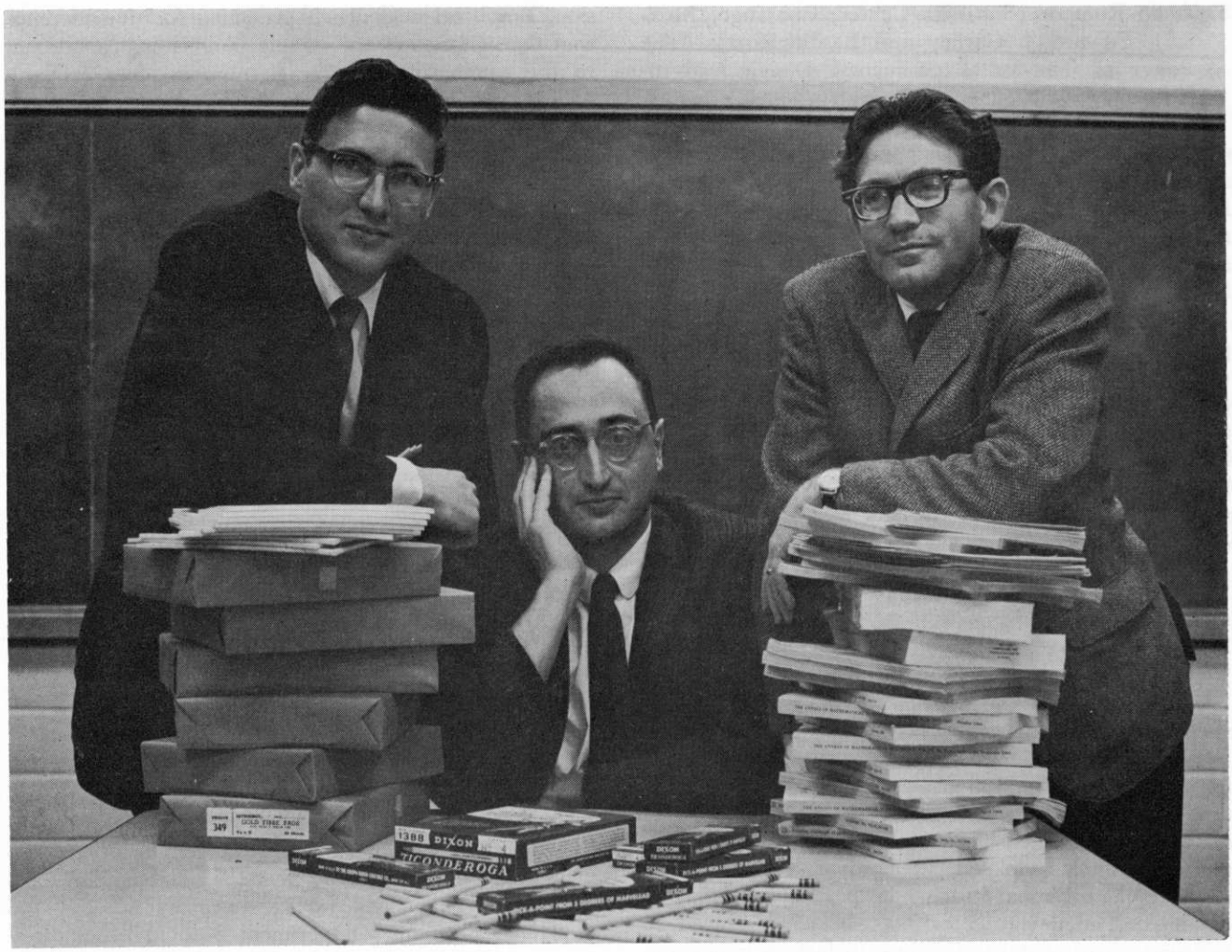
Most of the research conducted by Statistical Laboratory staff members is reported in papers presented at professional meetings and in articles published in professional journals. In addition, the staff members take an active role in the operation of the professional societies of which they are members, and the journals to which they contribute.

During the year, Dr. H. T. David, Dr. Chien-pai Han and Dr. George Zyskind served as referees for the Annals of Mathematical Statistics, and Professor C. Philip Cox was a referee for Biometrics. Editorial collaborators for the Journal of the American Statistical Association included Dr. Om P. Aggarwal, Dr. T. A. Bancroft, Dr. H. T. David, Dr. Oscar Kempthorne, Carl Roux, Dr. J. Sedransk and Dr. George Zyskind. Dr. James Walsh was on the editorial boards of Psychological Reports and Perceptual and Motor Skills. Dr. B. K. Kale continued as reviewer for the journal Zentralblatt für Mathematik. Dr. Carol E. Fuchs has been cataloguing abstracts for *Statistical Theory and Method Abstracts.*

An earlier publication, *Statistical Methods* by George W. Snedecor (1937), received recognition this year when it was named by its publisher, the Iowa State University Press, as one of two books published by the Press which has "made the strongest impact on contemporary society or most enriched its culture" (Saturday Review, June 10, 1967). The Press says about Snedecor's book: "Now going into a sixth edition, this study introduced several generations of statisticians and research workers here and abroad to the topic and provided a point of departure for subsequent works."

RECORD OF PUBLISHED RESEARCH

Articles published by staff members and graduate students during the past fiscal year are recorded on the following pages. 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.



Research which begins with paper, pencils and a statistician's idea, often is reported at professional meetings and then published in professional journals. Here Dr. Wayne Fuller, Dr. H. T. David and Dr. George Zyskind, left to right, pose with the tools of their trade and some of the journals which print their work.

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 (*).

* **Om P. Aggarwal:** "Bayes and Minimax Procedures for Estimating the Arithmetic Mean of a Population with Two-Stage Sampling." Annals of Mathematical Statistics, 37:5, 1186-1195. October 1966. Reprint Series No. 184, Statistical Laboratory, Iowa State University.

In this paper, the author discusses two-stage sampling using an approach similar to the one adopted in his previous paper (Aggarwal, 1959). The loss in estimating the mean is taken as a linear function of the squared error of the estimator and the cost of observations. The two cases, infinite and finite populations, are treated separately, and Bayes and minimax estimators are obtained in each case.

For the sake of generality, the author considers the case where the first-stage units, called clusters for simplicity, are of unequal sizes and obtains the results for equal-sized clusters as a special case. It is shown that in the case of equal-sized clusters and equal subsampling from each cluster, the simple mean of the cluster means, i.e. the overall sample mean, is a minimax estimator.

Foster Cady: "Research Techniques for Statistical Models." Agrociencia, 1, 51-55. 1966. (in Spanish)

In every experiment, the investigator is faced with the problem of expressing his results in quantitative terms. This paper describes the different sources and the basic steps in formulating a statistical model. By means of a statistical model, the structure of an observation in an experiment can be understood, and also the random error determined. Also described are some techniques for handling several types of models, and certain complications are discussed.

Sigifredo Romero (Statistics Center, Chapingo, Mexico), **Edward J. Carney** and Basilio Rojas: "The Power of Test on Experimental Designs." Agrociencia, 1, 31-50. 1966. (in Spanish)

The number of replications that must be used in an experimental design is closely connected with the power of the test. It is easy to understand the importance of knowing the power of a given test, since by means of this power and the size of the expected differences among treatments, it is feasible to determine the number of replications in an experiment.

It can be said that the importance of knowing the power of test has economical basis. If a number of replications greater than the necessary number has been used, then resources are wasted. On the other hand, if a number smaller than the necessary number is used, it is possible to conclude that there are not significant differences when in fact they do exist. This latter situation may be a consequence of the fact that the size of the experiment did not permit a test of sufficient power.

* **C. Philip Cox** and **Paul E. Leaverton** (University of Iowa, Iowa City): "Statistical Procedures for Bioassays when the Condition of Similarity Does Not Obtain." Journal of Pharmaceutical Sciences, 55:7, 716-723. July 1966. Reprint Series No. 183, Statistical Laboratory, Iowa State University.

Well established statistical procedures are available for the analysis of dilution parallel line or slope ratio assays for which the condition of similarity obtains. Research scientists have long been aware that this condition is commonly violated. In log-dose response assays, for example, divergent rather than parallel lines may be obtained. The deviation cannot always be traced to deficient experimental techniques. In fact, as indications of differences in the response processes of the standard and test preparations, or as indications of impure test preparations, such findings may provide the most important inference from an assay experiment and immediately suggest further investigation into the causes of the differences.

Statistical procedures have been developed to describe the phenomena in quantitative terms and, especially, to permit potency comparisons. The procedures may also have merit even in dilution assay situations where the condition of similarity may apparently be violated if appreciable differences between the responses of the standard and test preparations result from poorly matched doses.

* **C. Philip Cox** and **Thomas D. Roseberry** (C-E-I-R, Inc., Dugway, Utah): "A Note on the Variance of the Distribution of Sample Number in Sequential Probability Ratio Tests." Technometrics, 8:4, 700-704. November 1966. Reprint Series No. 187, Statistical Laboratory, Iowa State University.

During Monte Carlo studies to evaluate the performance of previously reported sequential covariance analysis test procedures, information was incidentially obtained on the variance of the sample number to decision. Empirical evidence is presented for the inference that the variance of the sample number is proportional to the square of the average number. B. G. Ghosh (1967) has since pointed out that moments of the distribution of sample number can be obtained from Wald's fundamental identity as a result of which it was then easily possible (Cox and Roseberry, 1967) to give the direct theoretical result substantiated by the above independent empirical study.

* **C. Philip Cox:** "Statistical Analysis of Log-dose Response Bioassay Experiments with Unequal Dose Ratios for the Standard and Unknown Preparations." Journal of Pharmaceutical Sciences, 56:3, 359-364. March 1967. Reprint Series No. 200, Statistical Laboratory, Iowa State University.

Well-known statistical analyses are available for the analysis of log-dose response assays when successive doses are in the same ratio for both the standard and unknown preparations. It is, however, sometimes convenient and advantageous in practice to use unequal dose ratios.

Appropriate analyses are offered for such cases, analyses which reduce to the usual ones when the ratios are equal. It is seen that the operational flexibility thus permitted is obtained in return for only slightly increased computation. Four-and six-point assays are discussed in detail together with a numerical example of the former. An improved method for calculating confidence interval estimates in log-dose response assays is also given.

* **C. E. Cress** (Michigan State University, East Lansing): "A Comparison of Recurrent Selection Systems." Genetics, 54:6, 1371-1379. December 1966. Journal Paper No. J-5487, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1448. Reprint Series No. 190, Statistical Laboratory, Iowa State University.

A set of comparisons was examined for all possible testing-mating systems utilizing two populations. Reciprocal recurrent selection (RRS) was used as a basis of comparison since this method was reported to have maximum potential and a good rate of progress under a wide range of conditions. The testing-mating system most competitive with RRS was termed "within population selection" (WPS).

For levels of positive dominance up to and including complete dominance, WPS has a rate of progress greater than or equal to RRS when $a_1 + b_1 > 1.0$, where a_1 and b_1 are the frequencies of the dominant alleles in the two populations. For levels of dominance in the overdominant range, the rate of progress by WPS was greater than or equal to RRS when $a_1 + b_1 > 1.0$ but less than twice the equilibrium gene frequency.

For other gene frequencies, the progress by RRS is greater than or equal to WPS. Any selection equilibrium in RRS is temporary with a finite number of parents per cycle. The disadvantages of using genetically divergent starting populations are discussed.

* **Wayne A. Fuller:** "Estimation Employing Post Strata." Journal of the American Statistical Asso-

ciation, 61:316, 1172-1183. December 1966. Reprint Series No. 195, Statistical Laboratory, Iowa State University.

Small sample estimators are developed for two post strata and compared with pooling or collapsing procedures commonly employed in practice. The estimators are not necessarily conditionally unbiased for a particular sample split, but their conditional M.S.E. may be smaller than that of the common post stratified estimator.

It is proven that it is always possible to construct an estimator superior to the practice of combining two post strata when one contains a few sample elements. A procedure for generalizing the two-strata procedures to any number of strata is illustrated. This procedure permits the construction of unbiased estimators for populations divided into a large number of small post strata.

W. D. Shrader, **W. A. Fuller** and **F. B. Cady:** "Estimation of a Common Nitrogen Response Function for Corn (*Zea mays*) in Different Crop Rotations." Agronomy Journal, 58, 397-401. July-August 1966. Journal Paper No. J-5292, Iowa Agricultural and Home Economics Experiment Station, Ames, Projects 1205 and 1578.

The premise that corn yields, over wide ranges of cropping systems, differ only because of differences in available nitrogen was tested, using as the criterion the representation of corn yields in long term rotation experiments by a common nitrogen response curve.

Data from two experiments in Iowa were analyzed. Rotation intensities varied from continuous corn to a rotation with three years of meadow. Nitrogen rates ranged from 0 to 160 pounds per acre per year. Experimental designs, rotations and treatments were somewhat different at the two sites, but at each the corn yields could be fitted to a common nitrogen response curve.

With this model rotation, effects were expressed in terms of nitrogen units. Estimates of nitrogen equivalents, in addition to those available to continuous corn, supplied by the different rotations, ranged from 10 to 130 pounds per acre.

Dewey L. Harris (DeKalb Agricultural Association, Inc., Sycamore, Illinois): "Biometrical Genetics in Man." Pp. 81-94 in *Methods and Goals in Human Behavior Genetics Research*. Academic Press, New York. 1966. Journal Paper No. J-4883, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 1448.

The biometrical genetic theory concerning random mating populations is reviewed and discussed. The relevance of this theory for human populations is then considered with emphasis on the difficulties of relating the theoretical results to human data. Although these results can be quite informative, the possible pitfalls of blindly using this theory is emphasized.

