COMPUTER PROGRAM FOR ANALYZING
PARASITOID-Host
OR PREDATOR-PREY RELATIONSHIPS

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Abstract

A computer program is available for analyzing experimental data from parasitoid-host or predator-prey studies. The analysis indicates how and to what extent a natural enemy disperses, destroys hosts, and reproduces relative to the point of release. This program may be utilized for experiments conducted in open fields, field cages, greenhouses, and in the laboratory. It is written in Fortran IV and is currently being run on an IBM 370 Model 165 computer.

Computers are best suited for analyzing large quantities of data because they can perform an analysis faster, cheaper, and with an unequaled degree of precision and detail. Today, many of the computer programs available for data analysis are general statistical packages (Dixon 1973, Nie et al. 1970, Service 1972) which may not be specific enough to satisfy the needs of the entomologist. In addition, most entomologists are unfamiliar with the techniques involved in computer programming.

The computer program discussed herein has been designed specifically for the entomologist and is generalized enough to accept experimental data from studies conducted in open fields, field cages, greenhouses, and within the laboratory. The principal objective of the program is to provide the entomologist with a very thorough and concise analysis of his experiment. The object of the analysis is to show how and to what extent a natural enemy disperses, destroys hosts, and reproduces relative to the point of release.

Original Purpose and Applications

The program was written to provide an arithmetical analysis of field cage studies made with the egg parasitoid, Trichogramma (Ashley et al. 1973, Ashley et al. 1974). Each field cage covered four 10-ft rows of cotton. Eight stations were located equidistant down every row, and at each station host eggs were artificially fastened to the cotton plants. The Trichogramma were released from a container placed on the ground in the center of the cage. The hosts were removed 3 1/2 days later and taken back to the laboratory where the number of eggs parasitized as well as the number and sex ratio of the progeny emerging from the parasitized eggs were determined. Thus, for each of the 32 stations within a field cage we could determine (1) whether or not the station had been found (i.e. if 1 or more hosts were parasitized), (2) the number of hosts parasitized at each station, and (3) the number and sex ratio of the progeny produced. Each treatment usually consisted of 3 or 4 field cage replicates. The computer analyzed each field cage separately and then combined the data from all the cages within the treatment to produce a treatment summary.

The program is easily adapted to other experimental situations in which the replicate design meets the described specifications. Besides field cages, this
program will analyze open field and greenhouse experiments as well as searching or ovipositional studies carried out within or outside the laboratory.

Maximum utilization of the program is achieved in experimental situations where hosts are placed at specific locations (stations) and collected after exposure to parasitoids. However, it is quite feasible to use the program to analyze studies with predators where only the amount or number of hosts destroyed at each station is recorded and no information on progeny production is available.

**Limitations and Card Punching**

Modifications were made to increase the size and variability of a replicate and to generalize the program so it would accept data from other types of studies. The size of a replicate has been increased from 4 rows with 8 stations/row to 10 rows with 10 stations/row (Fig. 1A). A minimum of 2 rows and 2 stations/row is required in each replicate. The replicate design may have any square or rectangular configuration consisting of any number of rows and stations so long as the above maximum and minimum specifications are not violated.

The rows and stations having the same number designations do not have to be perpendicular to each other (Fig. 1A), but may be arranged in circular patterns (Fig. 1B). When arranged in this manner, the circles are equivalent to rows with stations having the same number forming the rays that emanate in linear fashion from the innermost circle. The replicate must have a minimum of 2 circles with at least 2 stations/circle, but cannot exceed 10 circles and 10 stations/circle. Each circle must contain the same number of stations even though the distance between stations increases with each additional circle. The stations must have the linear arrangement between consecutive circles shown in Fig. 1B. The innermost circle corresponds to row 1, and any station on this circle can be designated as station 1. It makes no difference in which direction (clockwise or counter clockwise) the remaining stations are numbered after station 1 has been selected. The numbering of the stations in the remaining circles must be the same as the numbering in the innermost circle so that all of the stations forming a given ray have the same number.

A maximum of 10 replicates/treatment exists and there is no limit to the number of treatments/experiment or the number of experiments that can be analyzed at a given time. The program is written in Fortran IV and is now being run on an IBM 370 Model 165 computer.

The items for labeling each page of output must be punched on computer cards (5 cards/experiment, 3 cards/treatment). The data from each row are punched on 4 separate cards. Punching these data on computer cards is relatively easy because the key punch can be programmed to skip to the appropriate columns on the card.

**Description of Output**

The basic functions of the program are (1) to analyze each row separately, producing a horizontal analysis of the replicate, (2) to analyze each set of stations having the same number, thus providing a vertical analysis (Fig. 1A), (3) to analyze the data from the entire replicate, (4) to combine the data from the row and station analyses of each replicate into row and station analyses
Fig. 1. Basic designs of replicates which the computer program will analyze—(A) rows and stations having square or rectangular configurations, (B) rows converted to circles with the stations forming rays.
for the treatment, and (5) to combine the data from each replicate for the
calculation of a treatment summary.

The program produces 3 different pages of output for each replicate. The
1st page (not illustrated) lists in columns the row and station numbers, the
number of hosts destroyed, and the number of male and female parasitoids
emerging at each station. The 2nd page (Fig. 2A) illustrates the row analysis
for a replicate consisting of 10 rows with 10 stations/row. The numbers 1-10
located above the columns stand for each of the rows. A 3rd page of output
(similar to Fig. 2A but not illustrated) is produced for each set of stations
having the same number.