William J. Hemmerle (University of Rhode Island, Kingston): *Statistical Computations on a Digital Computer*. Blaisdell Publishing Company, Waltham, Massachusetts. 1967.

This monograph is one of a series on computer science presenting individual topics useful in the classroom and computation laboratory.

This text, at the senior-graduate level, is intended to be useful both to statisticians and to numerical analysts. Consequently, the statistical theory is briefly presented for various applications which are selected because of their importance in applied statistics and numerical analysis. A basic knowledge of computer programming and some advanced calculus and matrix algebra are assumed of the reader.

* **Klaus Hinkelmann** (Virginia Polytechnic Institute, Blacksburg): "Partial Triallel Crosses." Sankhyā, The Indian Journal of Statistics, Series A, 27: Parts 2, 3 and 4, 173-194. Journal Paper No. J-5301, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 830. Reprint Series No. 189, Statistical Laboratory, Iowa State University.

Sampling a complete set of three-way crosses is considered from a genetical and statistical point of view. A partial triallel cross (PTC) is defined to be a set of matings in which every line occurs r_H times as a half-parent, and r_F times as a full parent, and possible three-way crosses occur once or not at all. A correspondence is set up of PTC's to generalized partially balanced incomplete block designs, and types of PTC are discussed. The analysis of PTC's is developed, using the ideas of association matrices of incomplete block designs.

David V. Huntsberger: *Elements of Statistical Inference*, Second Edition. 398 pp. Allyn and Bacon, Inc., Boston. 1967.

The second edition, like the highly successful first, is intended as an introduction to some of the basic concepts and techniques of statistical inference. It is hoped that the reader will acquire an appreciation for and an understanding of the statistical approach to many types of problems which arise in our increasingly complex society.

The material of the earlier edition has been regrouped, examples and illustrations that have been found effective in the classroom have been added, and those topics for which experience indicates clarification would be helpful have been developed more fully. Only those topics which appear to be of interest in diverse fields of application have been added to the contents of the first edition. The major additions are the paired t-test, an elementary treatment of Bayes theorem, and an introduction to the analysis of variance for two-way classifications. Many more problems from all areas of application are included.

This book is intended to serve as a text for a general course for those who want to know "what statistics is all about," or who need to be familiar with at least the language and fundamental concepts of statistics to achieve additional competence in their chosen fields. Such a course would also provide the necessary back-

ground for those who will take more advanced courses in statistics, including the specialized applications.

Chapter headings are as follows: Introduction; Empirical frequency distributions; Descriptive measures; Elementary probability; Populations, samples and theoretical distributions; Sampling distributions; Estimation; Tests of hypotheses; Two-sample techniques and paired comparisons; Approximate tests: Multinomial data; Regression and correlation; and Analysis of variance.

H. Doggett and **D. Jowett:** "Yields of Maize, Sorghum Varieties and Sorghum Hybrids in the East African Lowlands." Journal of Agricultural Science, Cambridge, 67, 31-39. 1966.

Yield data are reported for sorghum varieties and hybrids at sites throughout East Africa for the years 1961-63. Substantial yield advantage is shown for hybrids produced from U.S. male-steriles and African restorer lines. However, hybrids entirely of U.S. origin, e.g. RS 610, perform very badly at almost all locations. Sorghum proved capable of outyielding maize at many sites when rainfall was either poor or excessive, indicating that sorghum is better adapted to adverse soil moisture conditions.

* **B. K. Kale** and **T. A. Bancroft:** "Inference for Some Incompletely Specified Models Involving Normal Approximations to Discrete Data." Biometrics, 23:2, 335-348. June 1967. Reprint Series No. 202, Statistical Laboratory, Iowa State University.

This paper considers the problem of pooling of two sample means of two independent random samples from discrete distributions (in particular Poisson and binomial) which can be approximated by normal distributions after the appropriate transformations.

The authors first develop the theory for two samples from $N(\mu_i, \sigma^2)$, $i = 1, 2$, σ^2 assumed known, and the parameter of interest being μ_1. Using a preliminary test of significance (PTS) at level α to test $\mu_1 = \mu_2$, a new estimator $\bar{x}^*$ for μ_1 is proposed to estimate μ_1, and to test hypothesis $\mu_1 = \mu_0$. The bias and the mean squared error of $\bar{x}^*$ is studied and the regions in the parameter space in which $\bar{x}^*$ has smaller mean squared error than $\bar{x}_1$, the mean of the first sample, are determined.

Similarly in the hypothesis testing problem the size and the power of the overall test procedure is studied. It is recommended that in order to control the mean squared error and the size of the overall test procedure based on $\bar{x}^*$, the level of significance of PTS should be about .25. These results are then applied to corresponding problems for the data from Poisson and binomial distributions.

* **Oscar Kempthorne:** "Multivariate Responses in Comparative Experiments." Pp. 521-540 in *Multivariate Analysis,* AF33(615)-3016. Academic Press, Inc., New York. 1966. Reprint Series No. 199, Statistical Laboratory, Iowa State University.

This paper contains a discussion of the present knowledge of methods of handling multivariate data in planned experiments. Most experiments yield multivariate data, but very few analyses used intimate the multivariate nature of the data. The paper discusses possible reasons for this. It gives some opinions of what experimenters want from experiments, and assesses the contributions of available multivariate procedures to these needs.

The paper reviews some permutation evaluation procedures for multivariate data. It concludes that main reasons for lack of use of multivariate procedures are (1) attention to decision making rather than opinion-forming, (2) primitive state of knowledge of multivariate techniques, (3) insufficient exploitation of modern computing and plotting devices and (4) the essential linearity of available multivariate techniques.

O. Kempthorne, G. Zyskind, R. P. Basson (Atlas Chemical Industries, Wilmington, Delaware), **F. B. Martin, T. E. Doerfler** (Booz-Allen Applied Research, Chicago, Illinois), **E. J. Carney:** "Research on Analysis of Variance and Data Interpretation." Aerospace Research Laboratories Report 66-0240. December 1966.

Research on analysis of variance and data interpretation is described in this report. Section I discusses estimation problems in variance component and mixed model problems. Section II considers the combination of information on estimable functions from distinct uncorrelated sources and justifies some of the common applications in experimental design problems.

Section III discusses size and power under experiment randomization of several competitive tests for the paired design and presents conclusions about the high relative merits of the variance ratio randomization and the Wilcoxon tests. Section IV discusses the development of high speed computational methods for the calculation of fourth degree generalized polykays of variances and covariances of estimated variance components for balanced samples from balanced populations. Section V summarizes briefly papers on the design of experiments and multivariate responses in experiments and the 1965 Fisher Memorial lecture on experimental inference.

* J. F. Kidwell and **O. Kempthorne:** "An Experimental Test of Quantitative Genetic Theory." Der Zuchter, 36:4, 163-167. 1966. Journal Paper No. J-5354, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 890. Reprint Series No. 188, Statistical Laboratory, Iowa State University.

An experiment was conducted with *Drosophila melanogaster* to test a theory of quantitative inheritance. The covariances among half and full sibs did not increase with increasing levels of F.

The results pose the question: "Why did inbreeding not behave as expected?" Some possible causes include: (1) selective elimination of particular genotypes during inbreeding, (2) inbreeding and/or selection within the reference population, (3) maternal age effects, and (4) linkage. Linkage and selective elimination of some genotypes appear most likely to be of greatest importance.

* **A. Kudô** and H. Fujisawa: "Some Multivariate Tests with Restricted Alternative Hypotheses." Pp. 73-85 in *Multivariate Analysis,* AF33(615)-3016. Academic Press, Inc., New York. 1966. Reprint Series No. 198, Statistical Laboratory, Iowa State University.

This paper is concerned with the power function of a bivariate normal test with a two-sided alternative, $H_1 : (\Theta_1 > 0, \Theta_2 > 0)$ or $(\Theta_1 < 0, \Theta_2 < 0)$. In case the alternative hypothesis is not restricted, namely $H_1 : \Theta_1 \neq 0, \Theta_2 \neq 0$, the ordinary test of significance based on a χ^2 distribution would be the most appropriate one. It discusses the power function of the likelihood ratio test worked out by the authors and the maximum and minimum power and ratios to the power of the ordinary test based on χ^2 distributions are tabulated. Another test is also proposed and its power is discussed.

***William D. Lawing** (Research Triangle Institute, Durham, North Carolina) and **H. T. David:** "Likelihood Ratio Computations of Operating Characteristics." Annals of Mathematical Statistics, 37:6, 1704-1716. December 1966. Reprint Series No. 191, Statistical Laboratory, Iowa State University.

The point of this paper is that likelihood ratios, especially in conjunction with suitable symmetry, yield at least partial operating characteristic (OC) information for procedures other than the sequential probability ratio test (SPRT).

The authors discuss OC computations in terms of mutually "conjugate" parametric values. The ideas are applied to the Wiener process, for two-decision "wedge" procedures and certain three-decision procedures. Certain absorption probabilities for multidimensional Brownian motion are discussed, as is the binomial case.

* **Frank B. Martin** and **George Zyskind:** "On Combinability of Information from Uncorrelated Linear Models by Simple Weighting." Annals of Mathematical Statistics, 37:5, 1338-1347. October 1966. Reprint Series No. 185, Statistical Laboratory, Iowa State University.

Within the set of all linear parametric functions, $\lambda'\beta$, estimable from either or both of two uncorrelated sets of data, $y_1 = X_1\beta + e_1$ and $y_2 = X_2\beta + e_2$ with known non-singular variances, a general characterization is presented of those $\lambda'\beta$'s for which the best linear unbiased estimator (b.l.u.e.) is obtainable from one source of information alone or by simple weighting of the respective b.l.u.e.'s from each of the two sources.

It is shown that if the intersection of the row spaces of X_1 and X_2 has rank r, then in the intersection space there are exactly r independent vectors λ' for which the b.l.u.e. of $\lambda'\beta$ is obtainable by simple weighting. Some related statements are made for $k > 2$ uncorrelated sources of information.

In the case of incomplete block designs, the reduced intrablock normal equations and the interblock normal equations may be regarded as originating from two uncorrelated sources of information on the treatment parameter vector τ. It is shown that an estimable treatment contrast, $\gamma'\tau$, is best estimated from one source alone or by simple weighting of b.l.u.e.'s from the respective sources if and only if γ is an eigenvector of $\Lambda = (\lambda_{ij})$, where λ_{ij} is the number of times treatments i and j occur together in a block.

For symmetric factorial or quasifactorial designs, it is shown that any effect or interaction degree of freedom contrast is an eigenvector of Λ, and hence is best estimated by simple weighting of its interblock and intrablock estimates.

* **Edward Pollak:** "Some Effects of Fluctuating Offspring Distributions on the Survival of a Gene." Biometrika, 53:3 and 4, 391-396. December 1966. Reprint Series No. 194, Statistical Laboratory, Iowa State University.

The subject of this paper is the study of the fate of a gene that has just been introduced into a large population that is stationary in size. It is assumed that lines descended from two or more genes of this type develop independently of each other. But in contrast to the usual treatment of this subject, offspring distributions are not assumed to stay the same from generation to generation.

Particular attention is paid to two cases: (a) cyclical fluctuation of the offspring distribution, and (b) the case in which a new gene has an advantage which is gradually lost as time passes.

* **J. E. Schlater** (United States Steel Corporation, Monroeville, Pennsylvania) and **W. J. Hemmerle** (University of Rhode Island, Kingston): "Statistical Computations Based Upon Algebraically Specified Models." Communications of the ACM, 9:12, 865-869. December 1966. Reprint Series No. 192, Statistical Laboratory, Iowa State University.

Based upon a machine-readable statistical model and related symbolic specifications, an efficient method of performing calculations for statistical models of a balanced complete nature is presented. Fixed, mixed and random analysis of variance models are considered. A procedure for obtaining variance components and calculated F statistics for the model terms is included.

* **J. H. Sedransk** and Robert W. Clyde: "A Generalized Technique for Predicting Election Results from Early Returns." Public Opinion Quarterly, 30:3, 416-422. Fall 1966. Reprint Series No. 186, Statistical Laboratory, Iowa State University.

A follow-up study to a previously reported application of the "post-stratification" technique to a statewide election prediction was carried out by the Iowa State University Statistical Laboratory in the 1964 general election.

Even though early returns in the 1964 Iowa general election foretold the heavy Democratic landslide in the state, the estimator used in this study accurately predicted, from a very small sample, the final vote percentages for a number of races.

These predictions, based on election returns obtained

after the closing of polls on November 3, 1964, were used as a part of the election night report of the University owned and operated television station, WOI-TV. Although principal emphasis was placed upon the Iowa gubernatorial race, as in the 1962 WOI-TV election analysis, subsequent research offers evidence that this procedure is equally applicable to the prediction of other statewide election contests.

* **J. Stavrou** (Department of Economics, Iowa State University) and **F. B. Cady:** "Confounding the Triple Cube Response Surface Design to Reduce Block Size." Soil Science Society of America Proceedings, 31:1, 126-128. January-February 1967. Journal Paper No. J-5430, Iowa Agricultural and Home Economics Experiment Station, Ames, Project 101. Reprint Series No. 201, Statistical Laboratory, Iowa State University.

Modification of the composite response surface designs, called cube designs, have been effected by experimenters but result in large block size. Block size may be reduced with the use of confounding procedures. The resulting design, which retains the same orthogonality as the cube design, is given for the triple cube with discussion of its appropriate use in agronomic studies. Designs, modified by the inclusion of certain "star points" or use of single blocks, are studied and the resulting properties and potential uses are given.

* **David R. Thomas** and **H. T. David:** "Game Value Distributions I." Annals of Mathematical Statistics, 38:1, 242-250. February 1967. Reprint Series No. 196, Statistical Laboratory, Iowa State University.

This paper is concerned with the distribution of the value of a game with random payoffs. Two types of games are considered: matrix games with iid matrix elements, and games of perfect information with iid terminal payoffs.

Let $||x_{ij}||$, $i:1, 2, \ldots, m; j:1, 2, \ldots, n$, be the matrix of player I's payoffs in a zero-sum two-person game, and let $v(||x_{ij}||)$ be its (possibly mixed) value. Conider the random value $V_{m,n}(f) \equiv v(||X_{ij}||)$, where X_{ij} are mn iid random variables, each distributed according to the density f. It is pointed out in Section 2 that the conditional distribution of $V_{m,n}$, given that it is pure, is that of the nth largest of $m + n - 1$ iid random variables, each distributed according to f. For f uniform on (0, 1) (i.e., $f = u$), a method is given for determining the conditional distribution of $V_{2,n}(u)$, given that it is mixed. This leads to an elementary expression for the distribution of $V_{2,2}(u)$ and the asymptotic distribution of $V_{2,n}(u)$.

Consider as well two players alternately choosing one of two alternative moves, with n choices to be made in all by each. Corresponding to each of the 4^n possible sequences of moves, there are 4^n payoffs $x(i_1, i_2, \ldots, i_{2n})$ for player I, $i_k = 1$ or 2, where the odd and even locations indicate, respectively, the successive alternatives chosen by players I and II. The (pure) value $v(\{x(i_1, \ldots, i_{2n})\})$ of such a game is

$$\max_{i_1} \min_{i_2} \max_{i_3} \min_{i_4} \ldots \max_{i_{2n-1}} \min_{i_{2n}} x(i_1, \ldots, i_{2n}).$$

Now replace the 4^n numbers $x(i_1, \ldots, i_n)$ by independent uniformly distributed random variables $X(i_1, \ldots, i_{2n})$. The asymptotic behavior of the random value $V_n \equiv v(\{X(i_1, \ldots, i_{2n})\})$ is investigated in Section 3; it is shown that the asymptotic distribution L of V_n is everywhere continuous and monotone-increasing, and satisfies a certain functional equation; it is also shown that the moments of the normed V_n converge to those of L.

* **David R. Thomas:** "Game Value Distributions II." Annals of Mathematical Statistics, 38:1, 251-260. February 1967. Reprint Series No. 197, Statistical Laboratory, Iowa State University.

This paper considers a more general class of games than those considered in a previous paper (Thomas and David, 1967); games with p and q alternatives available, respectively, for players I and II at every move, and with the terminal payoffs arbitrarily distributed, though still iid.

Specifically, consider a two-person zero-sum perfect information game, with player I and player II alternately choosing one of several alternative moves, with n choices to be made in all by each. It is assumed that there are always p and q alternatives available respectively to players I and II. Corresponding to each of the $(pq)^n$ possible sequences of moves, there are $(pq)^n$ payoffs (to player I) $x(i_1, i_2, \ldots, i_{2n})$, where the indices $i_1, i_3, \ldots, i_{2n-1}$, each with range $(1, 2, \ldots, p)$ indicate the successive alternatives chosen by player I, and the indices $(i_2, i_4, \ldots, i_{2n})$, each with range $(1, 2, \ldots, q)$, indicate the successive alternatives chosen by player II. The value $v(\{x(i_1, \ldots, i_{2n})\})$ of such a game is

$$\max_{i_1} \min_{i_2} \max_{i_3} \min_{i_4} \ldots \max_{i_{2n-1}} \min_{i_{2n}} x(i_1, \ldots, i_{2n}).$$

Now replace the $(pq)^n$ numbers $x(i_1, \ldots, i_{2n})$ by independent random variables $X(i_1, \ldots, i_{2n})$, each with cdf F.

This paper is concerned with the limiting behavior of the random values $V_n(F) \equiv v(\{X(i_1, \ldots, i_{2n})\})$. The limiting behavior of $V_n(F)$ is investigated in Section 2 for uniform F ($F = U$). Analogous to the results for $p = q = 2$ obtained in the previous paper, the limiting distribution for the sequence $\{V_n(U)\}$ is everywhere continuous and monotone increasing, and satisfies a certain functional equation. Limiting distributions arising from arbitrary F are considered in Section 3. Section 4 is devoted to some results concerning norming sequences and domains of attraction. The final corollary of Section 4 establishes that all of the common cdf's lead to the same limiting distribution.

Henry Tucker: "Basic Ideas on Linear Programming." Agrociencia, 1, 25-30. 1966. (in Spanish)

Linear programming is a technique used in finding the solution to problems that deal with several linear inequalities and an objective function. In general, the

set of inequalities gives a relation between incomes or expenses and some limited resources. Most of the time the objective function is concerned with making the profits a maximum or the costs a minimum.

Under very general conditions, linear programming can be applied to problems such as the mixture of foods needed for making rations with minimum cost when some nutritive requirements have been fixed. Also, in agricultural problems, when the resources have been fixed (land, capital, work) and it is desired to obtain maximum profits.

In order to establish the equations, it is necessary to obtain coefficients that relate incomes and expenses; also values for costs and prices. With the help of modern computers, these kinds of problems can be solved relatively easily, and alternative solutions can be obtained.

Henry Tucker: "Analysis of Variance and Covariance." Chapter 6, 87-99, in *Methods for Land Economics Research*. University of Nebraska Press. 1966.

The use of analysis of variance and covariance in land economics research is presented in a non-technical form, with emphasis on limitations of use and interpretations of results. Discussions on underlying assumptions, models, separation of means and evaluating the adequacy of the model are treated with respect to specific types of land economics problems.

The use of special techniques such as individual degrees of freedom, unequal subclass numbers and the use of transformations are considered. Analysis of covariance is presented as a hybrid between pure regression models for continuous variables and associated fixed effects of discrete variables.

J. W. Stull, W. H. Brown, Carlos Valdez and **Henry Tucker:** "Fatty Acid Composition of Milk. III. Variation with Stage of Lactation." Journal of Dairy Science, 49:11, 1401-1405. November 1966.

This study was designed to determine the variation in proportions of the various fatty acids of milk fat during the progress of lactation and to concurrently observe the variation in milk production, fat and protein.

Variations in component fatty acids in milk of four Holstein cows were measured during their entire lactation (43-50 weeks). Least-squares fits of the measured values were then made to a succession of polynomials, and the added contribution to reducing the unexplained variation was calculated to determine the best-fitting function.

Linear regression equations best describe the proportions of 6:0, 8:0, 16:0, and 16:1, with only 16:0 having a negative slope. The proportions of 10:0, 12:0, 16:iso, 17:0, 18:0, 18:iso, and 18:2 were best described by quadratic regression equations. There were wide variations throughout the progress of lactation in the slopes of the curves in these latter cases. Cubic regression equations adequately described the proportions of 10:1, 12:1, 14:0, 14:1, 15:0, and 18:3 fatty acids.

Douglas M. Klieger and **James A. Walsh:** "A Pictorial Technique for Obtaining Social Desirability Ratings from Young Children." Psychological Reports, 20, 295-304. February 1967.

A procedure for obtaining social desirability ratings from young children was described and tested. It was hypothesized that children six years of age would produce ratings essentially similar to those of adults using a set of nine standardized pictures as a rating device. These pictures were line drawings of a stylized female face, with expressions ranging from a deep frown through a bright smile.

It was found that children down to the age of four years gave ratings that correlated .90 with adult ratings obtained in either the usual fashion or by means of the pictures. The ratings of three-year-olds correlated .55 with adult ratings. Ratings of a set of items by both standard and pictorial rating methods by fifth-graders and adults correlated .89 and .96, respectively.

Richard D. Warren, George M. Beal and Joe M. Bohlen: *The Experimental Dealer Training Program.* Rural Sociology Report N. 56, Department of Sociology and Anthropology, Iowa State University. 1966. Iowa Agricultural and Home Economics Experiment Station (in cooperation with TVA), Project 1469.

The monograph reports the findings of a study to determine the influence of an intensive training program for general managers of local retail farm supply businesses for which fertilizer and agricultural chemicals were product lines. An attempt was made to determine 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 of the total business, the fertilizer department and agricultural chemicals department.

To accomplish this purpose, the problem setting was described, the objectives and content areas of the training program were reviewed, changes in the above areas were predicted and an attempt was made to measure the changes. The results from testing the empirical hypotheses concerning knowledge, attitudes, performance, general management and firm, and economic variables were presented.

*Jenniev Poulson, **Richard Warren** and William F. Kenkel: "The Measurement of Goal Agreement between Husbands and Wives." The Sociological Quarterly, 7:4, 480-488. Autumn 1966. Reprint Series No. 193, Statistical Laboratory, Iowa State University.

Alternative methods of measuring the extent to which husbands and wives agree on their goals and the extent to which goal agreement changes over time are discussed in this paper.

In the present study, family goals were measured by a forced-choice method calling for a selection and

ranking of five of fifteen listed goals and by a free-response method in which husbands and wives independently listed their most important goals. Three different methods of measuring goal agreement were developed for use with the forced-choice system of measuring goals. One method was developed for the free-response system. The paper concludes with a description of a method for measuring change in goal agreement.

Book Reviews

Barry C. Arnold and **T. A. Bancroft:** Review of *The Statistical Analysis of Series of Events,* by D. R. Cox and P. A. W. Lewis. International Statistical Institute, 34:3, 448. 1967.

H. T. David: Review of *The Statistical Analysis of Experimental Data,* by John Mandel. Journal of the American Statistical Association, 61:315, 882-883. September 1966.

James A. Walsh: Review of *Basic Concepts of Measurement,* by Ellis. Educational and Psychological Measurement, 27, 223-225. 1967.

Letter

C. Philip Cox and **Thomas D. Roseberry.** Technometrics, 9:2, May 1967.

ABSTRACTS OF THESES

Joe Dean Atkinson: "An Investigation of Goodness of Fit Tests for Normality." M.S. thesis. Iowa State University Library. May 1967.

This thesis presents the theoretical background and operating characteristics of several procedures for testing goodness of fit of a normal distribution. The procedures considered are: Fisher tests using the product moment function, $\sqrt{b_1}$ and b_2, of skewness and kurtosis; the classical chi-square goodness of fit criteria χ^2 based on equiprobable cells; the Shapiro-Wilk Wn statistics, and a sample spacing test K* suggested by Dr. B. K. Kale and James Gebert.

The frequency distribution of χ^2 is studied for expected cell sizes $L = \frac{1}{2}$, 1, 2 and 5 for sample size n varying from 6 to 50. Comparisons show that the theoretical chi-square distribution adequately approximates the upper tail probabilities of χ^2, for testing both the completely specified model $N(0, 1)$ and the partially specified model $N(\mu, \sigma^2)$ for which μ and σ^2 were estimated. Methods for approximating the null sampling distributions of $\sqrt{b_1}$ and b_2 are discussed and a comparison is made between the observed empirical sampling estimates and the different methods of approximation for sample size 30.

In addition to these sampling studies, the frequency distribution of each test criteria is studied when samples of size 20 from a $N(0, 1)$ population are rounded to simulate grouped data, and these distributions are compared to distributions obtained under no rounding. Results show that χ^2, $\sqrt{b_1}$, and b_2 distributions are not affected. Results on Wn and K* indicate considerable sensitivity to rounding of data.

The methods of simulation are discussed and studied with regard to variability of the frequency distribution estimates as the number of samples varies.

The sensitivity of each procedure to samples obtained from several non-normal distributions is studied. Results for $\sqrt{b_1}$, b_2 and Wn agree favorably with previous studies. It is shown that the optimal choice of cell size for the χ^2 criteria is dependent on the class of alternatives to be tested against.

It was found that the χ^2 type tests have distributions close to the mathematical χ^2 distributions when the number of cells is equal to the number of observations, or twice the number, when parameters are fitted.

The implications of the study are that for general testing for normality the χ^2, $\sqrt{b_1}$, and b_2 criteria are the most flexible for both small and large sample testing. For n less than 50, Wn is superior as long as the data are not affected by strong grouping error. The same qualification applies to the utility of K*. In addition, the asymptotic properties of K* are not sufficient to approximate its sampling distribution for sample size n as small as 50. The need for specification of the mean and variance of the sampling distribution from which the random sample was obtained, in addition to the above two qualifications, greatly restrict the utility of K* as a goodness of fit test of normality.

It is important to note that of the above discussed procedures only χ^2 and K* are general purpose tests and are not limited to the testing of normality as are Wn, $\sqrt{b_1}$, and b_2. Actually, it is remarkable that the general purpose tests do as well as they do compared to the specially tailored 'normal test' criteria. Both χ^2 and K* can be applied to the testing of goodness of fit of any completely specified distribution, and their null distribution behavior is independent of the nature of this completely specified distribution.

James C. Blinn: "A Statistically-Oriented Computer Language and a System of Statistical Programs." M.S. thesis. Iowa State University Library. November 1966.

This thesis describes a statistically-oriented computer language and the system of statistical programs to be used in conjunction with it. The motivation for the language is to aid the users of statistics in solving their problems on computers. The language serves as the communication link for the researcher or theorist with the general system of statistical programs provided. Through the language, problems can be specified in terms familiar to a statistician, and the desired output described.

The general statistical programs available are:

1. Complete analysis of variance and covariance for problems with equal numbers in all subclasses, as described in John Schlater's M.S. thesis (1965).

2. Multiple linear regression with several input and output options, and hypothesis testing.

3. Exact analysis for analysis of variance with unequal numbers in the last subclass, or equal numbers, by specifying the lines of the analysis of variance table desired—using regression technique and forming the X matrix by applying the normal restrictions.

Nell Kincaid Bruner: "On Pooling Normal Means: An Empirical Bayes Approach." M.S. thesis. Iowa State University Library. February 1967.