Three pages of output are produced for each treatment. The values on the
1st 2 pages are derived by summing and then analyzing the raw data from all
the replicates within the treatment. These 1st 2 pages give row and station
summaries, respectively, and have the same general format as Fig. 2A. This
method of analyzing the experimental universe provides a mathematical pic-
ture of how and to what extent the natural enemy dispersed, destroyed hosts,
and reproduced relative to the point of release. The last of these 3 pages
presents a summary for each replicate in the treatment as well as the treat-
ment summary. A replicate summary is derived from an analysis of all the
stations comprising the replicate. The treatment summary is calculated by
summing and then analyzing the raw data from all the replicates in the
treatment. Figure 2B illustrates this 3rd page of output for a treatment
consisting of 10 replicates. The numbers 1-10 located at the top of the columns
correspond to the replicates. The treatment summary (Fig. 2B, column 11)
is obtained by analyzing all stations comprising the 10 replicates.

DISCUSSION

The significance of this program lies in the methods employed to analyze
each replicate, the summation of the replicate data into treatment summaries,
requiring the research data to be punched on cards, the quantity of values
calculated, and the accuracy and economy of letting the computer perform
the analysis.

This program cannot be applied economically to experiments composed of
a small number of replicates. Therefore, a potential user must decide whether
it would be more economical to analyze his data by another method or to
invest the time necessary to set up the program and punch the data on
computer cards.

As stated earlier, the program was originally used to analyze a series of
studies in which a replicate consisted of 4 rows with 8 stations/row. At the
conclusion of these studies, data had been gathered from 10 experiments
consisting of 79 treatments and 234 field cage replicates. The analysis of these
10 experiments resulted in 30,000 lines of output, the calculation of 81,360
values, took 7.5 min to complete, and cost $18.00. A copy of the program
punched on cards, a set of data cards (so the program can be tested at your
computer facility), and an example of the program's output are available.

LITERATURE CITED

tiveness of laboratory reared Trichogramma. Environ. Ent. 2:1069-73.
TRICHIGRAMMA FIELD CASE STUDIES (TEST) 1973

NAME OF THE NATIONAL ENTITY - MEXICO
HOST - MACROSCELIUS SP. 153.00 M.J.A. 14-15 1971
HOSTS PER REPLICATE = 15
STATIONS PER REPLICATE = 10
STATIONS ON REPLICATE = 100
TREATMENT NUMBER OF TREATMENTS = 4
TREATMENT OBJECTIVE = EVALUATE LABORATORY SELECTIVE BREEDING

REPLICATE ANALYSIS - ROWS

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<tr>
<th>STATIONS FOUND</th>
<th>TOTAL NUMBER</th>
<th>HOSTS PER STATION</th>
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EXPERIMENT NO. 1

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Fig. 2. The output (A) for the rows in a replicate analysis and (B) for the replicate analyses and treatment summary.
BOOK REVIEW

Borne on the Wind: The Extraordinary World of Insects in Flight. Stephen Dalton, 1975, Reader’s Digest Press, E. P. Dutton & Co., Inc., New York. 160 p. illus. $18.95 (7b-6517). It is rare to find a book that is both scientifically correct and a visual masterpiece all in the same dust jacket. I am no doubt biased as a reviewer for according to the preface my background almost exactly parallels that of the author. I took my first photographs of birds as a teenager. I did not use a Brownie as did the author, but instead a Jiffy Kodak, and my love of flight did not develop from the RAF but rather the USAF—minor dissimilarities! Like Mr. Dalton, I have collected insects since boyhood. The author correctly points out that insects were the first organisms to fly and that man’s flying techniques are but a second rate imitation of the flight of insects. Mr. Dalton accepts the theory that insect wings probably developed as extensions of the thoracic wall into stabilizers for jumping, and later enlarged into gliding airfoils. Considering the present state of evolutionary knowledge most entomologists would probably agree that the thoracic lobe theory is still the best guess about the evolution of insect flight, although the theory will no doubt be modified with time. The development of efficient flight in the insect has been one of the main reasons for the insects’ evolutionary success. The author points out that insect wings have no muscles and it is the complex structure of the thorax and its contained muscles that impart power to the insect airfoil. The thoracic power mechanism allows the insect to perform maneuvers that cannot be imitated by any other flying machine, living or man made. The author’s simplified explanation of insect aerodynamics is lucid and much the same as the explanation by this reviewer in his book “Insects and How they Function.” The real “guts” of the book is in the refined techniques that Mr. Dalton used to take the photographic masterpieces that cover many different orders of insects. It is useless in a review to attempt to describe the “in flight” color photographs for they alone are the reason for the book’s existence. It is a “coffee table” book that no lover of insects will want to leave out of his library. I have only one small criticism of this beautiful work and that is not of the author’s doing, but rather the gentleman that wrote the foreword. Dr. Howard Evans states in the foreword that these photographs represent the first insect photographs in full free flight. I believe, if my memory serves me right, that a certain P. S. Callahan wrote a paper on moth flight behavior in 1965 and illustrated the paper with photographs of moths in free flight (Ann. Entomol. Soc. Amer. Vol. 58:159-169) (Fig. 1). One of his color slides appears in the LIFE science series “Animal Behavior,” and other photographs of different orders have been published elsewhere and in his own books.

P. S. Callahan