The problem treated here is that of estimating the mean, μ_1, of a normal population with known variance, σ^2, when samples are available both from the population of interest and from a second normal population with mean, μ_2, which is known to be close to μ_1, and with the same variance σ^2. Using the mean squared error as a criterion for comparison, an estimator "better" than $\bar{x}$, the mean of the sample from the population of interest, is sought using an Empirical Bayes approach.

First, a normal distribution with mean zero and variance a^2 is applied to $\frac{\mu_2 - \mu_1}{\sigma}$, where a^2 expresses the degree of confidence with which μ_2 is expected to be close to μ_1. The usual Bayes estimator, assuming a^2 known, (a weighted estimator with the weights as functions of a^2) is derived. The assumption of known a^2 is then relaxed and a^2 is regarded as an unknown parameter. Following the usual Empirical Bayes approach, some form of past experience is assumed to be available to estimate a^2, and hence, to estimate the prior distribution of $\frac{\mu_2 - \mu_1}{\sigma}$. Using this estimated prior, an estimator is derived which is a weighted linear sum of the two sample means.

Two different sets of assumptions lead to two types of estimators. In Case I, the observations in the sample from the second population are assumed to be independently normally distributed with mean μ_2 and variance σ^2 (conditionally upon μ_2). The unconditional (averaged over the prior distribution of μ_2) distributions of the observations in this sample are independent normal with mean μ_1 and variance $(\frac{n_2a^2 + 1}{n_2})\ \sigma^2$, where n_2 is the size of the sample. To estimate $\frac{n_2a^2 + 1}{n_2}$, it is assumed that past observations are available from an independent source.

In Case II, the observations in the sample from the second population are assumed to be normally distributed with different means μ_{2j} and common variance σ^2 (conditionally upon the μ_{2j}). The prior distributions of the $\frac{\mu_{2j} - \mu_1}{\sigma}$ are independent normal with mean zero and variance a^2, where a^2 is unknown. The unconditional (averaged over the distributions of $\frac{\mu_{2j} - \mu_1}{\sigma}$) distributions are normal with mean μ_1 and variance $\frac{a^2 + 1}{n_2}$. While Case I assumed p observations constituting the past experience which makes it possible to estimate a^2 and thus the prior distribution on $\frac{\mu_2 - \mu_1}{\sigma}$, Case II uses only the given sample from the second population. In both situations, an estimate of a^2 which is a gamma variable is obtained. The two cases lead to estimators which are therefore similar in form.

Justifications for both sets of assumptions and examples of experimental situations suitable to each are given. Precise analytic expressions are derived for the mean squared errors of the proposed estimator for Case I when p is odd and Case II when n_2 is odd. It is proved that the proposed estimators have uniformly smaller mean squared error than $\bar{x}$, when p is greater than 10 (in Case I) or when n_2 is greater than 10 (in Case II).

Leon Forrest Burmeister: "Unequal Probability Sampling for Comparative Studies." M.S. thesis. Iowa State University Library. November 1966.

To evaluate the present characteristics and future needs of the food service institutions in Iowa, a study of the state's restaurants, nursing homes and hospitals was proposed.

Clusters or primary sampling units composed of one or two counties were formed and a sample selected with probability proportional to.

$S_i = R_i + 3NH_i + 3H_i$

where R_i = the number of restaurants in the i^{th} cluster, NH_i = the number of nursing homes in the i^{th} cluster, and H_i = the number of hospitals in the i^{th} cluster.

The sampling scheme was compared to several other methods of selection in an attempt to evaluate the performance of the alternatives under different situations. To facilitate this evaluation, the variances of the estimated means for both ratio and non-ratio estimators are expressed in terms of the following model:

$Y_i = \alpha + \beta M_i \times M_{(i)}{}^g \sigma^2$

where Y_i = the cluster total for the characteristic of interest, M_i = the size of the i^{th} cluster, and $g = 0$, $\frac{1}{2}$ or 1. The resulting variance expressions lead to the conclusion that in most practical situations a ratio estimator is superior to a non-ratio estimator since there are no β terms in its variance. A non-ratio estimator may give more precise results if β is near zero.

In any specific problem, consideration must be given to the nature of the model that best describes the relation between cluster size and variance of cluster totals, and also to the nature of the estimates desired. If the variance of a cluser total is constant regardless of the number of elements in that cluster, selection of the primary sampling units with equal probabilities will give the more precise estimates. However, if the variance is highly correlated with cluster size, more precise estimates are obtained by sampling with probabilities proportional to a measure of size.

The measure of size which gives lowest variances depends on the nature of the estimates desired. If the study were limited to a single class of institutions, such as restaurants, it follows that the best procedure would be sampling with probability proportional to this institution. However, if interest is high in comparison among institutions, the clusters should be sampled with a probability proportional to a function of all institutions under consideration and the measure of size, S_i, proved to be very efficient.

Edward John Carney: "Computation of Variances and Covariances of Variance Component Estimates." Ph.D. thesis. Iowa State University Library. February 1967.

The work reported in this thesis is directed toward development of procedures for the computation of estimated variances and covariances of variance component estimates. The approach is a finite population development which also may be regarded as a distribution-free treatment of infinite populations.

The problem of estimating components of variance arises with samples from populations, the elements of which are classified in one or more ways. The usual estimates can then be represented as quadratic functions of multiple subscripted variables. The variances and covariances of such estimates are quartic functions of the population variables, and are estimated by appropriately chosen quartic functions of the sample values. The problems which ensue are the development of formulas, and the analysis and modification of these, to lead to feasible computing procedures for actual data. Previous work in the literature indicated that a formulation in terms of generalized polykays was useful.

The symbols for generalized polykays and generalized symmetric means for crossed structures are shown to form elements of a lattice of ordered partitions which is used in relating the two sets of quantities. Similar relationships are found to exist between the numerators of the generalized symmetric means and unrestricted sums. The latter quantities may be computed much more efficiently than the generalized symmetric means. These results are generalized to arbitrary balanced complete response structures.

The relationships of response structures and of the lattice of ordered partitions are adapted to the development of algorithms for the digital computer which handle the algebraic formulation of the variances and covariances as linear functions of the unrestricted sums. Further algorithms are developed for the machine computation of the unrestricted sums.

Use of the algorithms should allow the computation of variances and covariances of estimates of variances and covariances for at least five-factor structures. This should be useful in processing experimental results, and in the evaluation of alternative approaches using approximations or simplifying model assumptions to decrease the amount of computation.

Kweku T. deGraft-Johnson: "Some Aspects of Measurement Errors." M.S. thesis. Iowa State University Library. November 1966.

This thesis is devoted to a discussion of some of the factors which contribute to measurement errors and to the use of various devices designed to gauge the magnitude of response errors in survey data. In particular, an index of inconsistency proposed by Hansen, Hurwitz and Pritzker, which measures the proportion of total variability attributable to the response variance, is discussed extensively. Alternative versions of this index are considered.

Some illustrative examples, taken from the 1960 Ghana Population Census and the five percent Post-Enumeration Sample Survey (PES) which followed it, are given. An approximation to the mean square error of the estimator of the index of inconsistency in the case of (single stage) random sampling is given. Also presented are estimators of the index when different sampling designs (e.g. two-stage unstratified random sampling) are used. It is indicated that an estimator may be derived under any assumed sampling scheme, even though the estimators become more complicated as the sampling scheme becomes more complex.

Finally, an alternative to the index of inconsistency is discussed, a general review of the quality of the 1960 Ghana Census data is made and some suggestions are given about the best approach to the study of measurement errors in developing countries for the 1970 round of world population censuses.

Ralph Edward Folsom, Jr.: "Balancing Lot Means as Contrasted to Covariance or Constrained Randomization for Evaluating Treatment Differences in Completely Randomized Designs." M.S. thesis. Iowa State University Library. November 1966.

In this thesis two designs, the one balanced for lots, the other for treatments, were compared to their corresponding completely randomized designs, and their properties of unbiasedness, relative efficiency, and sensitivity were studied.

As an alternative to these systematic or non-random designs, a technique known as constrained randomization was explored. This concept involves constructing a subset of the $(rt)!/(r!)^t$ possible randomization plans which has the properties of unbiasedness inherent to the complete set, but does not contain special plans which seem to be undesirable. However, although the constrained set disallows very unbalanced plans, it also eliminates more perfectly balanced plans. The constrained set, while providing the same expectation of the error sums of squares as would be achieved with the complete set, can significantly reduce the variance of the error estimates over that for the complete set.

The example performed in this thesis on two constrained sets of plans seems to indicate that the bias

of the adjusted error mean square from a covariance analysis is small, as Cox (1956) had surmised, when plans are chosen with equal probability from the set of plans available under complete randomization. The example shows that the variance of these weighted adjusted estimates of the error sum of squares is greater over the constrained sets than is the variance of the unweighted estimates. One might find that the unweighted estimates are better when the criteria of unbiasedness and minimum variance are used collectively.

James Robert Gebert: "Tests of Goodness of Fit Based on Discriminatory Information." Ph.D. thesis. Iowa State University Library. February 1967.

In this thesis, the goodness of fit problem $H_0: F = F_0$ against $H_A: F \neq F_0$ is studied using four statistics based on sample spacings $\{V_i\}$ where $V_i = F_0(X_{(i)}) - F_0(X_{(i-1)})$ where $-\infty = X_{(0)} < X_{(1)} < X_{(2)} < \ldots < X_{(n)} < X_{(n+1)} = \infty$. Here F_0 is assumed to be a known distribution function and the null hypothesis is a simple one. Further, we assume that the underlying F belongs to $\mathcal{F}$, the class of all everywhere continuous distribution functions on R_1. The four statistics are:

1. Kimball's: $\sum_{i=1}^{n+1} v_i^r \qquad r > 0$

2. k: $-\sum_{i=1}^{n+1} \frac{\log V_i}{n+1} - \log (n+1)$

3. k*: $\sum_{i=1}^{n+1} V_i \log V_i + \log (n+1)$

4. J: $k + k^*$

k and k* are the two information statistics proposed by Kale (1965) and J is the divergence between the information indices k and k*.

The first two moments of these four statistics under the null hypothesis are found in Chapter 2. In Chapter 3, the asymptotic normality of these four statistics is proved under H_0. In Chapter 4, the power of these four test statistics is studied against Weiss' (1965) alternatives $F_n(X)$ where

$$F_n(X) = F_0(X) + \frac{1}{\frac{\delta}{n}} \int_0^{F_0(X)} r(y)\,dy$$

where $\int_0^1 r(y)dy = 0, \; | r''(y) | < D$ for $0 < y < 1$

and $\delta > 0$ positive. Greenwood's statistic (Kimballs' with $r = 2$) is shown to be optimum among these four statistics. Finally in Chapter 5, a small sampling experiment on the power of the four statistics is discussed.

Charles Kent Graham: "Comparison of Alternative Methods of Gathering Data for the Evaluation of the 1964 Census of Agriculture." M.S. thesis. Iowa State University Library. May 1967.

Whenever a complete census is attempted for a large population, many problems are encountered which can cause errors in the final results. The Evaluation Survey was an attempt to evaluate the accuracy of the 1964 Census of Agriculture for the following: (1) total number of farms, (2) total land in farms, and (3) total land from which crops were harvested.

This was done by carefully enumerating the agricultural operations in a large area sample and comparing these results with the results obtained in the regular Census of Agriculture enumeration. Whenever sizeable discrepancies occurred, these were investigated further in order to obtain the most accurate data possible. The Enumeration Survey and some experiments in gathering data conducted in the second phase (the reconciliation of discrepancies) are described.

Whenever discrepancies could be reconciled by the answers to a few simple questions, letters were sent to the farmers. This was an inexpensive method, but it was not felt to be as accurate as a personal interview. The accuracy of the letter responses was evaluated by comparing the letter results with the results obtained by personal interviews. It was determined that letter writing was a valuable method for gathering data for these cases when the results were properly interpreted.

An experiment was conducted to see if trained personnel could "resolve" discrepancies on the basis of the information available prior to the second field enumeration. It was determined that the accuracy of the first enumeration could be improved, but not enough to eliminate further field followup.

The final conclusions were: (1) letters should be sent to the farmers whenever there is a reasonable chance for an answer, (2) qualified personnel should attempt to reconcile differences prior to the second field enumeration, but the figures obtained should represent "improved" preliminary figures, and (3) a subsample of the cases involving discrepancies should be returned to the field for further enumeration.

Irving James Hall: "Contributions to the Theory of Symmetric Multiple Decisions." Ph.D. thesis. Iowa State University Library. November 1966.

A prototype of classical slippage problems with which the investigation is begun is as follows: It is assumed that there are a populations with densities $f(x;\theta_i)$ $(i = 1, \ldots, a)$. To test the hypothesis H_0: $\theta_1 = \ldots = \theta_a$ against a alternatives $H_i: \theta_1 = \ldots = \theta_i - \triangle = \ldots = \theta_a$ with a zero-one type of loss function where $\triangle > 0$, let D_i be the decision to accept H_i and $Pr(D_i \mid H_j)$ be the probability of taking D_i when H_j is true. The requirements that $Pr(D_0 \mid H_0) > 1 - \alpha$ where $\alpha \epsilon (0, 1)$ and $Pr(D_i \mid H_i)$ is independent of i are imposed, the first is called a size condition and the second a symmetry condition.

It seems that these two conditions have been regarded as being insufficient for ensuring an explicit solution and thus the condition of invariance on the test procedures was imposed.

The main purpose of the thesis is to discuss slip-

page problems without assuming the usual condition of invariance.

Development begins with a generalization of the Neyman-Pearson lemma to slippage problems. As in the case of hypothesis testing, this permits solving problems where the null hypothesis is simple and the alternatives are simple, and in some cases where the alternatives are composite. When the null hypothesis is composite, the generalization of the Neyman-Pearson lemma can be used in some cases to obtain a uniformly most powerful test by introducing an adequate least favorable probability distribution over the space of the null hypothesis. Applications of this technique are given.

Theorem two gives conditions for the existence of a uniformly most powerful test and for the monotonicity of power of the test.

One of the most important techniques in testing composite hypothesis is that of similarity and this is applied to obtain a theorem which gives an "optimum" test for distributions belonging to the exponential family. Applications of this theorem are given.

Paul Arvid Johnson: "Four and Five Level Designs for Discriminating between Quadratic and Exponential Models." M.S. thesis. Iowa State University Library. November 1966.

Designs for discriminating between the quadratic and the exponential response are examined using three criteria: (1) power, the probability, given the error variance, of rejecting the quadratic given that the response is exponential, (2) variance of the estimator of the parameter, α_2, in the exponential model, $y = \alpha_0 + \alpha_1 e^{\alpha_2 x}$, and (3) variance of the estimators of the parameters β_1 and β_2 of the quadratic model $y = \beta_0 + \beta_1 x + \beta_2 x^2$.

The major emphasis is on the power which is a monotone function of the sum of squares for deviations from regression of the quadratic fitted to the exponential points. The sum of squares for deviations from regression was calculated for all designs consisting of four and five points that are integer multiple of 0.10 on the interval $(0, 1)$. All designs were evaluated for a range of exponential parameter values. Only the designs yielding the better power were analyzed with respect to the variances of the estimated parameters.

The results are tabulated such that the five level designs are compared with the four level designs; the equally spaced designs are compared with the unequally spaced designs; and the better four level and the better five level designs are ranked.

The four level designs give a higher probability of rejecting the quadratic when it is false than do the five level designs. But of the designs with better power, the five level designs are generally better than the four level for estimating the parameters of the response surface. Several designs displayed "robustness" in that they had comparatively large sums of squares for deviations from regression and hence comparatively large power over a wide range of exponential parameters.

James Ralph Olin: "Numerical Investigation of Sequential Weight-Function Tests." M.S. thesis. Iowa State University Library. February 1967.

This thesis is concerned with the empirical evaluation of the performance of sequential tests with special emphasis placed on the effect of introducing concomitant information. The sequential procedures considered were the weight-function tests, designed to discriminate between two treatment means, described in detail by Roseberry (1965).

Monte Carlo procedures were used in the evaluation to obtain estimates of average sample numbers together with average Type I error rates for comparison with those specified. By comparing the results of the non-covariance test statistics with those that used covariance, it was possible to obtain some information on the effects of utilizing concomitant information. It was also shown that the distribution of sample number could be fairly well approximated by either the gamma or Weibull distributions.

Implementation of the weight-function tests was also considered in this thesis. A computer program was devised to calculate any one of the several sequential test statistics. Procedures have also been developed for using the test statistics in a simpler form in order to facilitate their computation on a desk calculator.

Hans Tijmen Schreuder: "Unequal Probability and Double Sampling in Forestry." Ph.D. thesis. Iowa State University Library. November 1966.

This is a report about the study of double sampling and unequal probability sampling and application of these techniques to problems in forest inventory.

The sampling aspects of point sampling are treated in the context of sampling with unequal probability, and the forestry application is considered. Some existing theory for single-phase point sampling is simplified and some new theory is added for point sampling with subsampling for volume estimation. Some suggestions are made for additional theoretical and practical work to be done in the area of point sampling with double sampling.

The sampling aspects and properties of Grosenbaugh's three-pee sampling procedure are discussed. The true variance and sample estimate of the variance of Grosenbaugh's "unadjusted estimate" are derived here. New methods are described for obtaining random samples from a population for which no list is available before sampling. Three-pee sampling is then compared with some alternate sampling plans (selection rules and estimators) that also permit the use of ocular estimates (of, for example, tree volume) in an efficient manner. Several questions are raised about the utility of three-pee sampling in certain applications.

Certain estimators are obtained for use in double sampling and their variances and estimated error variances derived where possible. The sampling schemes considered are double sampling with simple random

sampling at the first phase and sampling with p.p.s. with and without replacement at the second phase. Also, there is a discussion of double sampling with stratification, where information for both phases is collected simultaneously in the field.

Some of these methods of sampling are then applied to some populations of interest in forest inventory, and a numerical analysis is carried out using "Monte Carlo" methods. This numerical work constituted an exploratory study, but the computer program developed here should be useful for extending the study to other populations and estimators.

Mary Ann Smith: "Bayes Sequential Sampling Plans Under Control." M.S. thesis. Iowa State University Library. May 1967.

Consider a manufacturing operation producing discrete items which are grouped into lots of fixed size N. Let the lot quality distribution, $\Phi(p)$, be binomial with parameters N and π, the distribution under which lots are considered as random samples of size N from a theoretical infinite binomial process. The case of binomial lot quality is referred to as "statistical control" in the area of quality control and sampling inspection.

A. M. Mood showed in 1943 that, under control, the number of defective items in the sample and the number of defective items in the remainder-lot are independently distributed and thus concluded that sampling of lots drawn from a binomial population will provide no basis for inferences concerning the remainder of the lot. Barnard, motivated by Mood's theorem, suggested that when input to inspection is pure binomial, the optimum sampling scheme consists in no inspection at all.

Eisenberg (1959) verified Barnard's suggestion for linear loss function of special type; this thesis extends this verification to the general linear case, and shows that the suggestion is not correct in the quadratic case.

Nimnual Sriplung: "Design and Estimation for a Survey of Use of Soil Insecticides on Iowa Farms and Insecticide Residues in Milk." M.S. thesis. Iowa State University Library. February 1967.

In the spring of 1965, a sample survey of dairy farms was conducted for the purpose of analyzing insecticide residues in milk. The universe of interest consisted of farms with headquarters in the open country zone of Iowa, having an area of 10 acres or more, more than one milk cow, selling milk and/or cream, using soil insecticide on corn land and in operation during 1964.

Stratification by county was used with the number of segments drawn in each stratum proportional to its size. A systematic, cluster sample of segments was drawn in each stratum (county). Master sample materials and county highway maps were used to locate the sample segments.

For the purpose of estimation of population totals, the regression estimator using total farm acreage as the control variable was judged the best among the three different methods: mean per unit, ratio estimator and regression estimator. It was estimated that about 39 percent of the open country farms used soil insecticides.

Samples of milk and feed were taken from 194 dairy farms using soil insecticide. These samples were analyzed for insecticide residues. Among the six kinds of residue (i.e., Lindane plus BHC, DDE, DDD, DDT, Heptachlor plus Heptachlor epoxide and Dieldrin), Dieldrin was present in the greatest amount. The average concentration of Dieldrin in milk was .0037 ppm. on a per farm basis.

Ing-Tzer Wey: "Estimation of the Mean Using the Rank Statistics of an Auxiliary Variable." Ph.D. thesis. Iowa State University Library. November 1966.

In a finite population consisting of N elements represented by the pairs (x_{0i}, y_i), the pairs are arranged in increasing order of magnitude with respect to the auxiliary x-variables and the ordered pairs are denoted by $(z_i, y_{(i)})$, where z_i is the rank of x_{0i} in the population and $y_{(i)}$ is the observed value associated with the z_i-variable. Suppose that a simple random sample of size n is drawn without replacement from this population. Two types of estimators for the population mean $\overline{Y}$ are derived in this study, namely (i) Pseudo-post-stratified estimator:

$$\hat{Y}_{p}^{(r)} = \frac{n+1}{n(N+1)}\left[\sum_{h=2}^{m-1} w_h^{(r)}\bar{y}_h + \frac{r(N+1)}{n+1}(\bar{y}_1 + \bar{y}_m)\right]$$

where $w_h^{(r)} = \frac{1}{2}(z_{hr} + z_{hr+1} - z_{hr-r} - z_{hr-r+1})$

$$\bar{y}_h = \frac{1}{r}\sum_{i=1}^{r} y_{(hr-r+1)}$$

This estimator is obtained by dividing the population into m strata with respect to the z-variables after selection of the sample of size $n = mr$ and then applying the method of stratified estimation. This estimator is, in general, biased. (ii) Unbiased estimator:

$$\underset{k}{\hat{\bar{Y}}}_u = \frac{1}{kN}\sum_{i=1}^{n} v_1^{(k)} y_{(i)}$$

where $v_1^{(k)} = \sum_{j=1}^{k} \frac{1}{j}(z_{j+1} - 1)$

$$v_h^{(k)} = \sum_{j=h}^{k} \frac{1}{j}(z_{j+1} - 1) + 1 + \frac{1}{k-1}\sum_{j=2}^{h-1}(z_{k+j} - z_j - 1)$$

for $h = 2, \ldots, k$

$$v_{ki+h}^{(k)} = \frac{1}{k-1} \sum_{j=1}^{k-1} (z_{ki+h+j} - z_{ki+h-j})$$

for $i = 1, \ldots, m-1$; $h = 1, \ldots, k-1$

$$v_{n+1-h}^{(k)} = \sum_{j=h}^{k} \frac{1}{j} (N - z_{n-j}) + 1 + \frac{1}{k-1} \sum_{j=2}^{h-1} (z_{n+1-j} - z_{km-j} - 1)$$

for $h = 2, \ldots, k$

$$v_n^{(k)} = \sum_{j=1}^{k} \frac{1}{j} (N - z_{n-j})$$

This estimator is obtained by averaging k conditionally unbiased estimators which are each derived by fixing a different set of paired observations and then applying the method of stratified estimation.

In some populations, e.g. where the regression of y on z is bell-shaped and the sample size is large enough so that the bias in $\hat{\bar{Y}}_P^{(r)}$ can be ignored, the estimator $\hat{\bar{Y}}_P^{(r)}$ may be used since it is simpler to compute than the estimator ${}_k\hat{\bar{Y}}_u^{(r)}$ and its mean square error may be less than the variance of ${}_k\hat{\bar{Y}}_u$.

The estimator ${}_k\hat{\bar{Y}}_u$ is compared with Fuller's post-stratified estimator and the ordinary post-stratified estimator, and it is shown that the estimator ${}_k\hat{\bar{Y}}_u$ is slightly less precise than Fuller's estimator and more precise than the ordinary post-stratified estimator under the assumptions of a linear model and equal stratum sizes. These comparisons were all based on approximations to order of n^{-1}.

Hermann Wiedenhofer: "The Estimation of Equipotent Concentrations in Replicated Single-Subject Bioassays." M.S. thesis. Iowa State University Library. July 1966.

A procedure for the point and interval estimation of the equipotent concentration relationship in replicated single subject assays is derived. Estimates of the required parameters are obtained from within subject contrasts for which the appropriate variance is that within subjects. A numerical example of the procedure is presented.

Mohammed Yusuf-Mia: "Sampling Designs Employing Restricted Randomization." Ph.D. thesis. Iowa State University Library. May 1967.

In this study, three different situations and sampling designs are considered.

In the first situation, no information other than an arbitrary order of the finite population is known. A pseudo-systematic sampling procedure is suggested. In this procedure, the first $\frac{n}{2}$ elements are drawn systematically with period 2k (where n is the sample size, $N = nk$) and then one element is drawn at random from each of $\frac{n}{2}$ strata specified by the elements drawn systematically.

A detailed examination is made of the efficiency of the procedure. It is found that in the presence of linear trend the procedure is more efficient than simple random sampling but loses to stratified sampling with one element per stratum and to systematic sampling. In the presence of periodic variations, the procedure is more efficient than simple random sampling but less efficient than systematic sampling if k is an odd multiple of $\frac{1}{4}$ th of the periodicity. If k is an even multiple of $\frac{1}{4}$ the periodicity, the procedure gains over systematic sampling, but loses to simple random sampling. It is shown that in the presence of periodicity, the procedure tends to gain or lose to stratified sampling in those situations where it gains or loses to simple random sampling. An unbiased estimator of the variance is available for the procedure.

In the second situation, the elements are known to show monotonic or linear trend. Two systematic sampling procedures are considered. Both procedures divide the population into n strata and group the strata into $\frac{n}{2}$ groups such that in each group one stratum has elements in ascending order and the other in descending order. If the sample size is 2, the procedures become identical.

It is shown that under both procedures the within strata correlation is always zero or less than zero. As a result, the procedures are more efficient than stratified sampling with one unit per stratum. If the population consists of linear trend and a random component, the procedures can be simplified. It is shown that the variance for the linear component under the two procedures is zero for even sample size and $\frac{1}{n}$ times the variance of stratified sampling with one per stratum for n odd. For $n = 2$, the procedures are less efficient than stratified and systematic sampling, if autocorrelation is present and the correlogram is concave upward. Estimators of variance also have been considered.

In the third situation, two criteria are available for stratification with one of the criteria being dichotomous. A sampling design is developed and is shown to be particularly efficient if the cell means follow an additive model. The within strata variance component for the procedure is the same as for one-way stratification.

It is shown that the procedure is equivalent to Bryant, Hartley and Jessen's (1962) procedure, if the cell frequencies are proportional to the marginal frequencies. The between variance component in this case reduces to the interaction sum of squares. Further, if the cell means follow an additive model, the between variance

component is zero. An unbiased estimator of the variance is available.

Papers and Speeches

Papers presented at scientific and professional meetings reflect the research and activities of the Statistical Laboratory staff. Many of these papers will appear later in publications. Abstracts of papers often are published, and in such case references are given.

Florence Tetreault and **T. A. Bancroft:** "Inferences Concerning a Population Mean from a Single Sample Subsequent to an Outlier Test," at the anual meeting of the Institute of Mathematical Statistics, Rutgers, August 30-September 2. Abstract 59 in Annals of Mathematical Statistics, 38:2, 634, April 1967.

T. A. Bancroft: "Inference for Incompletely Specified Models," at the Mexican National Biometric Society Group meeting, Graduate College of the National School of Agriculture, Chapingo, Mexico, June 7.

H. T. David: "Goodness of Fit," at Pennsylvania State University, University Park, May 25.

Wayne Fuller and **Ing-Tzer Wey:** "Estimation of the Mean Using the Rank Statistics of an Auxiliary Variable," at meetings of the Biometric Society (ENAR), Institute of Mathematical Statistics (Eastern Region), American Statistical Association (Biometrics Section and Section on Physical and Engineering Sciences), Georgia Institute of Technology, Atlanta, April 3-5. Abstract 1300 in Biometrics, 23:2, 378, June 1967.

Wayne Fuller: "Statistical Analysis of Production Experiments," and "Problems in Data Collection by Sample Survey," seminars at Oklahoma State University, Stillwater, April 28.

Donald K. Hotchkiss: "Utilizing the Computer for Statistical Evaluation of Data," at a seminar on "Computers in Biological Research," Ames, January 10.

Donald K. Hotchkiss: "Biological Applications of Statistics," at a mathematics conference of the Iowa Council of Teachers of Mathematics, Marshalltown, March 11.

Donald K. Hotchkiss: "Statistical Evaluations of Entomological Problems," at meetings of the Entomological Society of America, East Lansing, Michigan, March 22-24.

David Jowett: "Breeding Bird Resistant Sorghum in East Africa," and "Sorghum Breeding in East Africa (H. Doggett and Jowett)," at the annual meeting of the American Society of Agronomy, Oklahoma State University, Stillwater, August 23-25.

B. K. Kale: "An Example in which the Preliminary Test of Significance Leads to a Uniformly Better Estimator," at the annual meeting of the Institute of Mathematical Statistics, Rutgers, August 30-September 2. Abstract 28 in Annals of Mathematical Statistics, 37:5, 1426-1427, October 1966.

B. K. Kale: "Test of Goodness-of-Fit Based on Information Indices," at Department of Mathematics colloquium, University of Alberta, Edmonton, Canada, November 15.

B. K. Kale: "On Pooling Sample Means," at the University of Manitoba, Winnipeg, Canada, March 27.

J. R. Gebert and **B. K. Kale:** "A Test of Goodness of Fit Based on Sample-Spacings," at meetings of the Biometric Society (ENAR), Institute of Mathematical Statistics (Eastern Region), and American Statistical Association (Biometrics Section and Section on Physical and Engineering Sciences), Georgia Institute of Technology, Atlanta, April 3-5. Abstract 19 in Annals of Mathematical Statistics, 38:3, 961-962, June 1967.

O. Kempthorne: "The Condensation of Data," the Sigma Xi local honor lecture, Ames, January 19.

O. Kempthorne: "Condensation of Data" and "The Aims of Data Analysis as Exemplified by Transformation Procedures," seminars at Colorado State University, Fort Collins, April 24-25.

O. Kempthorne: "Principles of Statistical Methodology for Data with Genetic Structure," at the International Conference on Cranio-facial Growth, Center for Human Growth and Development, University of Michigan, Ann Arbor, May 1-3.

O. Kempthorne: "The Future of Statistics Departments," a panel at a conference on the Future of Statistics, University of Wisconsin, Madison, June 7-9.

Edward Pollak: "Inbreeding in Subdivided Populations," a seminar at the Genetics Center, University of Minnesota, Minneapolis, October 28.

Edward Pollak: "The Limiting Behavior of a Branching Process," at meetings of the Biometric Society (ENAR), Institute of Mathematical Statistics (Eastern Region), and American Statistical Association (Biometrics Section and Section on Physical and Engineering Sciences), Georgia Institute of Technology, Atlanta, April 3-5. Abstract 1314 in Biometrics, 23:2, 384, June 1967.

Donna Ruhl and **J. Sedransk:** "Combining Information from Two or More Sample Surveys," at the central regional meeting of the Institute of Mathematical Statistics, Ohio State University, Columbus, March 23-25.

J. Sedransk: "Analytical Studies of Survey Data," a seminar at the University of Chicago, November 4.

J. Sedransk: "Designing Some Analytical Surveys," a seminar at the University of Wisconsin, Madison, April 27.

S. R. Srivastava and V. P. Gupta: "Inference for a Linear Hypotheses Model Using Two Preliminary Tests of Significances," at the annual meeting of the Institute of Mathematical Statistics, Rutgers, August 30-September 2.

Henry Tucker: "Statistical Consulting in the University," at joint meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics (Western Region), and the Western Farm Economics Association, Los Angeles, California, August 15-19. Abstract 1271 in Biometrics, 22:4, 958, December 1966.

James A. Walsh and Doris K. Penberthy: "An Examination of Situational Determinants of Retest Reliability," at the Midwestern Psychological Association meeting, Chicago, May 4-6.

Richard D. Warren: "Field Experiments in Sociology—Methodological and Statistical Implications," at the annual meeting of the Rural Sociological Society, Miami Beach, Florida, August 26-29.

Leroy Wolins: "Identifying the Hazardous Driver," at the annual meeting of the National Independent Statistical Service, Chicago, September 14.

Alyce Fanslow, Hester Chadderdon and **Leroy Wolins:** "An Instrument to Measure Women Students' Perceptions of their College Environments," at an American Educational Research Association meeting, New York City, February 18.

George Zyskind: "A Covariance-Like Analysis for Incorporating Extra Observations," at the annual meeting of the Institute of Mathematical Statistics, Rutgers, August 30-September 2. Abstract 58 in Annals of Mathematical Statistics, 37:6, 1861, December 1966.

George Zyskind and **Frank B. Martin:** "A General Gauss-Markoff Theorem in the Case of any Non-Negative Covariance Matrix of Observations," at the European meetings of statisticians, Imperial College, London, England, September 5-10. Abstract 15 in Annals of Mathematical Statistics, 37:6, 1862, December 1966.

George Zyskind: "Linear Models, Singular Covariance Matrices and Randomized Experiments," at a meeting of the Dayton Chapter, American Statistical Association, Dayton, Ohio, March 27.

George Zyskind: "On Methodologies and Connections in Partitioned Linear Models," at a meeting of the Statistics and Mathematics Groups of the Aerospace Research Laboratories, Wright-Patterson Air Force Base, Dayton, Ohio, March 28.

George Zyskind: "On Best and Simple Linear Estimation in Linear Models with Arbitrary Covariance Structure," a colloquium given as an NDEA visitor at the University of Missouri, Columbia, May 4-5.

PARTICIPATION IN PROFESSIONAL ACTIVITIES

Dr. T. A. Bancroft continues as a member of the Regional Advisory Board, Biometric Society, ENAR. He has been elected a member of the council of the International Biometric Society, and reappointed to the National Research Council, Division of Biology and Agriculture, as a representative of the Biometric Society, ENAR. He has also been named a member of the Committee on Affiliations of the Biometric Society.

Dr. Bancroft continues as a member of the American Statistical Association's Advisory Committee on Statistical Policy to the Bureau of the Budget. He also continues as organizer for the International Symposium on "Biometry and Statistics in Food, Population and Health Research."

Dr. Bancroft served as a panel member for the session on "Recent CUPM Recommendations for Basic Courses in Probability and Mathematical Statistics," at joint meetings of the American Statistical Association, Biometric Society (ENAR and WNAR), Institute of Mathematical Statistics (Western Region) and the Western Farm Economics Association, in Los Angeles August 15-19. He chaired a session on "Statistical Needs in a Changing Agriculture" at the American Farm Economics Association meeting at the University of Maryland, College Park, August 23-26.

On April 17 and 18, Dr. Bancroft was at Auburn University, Auburn, Alabama, to assist in the further development of a centralized statistical program at the University. He established a Statistical Laboratory at Auburn and served as its first director before coming to Iowa State in 1949.

Dr. Barry Arnold spent a week in July at a summer workshop on Temporal Processes in Behavior, at the University of California, San Diego. His trip was sponsored by the Mathematical Social Science Board of the Center for Advanced Study in the Behavorial Sciences.

Dr. Foster B. Cady was re-elected secretary of the Biometric Section, American Statistical Association, to serve until January 1968.

Professor C. Philip Cox served as a member of the Regional Advisory Board, Biometric Society, ENAR. He chaired a session on "Bioassay" at meetings of the Biometric Society (ENAR), Institute of Mathematical Statistics (Eastern Region), and American Statistical Association (Biometrics Section and Section on Physical and Engineering Sciences), Georgia Institute of Technology, Atlanta, April 3-5.

Professor Cox lectured at the 1966 Graduate Summer Session of Statistics in the Health Sciences at Yale University, June 27 through August 5. He taught a short course "Statistical Methods for Biological Assays" as a visiting summer faculty professor at Oregon State University, beginning June 20, 1967.

Dr. H. T. David continues on the organizing committee of the Visiting Lecturer Program sponsored by the National Science Foundation and the statistical societies.

Dr. David has been active during the year on Iowa State committees, serving on two standing committees: Annuities and Insurance, and University Academic Standards, and as chairman of the Scholastic Standards Committee of the College of Sciences and Humanities. He also has been a member of the ISU Daily publications board.

Dr. Donald K. Hotchkiss has participated in Career Day presentations during the year, including Rock Rapids on November 3 and Orange City on March 30. He continues as American Statistical Association faculty representative for Iowa State.

Dr. David V. Huntsberger has been busy with Iowa State committees, serving as a member of the nominating committee for the College of Sciences and Humanities, and on the Committee on Fellowships of the Graduate College. He is a member of the Executive Council of the Iowa State Chapter of Sigma Xi. Dr. Huntsberger also has continued serving as a member of the COPSS (Committee of Presidents of Statistical Societies) Career Brochure Committee.

Dr. Oscar Kempthorne is completing a two-year term as a council member of the Biometric Society, representing ENAR. He served again as a member of the American Statistical Association's Wilks Award committee.

Dr. Kempthorne continues as a member of the Human Adaptability subcommittee for the U.S. National Committee for the International Biological Program. He served as a discussant at the Institute of Mathematical Statistics annual meeting at Rutgers, August 30-September 2.

Dr. J. Sedransk, who has been vice-president of the Iowa Chapter of the American Statistical Association, was elected to the presidency for the coming year. Dr. Sedransk chaired a session at the Institute of Mathematical Statistics central regional meeting at Ohio State University, Columbus, March 23-25.

Donald J. Soults attended the fall Joint Computer Conference at the Civic Center, San Francisco, November 7-11. The program was planned to evaluate new computer techniques, especially concerning mathematical programming, and applications.

Dr. Henry Tucker is the international treasurer of the Biometric Society. He and Dr. Foster Cady, serving in Mexico on the Chapingo project, assisted with the organization of 20 members-at-large of the Biometric Society who have petitioned to be recognized as the National Group of Mexico of the Biometric Society.

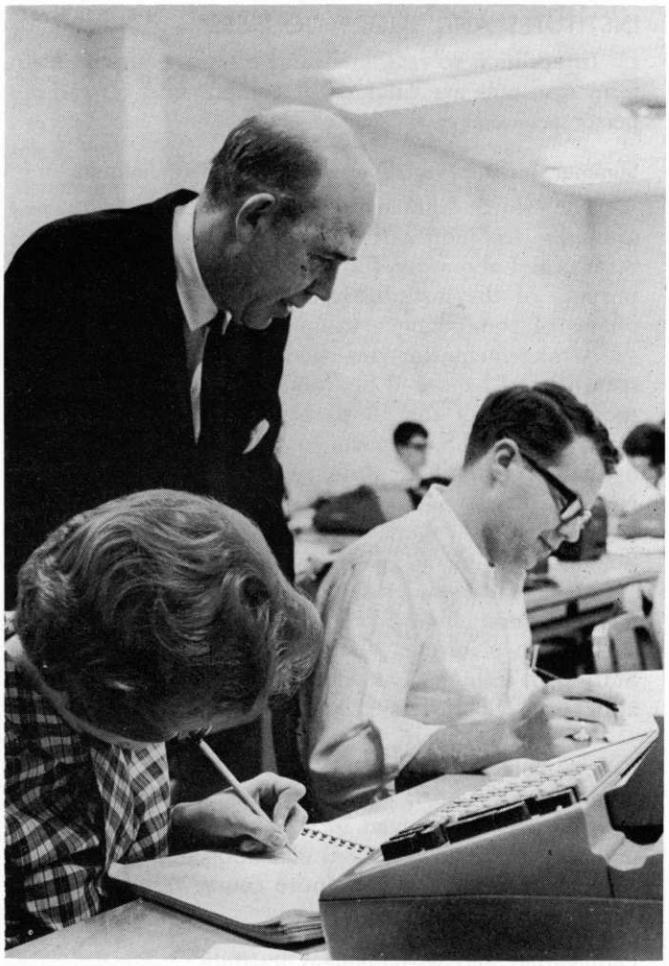
Dr. Richard D. Warren served as a discussant at the section on "Illustration of Cross-Cultural Research Methodology," at the annual meeting of the Rural Sociological Society, Miami Beach, Florida, August 26-29.

Dr. Leroy Wolins attended the American Psychological Association meeting in New York City, September 2-5, and the spring meeting of the Psychometric Society in Madison, Wisconsin, March 29-April 1.

Dr. George Zyskind served on the program committee for the annual meeting of the Institute of Mathematical Statistics at Rutgers, August 30-September 2.

Newly elected members of Sigma Xi, honorary society of pure and applied research scientists, include Dr. Irving J. Hall, Dr. David Jowett and Dr. Leroy Wolins as full members, and James C. Blinn, Leon F. Burmeister, Ralph E. Folsom, Jr., and James R. Olin as associate members.

As the Department of Statistics in the College of Sciences and Humanities reached its 20th anniversary (it was organized officially in 1947), enrollment continued to break all records. Last year's record high of 1157 students studying statistics during spring quarter was topped winter quarter with 1294 students and again in the spring, with 1397. The increase can be attributed both to an increase in statistics majors, seeking the degrees of bachelor of science, master of science and doctor of philosophy, and to a substantial rise in the number of non-majors seeking statistical training. Many other departments now require students to take one or more statistics courses, so that they will be better equipped to conduct and interpret research in their own fields. At all levels, the program in statistics is designed to emphasize the close relationship between sound application and modern statistical theory.



Dr. David Huntsberger, undergraduate advisor, checks on the progress of students in the machine laboratory. He wrote their text, Elements of Statistical Inference, *the second edition of which was published this year.*

Each statistics major is built around a common core of courses in theory and methods, with other courses chosen to fit the individual student's background and interests. A joint major program may be arranged between statistics and agriculture, biology, computer science, economics, engineering, entomology, genetics, mathematics or psychology.

COURSE OFFERINGS IN STATISTICS

The courses offered by the Department of Statistics during the academic year 1966-67 were as follows:

Courses for Undergraduate Students Only

201,	Principles of Statistics	5	FWS*	DeGracie, Fuchs
201A,		3	WS, SS_1	Conn, Hall
201B		3	FS	Conn, Mensing
327	Elementary Business Statistics	3	F	Fuchs
341,	Introduction to Theory	3	F	Huntsberger
342,	of Probability and	3	W	Huntsberger
343	Statistics	3	S	Huntsberger
380	Statistical Applications of Digital Computers	3	FWS	Carney, Jespersen, Kennedy, Mexas

Courses for Graduate Minors and Undergraduates

401,	Statistical Methods for Research Workers	4	FW, SS_1	Conn, DeGracie, Fuchs, Hotchkiss, Jowett, Mensing, Thomas, Walsh, Warren, Wolins
402		4	SS_2WS	DeGracie, Fuchs, Hotchkiss, Jowett, Mensing, Thomas, Walsh, Warren, Wolins
411	Experimental Design for Research Workers	3	S, SS_1	Huntsberger, Jowett
421	Survey Design for Research Workers	3	SS_2, S	Aggarwal, Baker, Fuller
431	Elementary Statistical Quality Control	3	S	Carney
446,	Statistical Theory for	3	F	Conn
447,	Research Workers	3	W, SS_1	Huntsberger
448		3	SS_2, S	Han, Huntsberger
480,	Processing of Statistical	2	F	Mosier
481,	Data	2	W	Mosier
482		2	S	Mosier

499	Special Problems	Arr.	SS_2, FWS SS_1	Huntsberger, Jowett, Soults, Strand, Warren
499A	Non-parametric Methods	4	F	Wolins

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	Walsh
511,	Design of Experiments	3	W	Kempthorne
512		3	S	Zyskind
521,	Design of Surveys	3	W	Sedransk
522		3	S	Sedransk
531	Industrial Statistics: Sampling Inspection	3	F	David
532	Industrial Statistics: Design of Experiments	3	S	David
535	Biological Statistics	3	S	Cox
536,	Genetic Statistics	3	F	Pollak
537		3	W	Pollak
538	Econometric Statistics	3	F	Fuller
539	Operations Research	3	W	Thomas
540	Operations Research Methods and Economic Analysis	3	S	Sengupta
541,	Theory of Probability	3	F	Arnold
542,	and Statistics	3	W	Arnold
543		3	S	Arnold
580	Computational Techniques in Statistics: Methods	3	W	Carney
581	Computational Techniques in Statistics: Theory	3	S	Kennedy
599	Special Topics	Arr.	SS_2, FWS SS_1	
	A. Theory			Bancroft, David, Fuller, Huntsberger, Kale, Thomas
	B. Methods			Bancroft, Carney, Walsh, Wolins
	C. Design of Experiments			Hotchkiss, Kempthorne, Zyskind
	D. Design of Surveys			Fuller, Sedransk, Strand

Courses for Graduate Students, Major and Minor

601	Advanced Statistical Methods	3	F	Cox
608	Seminar on Statistical Methods	3	W	Cox
611,	Advanced Design of Experiments	3	W	Zyskind
612		3	S	Kempthorne
622	Seminar on Design of Surveys	3	S	Sedransk
641	General Theory of Linear Hypothesis	3	F	Zyskind
642	Probability and Distribution Theory	3	W	Kale
643	Theory of Estimation and Testing of Hypotheses	3	S	Kale
646	Time Series	3	S	Fuller
647	Multivariate Analysis	3	F	Kudô
648	Seminar on the Theory of Statistics and Probability	3	SS_2	Arnold
649	Recent Developments in Probability and Statistics	3	SS_1	Kale
649A	Seminar on Stochastic Processes in Genetics	3	SS_1	Pollak
699	Research	Arr.	SS_2, FWS SS_1	Aggarwal, Arnold, Bancroft, Cady, Carney, Cox, David, Fuller, Hotchkiss, Kale, Kempthorne, Kudô, Pollak, Sedransk, Thomas, Walsh, Wolins, Zyskind

* Because the fiscal year began July 1, 1966, and ended June 30, 1967, the courses taught in the second summer session of 1966 through the first summer session of 1967 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.

INSTITUTES AND SHORT COURSES

In addition to regular course offerings, special short term institutes are offered for campus and off-campus personnel.

Summer Institute on Survey Sampling Techniques

The third annual summer institute on survey sampling techniques for foreign students met at the Statistical Laboratory July 18 through August 25. The purpose of the institute is to train participants in all phases of conducting a sample survey.

Arrangements for this special summer program are spearheaded by the U.S. Bureau of the Census, which sponsored 13 of the 18 participants. Four were sponsored by the U.S. Department of Agriculture and one by the Food and Agriculture Organization of the United Nations. Countries represented included Afghanistan, Ecuador, Korea, Malawi, Nepal, Nicaragua, Pakistan, Sudan, Thailand and Turkey.

Most of the students' time was spent working on a demonstration survey program under the supervision of Professor Norman V. Strand, and personnel of the Statistical Laboratory's Survey Group. Roy Hickman and Hazel Cook assisted with the institute.

The group heard lectures on various areas of statistics, including a short course in sampling statistics taught by Dr. Om P. Aggarwal and Dr. J. H. Sedransk. Orientations were given in the areas of Iowa business and industry and vocational education in Iowa. Participants who completed the entire course received certificates from Iowa State.

Engineering and Management Institute

For the seventh year, the Statistical Laboratory joined with Engineering Extension and the Department of Industrial Engineering to sponsor an institute on quality control, with the State Department of Public

Instruction cooperating. This year's program, Quality Control: Economics, Organization and Techniques, was held May 18 and 19 in the Memorial Union.

Once again Dr. E. J. Carney chaired the planning committee, and Dr. H. T. David served as a committee member. During the program Dr. Wayne Fuller discussed "Sampling Techniques for Polls and Surveys," and Dr. David Thomas spoke on "Sequential Sampling."

The conference dealt with underlying principles of quality control, with particular emphasis on acceptance sampling. In addition, problems of cost and organization were considered. It was planned for persons having responsibility for organizing and planning quality control, as well as those wishing a wider perspective of the field.

GRADUATE STUDENTS

The number of graduate students enrolled in statistics continues to rise. There has been more than a 40 percent increase in candidates for the M.S. degree since last year's annual report.

Ph.D. Candidates

Munir Ahmad
Leon Burmeister*
Alfonso Carrillo
Edward J. Carney
Leroy Edward Carver
Patricia Conn
James S. DeGracie
K. T. deGraft-Johnson*
Thomas Fears
James Gebert
Irving Hall
John W. Hazard
John Johnson
Leon Jordan
William Kennedy
Roland Loup
Richard Lund
Frank B. Martin
Donald McElhone
Ahmed Memon
Richard Mensing
John Meyer
Kenneth Mount
Syed T. M. Naqvi
Esmat Nouri
Panagiotis Papaioannou
Martin Rosenzweig
Carl Z. Roux
Donna J. Ruhl
Ahmed Salem
Charles Sampson
Hans Schreuder
Justus Seely
V. B. Solomon
Donald Soults
James Veale
Ing-Tzer Wey
Franklin Wolf
Mia Mohammed Yusuf

* fall quarter M.S. graduates

M.S. Candidates

Joseph Abbey
Farrukh Ahmad
Forrest Aspengren
Joe Atkinson
Sorachai Bhisalbutra
James Blinn
Gordon Booth
Nell Bruner
Leon Burmeister
Richard Chamberlain
K. T. deGraft-Johnson
Sharon Earley
Gregory Fawcett
Ralph Folsom
Richard Frauendorfer
Charles K. Graham
Robert Gray
Omar Henriquez
James Immordino
Carey Isaki
Louis Jensen
Paul A. Johnson
Sue Rowe Johnson
Khadija Khatun
John Lake
Mark Malone
Ronald Mead
James Mellon
Abel Mexas
Mallika Mokkhaves
Lindsey Murdah
Peter O'Brien
James Olin
C. M. Patel
David Pyne
Bonnie Roberts
MaryAnn Smith
Douglas Splitstone
Vincent Sposito
Nimnual Sriplung
Eric West
Hermann Wiedenhofer
James Wigton
Arlette Urguelles

With the addition of Dr. E. J. Carney, the graduate faculty included 21 statistics staff members during the year. Those serving as full members were Dr. Aggarwal, Dr. Bancroft, Dr. Cady, Professor Cox, Dr. David, Dr. Fuller, Dr. Kempthorne, Dr. Sedransk, Dr. Wolins and Dr. Zyskind. Associate members were Dr. Arnold, Dr. Carney, Dr. Fuchs, Dr. Hotchkiss, Dr. Huntsberger, Dr. Jowett, Dr. Pollak, Dr. Thomas and Dr. Warren. Dr. Kale and Dr. Kudô served as honorary members.

A survey conducted at the end of winter quarter indicates that professors continue to be busy serving on graduate committees for students with minor and supporting work in statistics, as well as for graduate students majoring in statistics. During fall and winter quarters the staff served on approximately 100 committees of students who took their final examinations during this time. Professors who served on five or more graduate committees of candidates who had their final exams during these two quarters included Dr. Bancroft, Dr. David, Dr. Fuller, Dr. Hotchkiss, Dr. Pollak, Dr. Walsh, Dr. Wolins and Dr. Zyskind.

Degrees Granted and Positions Taken

Titles and abstracts of theses written as partial fulfillment of the requirements for advanced degrees during the 1966-67 fiscal year appear in the publications section of this report. The students who were graduated and their location after graduation are listed here.

Recipients of the Ph.D. Degree

Edward John Carney (February 1967, under Oscar Kempthorne) remained in his position as an assistant professor with the Statistical Laboratory. He has accepted a position as associate professor of computer science at the University of Rhode Island.

James Robert Gebert (February 1967, under B. K. Kale) remained at Iowa State as a postdoctoral NIH trainee.

Irving James Hall (November 1966, under Akio Kudô) remained at Iowa State as a research associate-instructor. He has accepted a position with the Sandia Corporation in Albuquerque, New Mexico.

Hans Tijmen Schreuder, joint forestry-statistics (November 1966, under J. H. Sedransk) joined the faculty of North Carolina State University as a research instructor in forest management and experimental statistics.

Ing-Tzer Wey (November 1966, under Wayne Fuller) returned to National Taiwan University, Taipei, Taiwan.

Mia Mohammed Yusuf (May 1967, under Wayne Fuller) returned to his position with the Government of East Pakistan.

Recipients of the M.S. Degree

Joe Dean Atkinson (May 1967, under Oscar Kempthorne) accepted a position as associate statistician with the Upjohn Company, Kalamazoo, Michigan.

James C. Blinn (November 1966, under W. J. Hemmerle) joined Bell Telephone Laboratories as an associate member of the technical staff, Statistics and Data Analysis Research Department.

Nell Kincaid Bruner (February 1967, under B. K. Kale) was married and continued teaching as a graduate assistant in statistics until the end of the school year.

Leon Forrest Burmeister (November 1966, under Wayne Fuller) remains at Iowa State, working toward his doctorate.

K. T. deGraft-Johnson (November 1966, under J. H. Sedransk) remains at Iowa State working toward his doctorate.

Ralph Edward Folsom, Jr. (November 1966, under Donald Hotchkiss) is working toward his doctorate at the University of North Carolina.

Charles Kent Graham (May 1967, under Wayne Fuller) is employed as a civil service statistician at Hill Air Force Base, Ogden, Utah.

Paul Arvid Johnson (November 1966, under Wayne Fuller) is working toward his doctorate at Pennsylvania State University.

James Ralph Olin (February 1967, under C. Philip Cox) accepted a position as a systems and programming technician with the Upjohn Company, Kalamazoo, Michigan.

MaryAnn Smith (May 1967, under H. T. David) will become a statistician with the Shell Oil Company at the Houston Data Service Center.

Nimnual Sriplung (February 1967, under Wayne Fuller) returned to her position as chief of the Transfer Payments Section, Thailand Government Savings Bank.

Hermann Wiedenhofer (July 1966, under C. Philip Cox) returned to Venezuela where he was employed by the Veterinary Research Center.

The George W. Snedecor Award in Statistics

Winner of the 1967 George W. Snedecor Award was Irving J. Hall, who came to Iowa State as a graduate assistant in 1964 and was promoted to an associate-instructor in September. He is the 15th winner of the Award, given annually to the most outstanding candidate for the Ph.D. degree in statistics at Iowa State, in honor of Professor George W. Snedecor.

UNDERGRADUATES

The enrollment of undergraduates majoring in statistics has increased to such an extent that it became necessary to appoint an additional undergraduate advisor. Dr. D. V. Huntsberger continued in this post, advising about 45 students, the same as last year. He was joined by Dr. D. K. Hotchkiss, who advised an additional 12 students.

The first statistics major to participate in Iowa State's honors program, James Schuttinga, was graduated in May. The honors program is designed to give students with high ability the widest range of opportunity, corresponding to the needs, interest and aptitudes of the individual student. It is available to students with a 3.5 or above cumulative grade point, and permits them to take advanced courses and participate in special projects. Schuttinga, who was graduated with distinction, ranked 9th in the College of Sciences and Humanities. He was initiated into Phi Kappa Phi, the scholastic honorary. Dean Harvey also graduated with distinction, indicating an average of 3.5 or better.

The number of students receiving B.S. degrees increased 260 percent over last year.

Recipients of the B.S. Degree

Mohamed Yusuf Artan (August 1966)
Dennis Askvig (May 1967)
Richard Chapman (July 1966)
Roger Cook (February 1967)
Lester Hampton (May 1967)
Dean Harvey (May 1967)
Yunyong Hongsakaphadana (May 1967)
Joseph A. Kaled (August 1966)
Russel Powers (May 1967)
Carol Sees (May 1967)
Jan Shoemaker (May 1967)
Sandra Thompson (May 1967)

Iowa State University Statistics Club

The Statistics Club for undergraduate statistics majors began the year with a fall picnic, presented four professional programs and a field trip, and planned the statistics open house display for Veishea. The Veishea display won, for the third year, first place in the physical sciences division of the College of Sciences and Humanities, and was then, for the first time, named first in the entire College of Sciences and Humanities.

New officers of the Statistics Club for 1967-68 are: Sharon Burr, president; Mike Mersch, vice president; Sue Ritchie, secretary; and Larry Kinyon, treasurer. Dr. Carol Fuchs and Dr. D. K. Hotchkiss are faculty advisers.

SEMINARS

Statistical Laboratory-Department of Statistics Series

Once again weekly seminars were sponsored by the Statistical Laboratory and the Department of Statistics, featuring talks on current staff and graduate research projects and on more general developments in particular areas of statistics, followed by informal discussion. These seminars are offered on a non-credit basis and are open to students and faculty from other departments on the campus.

Dr. David Thomas headed the seminar committee for 1966-67, with Dr. Barry Arnold and Dr. David Jowett. The topics and speakers for the year's program included:

Summer 1966

July 14 Testing the Homogeneity of a Set of Correlated Variances. Chien-pai Han, Harvard University.

July 28 Limit Laws for Record Observations. Marcel Neuts, Purdue University.

Fall Quarter 1966

September 14 Statistics—Current Status and Outlook. T. A. Bancroft.

September 21 Computer Oriented Statistical Techniques. E. J. Carney.

September 28 Negative Estimates in Nested Designs. Fred Leone, University of Iowa.

October 5 Ratio and Regression Estimators as Minimax Procedures for Estimating the Mean of a Population. Om P. Aggarwal.

October 12 A General Gauss-Markov Type Theorem in the Case of Any Non-Negative Covariance Matrix of Observations. George Zyskind and F. B. Martin.

October 19 Predicting at Random, on film. David Blackwell, University of California, Berkeley.

October 26 Computer Simulation of Responses to Personality Test Items. James Walsh.

November 2 Multivariate Test of Normal Mean with Restricted Alternative Hypothesis. Akio Kudô.

November 9 Slippage Problems. Irving Hall.

Winter Quarter 1967

December 1 (meeting of Iowa Chapter, American Statistical Association, in Ames) A Framework for Studying Robustness in Estimation. David L. Wallace, University of Chicago.

December 7 The Examination of an Unknown Function Over an Interval. Oscar Kempthorne and Leon Jordan.

December 14 Unequal Probability Sampling of Comparative Studies. Leon Burmeister.

January 4 Inbreeding in Subdivided Populations. Edward Pollak.

January 11 Exact Finite Sampling Distributions of Estimators and Test Statistics Associated with a

Dynamic Simultaneous Equations Model. Robert J. Rohr, Purdue University.

January 18 Some Applications of Statistics to Microbiological Problems. Hans Thöni.

January 25 Measurement of Sociological Variables. Richard D. Warren.

February 1 Unequal Probability and Double Sampling in Forestry. K. D. Ware and J. H. Sedransk.

February 8 Some Aspects of Minimum Variance Unbiased Estimation. Joseph L. Abbey.

February 15 Some Sample Designs Employing Restricted Randomization. Mia Mohammed Yusuf.

Spring Quarter 1967

March 8 Tests for Linear Models Based on Ranks. K. L. Mehra, University of Alberta.

March 15 On Henderson's Methods of Estimating Variance Components. S. R. Searle, Cornell University.

March 22 Goodness of Fit Tests Based on Discriminatory Information. James Gebert.

March 29 Estimation of the Mean Using Order Statistics of an Auxiliary Variable. Wayne Fuller.

April 5 Economic Aspects of Acceptance Sampling Under Control. MaryAnn Smith.

April 12 Invariance in the Normal and Wishart Distributions. Morris L. Eaton, University of Chicago.

April 17 (joint Statistical Laboratory and Department of Economics) Testing Statistical Hypotheses in Econometrics. R. L. Basmann, Purdue University.

April 19 Generalized Polykays. E. J. Carney.

April 21 (informal seminar) Embedding of Orthogonal Arrays. S. S. Shrikhande, University of Bombay.

April 24 (meeting of Iowa Chapter, American Statistical Association, in Des Moines) Statistical Applications in Reliability. Frank Proschan, Boeing Scientific Research Laboratories.

May 3 International Statistical Programs of the Census Bureau. Milton Lieberman, Bureau of the Census. The Development and Operation of the Statistical Training Center, Ankara, Turkey. Yasar Yaser, Turkish State Institute of Statistics.

May 11 (meeting of Iowa Chapter, American Statistical Association, in Ames) On a Subjectivistic Bayesian View of Sampling Finite Populations. William Ericson, University of Michigan.

May 17 Pooling Regression and a Statistical Outlier Methodology for Lines. John P. Johnson.

Applied Statistics Series

A new series of bi-weekly seminars was originated by the Statistical Laboratory this year, planned especially for research workers from various substantive fields who use inferential statistics as a primary research tool. Topics included statistical aspects of current research and recent developments in statistical methods. Dr. D. K. Hotchkiss was chairman of the seminars, assisted by Dr. David Jowett and Dr. Leroy Wolins from the Department of Statistics, Dr. Richard Willham, Department of Animal Science and Dr. Geitel Winakor, Department of Textiles and Clothing. The following seminars were presented:

September 27 The Role of Statistics in Research at Iowa State.

October 11 Experimental Error in Swine Nutrition Experiments. Virgil Hays.

October 25 Statistical Comparisons. David Jowett.

November 8 Variance in Physicians Attributable to their Specific Educational Experiences: A Problem in Confounding. Edwin B. Hutchins, Association of American Medical Colleges.

December 13 Inference from Multiple Regression Procedures Based Upon Random Independent Variables. Leroy Wolins.

January 10 Industrial Property Life Analysis. Harold Cowles.

January 24 Farm Business Record and Analysis Systems of Iowa Farm Operators—An Example of Area Sampling. Roy Hickman.

February 7 The Aims and Methods of Transformation of Data. Oscar Kempthorne.

March 14 Variance Components: Some Introductory Remarks: S. R. Searle, Cornell University.

March 28 Use of Components of Variance in Animal Breeding. Gene Freeman.

April 11 Computing Variance Components. D. Dal Kratzer.

April 25 Variance Components in Psychology: Concepts and Misconceptions. James Walsh.

Quantitative Genetics Series

Staff members and graduate students from the departments of statistics, genetics, animal science, poultry science, agronomy and horticulture participate in seminars held regularly on topics in quantitative genetics. Dr. Oscar Kempthorne and Dr. Edward Pollak were in charge of arranging the series, which included:

October 11 Population Growth and Malthusian Parameters. Edward Pollak.

October 25 A Comprehensive Breeding System. Steve Eberhart.

November 8 Fisher's Fundamental Theorem of Natural Selection. Oscar Kempthorne.

December 6 Report on Summer Institute on Quantitative Genetics. Richard Willham and Frances Ward.

January 10 Some Theoretical Aspects of Selection as Applied to Members of Biological Groups. Bruce Griffing, Ohio State University.

January 24 Genetic Advance from Inter-line Selection in Poultry. Arne Nordskog.

March 14 Comparisons of Progeny Testing with Other Methods of Evaluation. S. R. Searle, Cornell University.

April 4 The Simulation of Quantitative Characters by Genes with Biochemically Definable Action (Preliminary studies). W. Seyffert, University of Tübingen, Germany.

April 11 The Analysis of Linkage Data in Tetrasomic Species. Henry Bennett, Ohio State University.

April 12 A Class of Enumerations in Genetics. Henry Bennett, Ohio State University.

FORD FOUNDATION MEXICAN PROJECT

The Statistical Laboratory has played an active role this year in the cooperative project with the Statistics Center at Chapingo, Mexico, sponsored by the Ford Foundation.

Dr. Foster Cady is currently serving as local administrative officer on the project for both statistics and economics, after replacing Dr. Lehman B. Fletcher, Department of Economics, in this role on September 1. Dr. T. A. Bancroft and Dr. Earl Heady continue in overall charge of the joint program at ISU, representing statistics and economics, respectively. Dr. J. B. Page, vice president for research, continues as administrative coordinator.

El Centro de Estadistica y Calculo del Colegio de Post-Graduados at Chapingo was established under the leadership of Dr. Basilio Rojas who has left for other employment. Dr. Eduardo Casas returned in March from North Carolina State to assume the directorship. He is presently engaged in strengthening the masters program and the computing service, coordinating certain aspects of the undergraduate program and developing a consulting service for users in different research areas. During June, Drs. Bancroft and Page visited Chapingo for a review of the project and a discussion of the long range plans for the Statistical Center.

Both Dr. Cady and Dr. Henry Tucker are on the teaching staff at the Statistical Center. Classes are conducted in Spanish and course offerings have included: statistical methods and theory, experimental design, survey sampling, econometric statistics, a users course in computer programming, advanced calculus and matrix algebra.

A three semester master's program has been developed, permitting the selection of a thesis topic during the first year of study so that advanced courses and thesis preparation can be integrated during the second year. Two Chapingo students have completed research for M.S. degrees at the Iowa State campus. Sigifredo Romero has been awarded his degree at Chapingo and is now on the statistical staff there. Alfonso Carrillo has returned to Chapingo for his final examination and will then continue as a doctoral candidate in statistics at Iowa State. His masters' research was directed by Dr. Barry Arnold and Dr. T. A. Bancroft. Plans are being made for two others to start their doctoral training this fall.

A sincere effort has been made to promote an environment whereby the graduate student feels the necessity to integrate thesis research with his total program. Six students are presently actively working on thesis projects. A range in topics includes the use of generalized inverses in analysis of data, the development of a modified approach to teaching statistical methods and multi-stage sampling procedures for agricultural surveys in Mexico. Thesis topics have been tied together directly with statistical problems present in actual ongoing experimental situations. Examples are: design of a four-stage sample in preharvest estimates of wheat yields, analysis of incomplete block designs with check varieties appearing in each block, and comparison of response surface designs when the true model is uncertain.

Both Drs. Cady and Tucker have worked with Dr. Reggie Laird of the International Corn and Wheat Center on research involving bias in estimating response surfaces when fitting alternative models and the influence of design criteria in reducing bias. Another joint research project with Dr. Laird involves the development of a procedure for the analysis of combined experiments with a number of measured, but not controlled, location variables.

A program of statistical consulting has been established for personnel from the Instituto Nacional de Investigaciones Agricolas, the research arm of the Secretary of Agriculture, and for graduate students, faculty members and others who seek assistance. The Statistical Center does not have the history that Ames has of experimenters using the consulting services in the planning and analysis of experiments and surveys. Endeavors have been made to increase the opportunities for assistance through seminars, organized consulting sessions and informal interchanges.

Examples of the type of consulting activities are a greenhouse study of the interactions between alfalfa residue and fertilizer with emphasis on the question of using an experimental error term from a similar experiment at a different time of the year, or using an error arising from higher order interactions, and a laboratory work investigating the relationship between available soil water and level of organic matter as influenced by other physical factors. The latter work involved a multiple regression analysis with correlated variables. Assistance was given in the analysis of a ration experiment with laying hens involving unequal and disproportionate numbers and in the combined analysis of a fertilizer experiment on alfalfa over the years when the experimental plots remained the same from year to year.

Another project attempted to find the factors influencing phosphorous soil tests and the criterion for selection of the most suitable test. In pathology, one study involved the effect of radiation level on survival.

Other examples of some of the year's consulting activities include the preparation of a sampling plan to estimate present and future production of citrus in Mexico, and an analysis of survey data on T.B. infection in cattle in Mexico and a study of locust migration. A computer program for the analysis of the international wheat trials is nearly completed.

Dr. Tucker has been working with the staff at Chapingo to improve the organizational procedure for the computation center, which operates a 1620 computer. Recommendations have been submitted concerning the training of personnel, the flow of data and the physical facilities. Short courses have been offered twice during the year for users of the computation facilities from the Instituto Nacional de Investigaciones Agricolas, which has moved to new offices in Chapingo.

A one-year program for people involved in the 1970 agricultural census will begin next year. Personnel in the program will be enrolled in statistics courses and will devote part of next summer to a special field exercise in survey sampling.

Plans have also been made to present a series of conferences and to conduct a survey on the use of statistical methods, including experimental designs, in agricultural research at the regional experiment stations. Work will begin on the project this summer.

Drs. Donald Hotchkiss and Richard Lund have joined the Iowa State staff in Chapingo, where they will be on assignment during the year ahead.

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