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An experiment was conducted that compared the teaching effectiveness of a computer assisted instructional module and a lecture-discussion. The module, Predator Functional Response (PFR), was developed as part of the SUMIT (Single-concept User-adaptable Microcomputer-based Instructional Technique) project. A class of 30 students was randomly divided into two groups, one which ran the module and the other which attended a lecture on the same material. Both groups were then given a posttest, and the results analyzed using analysis of covariance and individual item analysis. No significant differences were found between the groups. The implications of these results to microcomputers and to teachers are discussed, with the conclusion that although microcomputers are effective teaching instruments, they should be incorporated into the classroom situation with care and forethought. Provided in appendices are PFR documentation, performance objectives, the posttest, the random division program used to separate the students into two groups, lecture transcript, analysis of covariance, and PFR program listings (for Apple microcomputers). (JN)
DEVELOPMENT AND EVALUATION
OF THE SUMIT MICROCOMPUTER MODULE
ENTITLED 'PREDATOR FUNCTIONAL RESPONSE'

by
Mark B. Shaltz

done as part of the

SUMMIT

SUMMIT COURSEWARE DEVELOPMENT PROJECT
DEPARTMENT OF BIOLOGICAL SCIENCES
MICHIGAN TECHNOLOGICAL UNIVERSITY
HOUGHTON, MICHIGAN 49931

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A REPORT
submitted in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE IN THE BIOLOGICAL SCIENCES
ACKNOWLEDGEMENTS

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ABSTRACT

An experiment was conducted that compared the teaching effectiveness of a microcomputer module and a lecture. A class of 30 students was randomly divided into two groups, one which ran a module and the other which attended a lecture on the same material. Both groups were then given a posttest, and the results were analyzed using analysis of covariance and individual item analysis. No significant differences were found between the two groups. The implications of these results to microcomputers and to teachers were discussed, with the conclusion that microcomputers are effective teaching instruments, but they should be incorporated into the classroom situation with care and forethought.

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INTRODUCTION

Although computers have been a part of our society for over 25 years, they are just beginning to become popular in the educational field. This is not to say that no one has shown an interest in the subject of computer applications in education. To the contrary! As far back as 1958 individuals like Alfred Bork, then a physics professor at the University of Alaska saw the potential of computers in teaching and began research on the possibilities (Kiester, 1978).

The number of individuals interested in computers in education grew as computers became more popular in the 1960s. In that decade the number of schools having computers increased six-fold (ACM Bulletin, 1979). Unfortunately these computers were utilized mainly for administrative purposes, so the teaching applications of the computer lagged far behind this tremendous growth in computer popularity.

There are numerous uses of computers in education. The Illinois Series on Education (1979) listed eight different ways computers could be used in teaching, with others (Roecks, 1981; Watts, 1981) later adding to that list. Even so, the computer is not utilized nearly as much as its potential suggests. For example, although computers have applications in virtually every curriculum, over half of...
the student use of computers in higher education today is in only three departments: computer science, engineering, and business (Molnar, 1981).

One of the areas of study that does not make extensive use of computers is the biological sciences. The reasons for this, according to Tocci (1981), may stem from the belief that biology requires fewer quantitative analyses than such subjects as physics and engineering. But Tocci stresses that there are many uses of the computer other than for quantitative analysis, and several are directly applicable to the biological sciences. He blames the lack of computers in biology teaching on the teachers themselves, saying that many lack training in the area of computers, so they either do not know about the computer’s potential, or else they are suffering from "computerphobia" (Jay, 1981). Many teachers have almost no concept of what a computer is or what it is capable of doing. Another related fear is that the computer will soon replace teachers. This is a largely unfounded fear. Frank Clement (1981) studied the situation and came to the conclusion that there is no evidence that computers will replace teachers in education. He even postulated that the need for teachers who can use computers and also for teachers who can help develop high quality educational software may be responsible for the opening of more teaching jobs.

In 1971 semiconductor manufacturer Intel Corporation
developed the microprocessor chip (Marbach and Lubenow, 1982), which eventually had a far-reaching effect on educational computing. This is because the microprocessor chip made possible the development of the relatively inexpensive modern microcomputer, a small, stand-alone computer equipped with a keyboard and a TV monitor usually with graphics capabilities.

Suddenly any school could own its own computer for a tiny fraction of the cost of previous computers. Before microcomputers became available in 1977, the standard in education was the large time-sharing computer, which consists of two parts; the central processing unit (CPU) and the remote terminals. The CPU is the actual computer, where data is stored and processed. The remote terminals are keyboards used to communicate with the computer. These terminals could be located at various places and connected to the CPU by telephone lines.

Educators were quick to recognize the advantages of the microcomputer over the time-sharing computer system. According to McIsaac and Baker (1981), the major advantages are cost, user controllability, and convenience.

It is not unusual for a time-sharing computer system to cost several hundred-thousand dollars. A microcomputer costs as little as two thousand dollars, which is within the budget of many more schools. Additionally, a time-sharing computer costs a large amount of money to run.
and maintain. Each time a program is run it costs money, which tends to discourage use of such a computer system. A microcomputer costs almost nothing to run, so its use can be encouraged with no fear of mounting large computer processing bills.

The user of a microcomputer has much more control of the entire system than does a user of a time-sharing computer. On a time-sharing computer system the user must contend with problems beyond his/her control, such as computer down time and defective connecting telephone lines. Microcomputers are decentralized so that each one is a separate unit. There are no telephone lines connecting them and no problems with other users on the system at the same time. The microcomputer user does not have to be concerned with computer down time, or with waiting in line for the CPU to run a program, or with keeping user identification numbers secret.

Related to controllability is convenience. Microcomputers tend to be more convenient than time-sharing systems. Because microcomputers are decentralized, the user works with the entire unit. This eliminates such inconveniences such as i.d. numbers and long waiting periods both to run a program and to receive its output. Also more convenient is the fact that microcomputers have no running or processing costs. They can be used often and at any time of day with no worries of the resulting bill.
The running costs of a time-sharing system can vary at different times of the day and can get quite expensive, especially if the terminal is hooked to the CPU via a long-distance telephone connection.

Many agree that an additional advantage of the microcomputer for educational applications is its color graphics capabilities, which allow it to use graphs, charts, pictures, and even animation (Bork, 1980; Bork and Franklin, 1979; Smith, 1979; Zinn, 1979). This allows the microcomputer to do more than process numbers and display text, thus adding a new dimension to its applications.

It is the combination of all these advantages which make the microcomputer an attractive package in education. For example, there is a large time-sharing system that has been developed that shares many of the advantages of the microcomputer. It is called PLATO (Programmed Logic for Automatic Teaching Operations) and is available to many colleges and universities. PLATO is essentially a computer terminal and TV screen connected to the CPU via long-distance telephone lines. PLATO has excellent graphics capabilities and immediate, interactive feedback to user inputs. But its major drawback is cost. According to Gerald Gleason (1981), a single terminal hooked to PLATO would cost a school $6000 a year. With such a high cost, PLATO cannot compete with the microcomputer for the educational computing market.
With all of their advantages, microcomputers are rapidly becoming popular in education. But one of the major obstacles to their growth at this time is the long-time establishment of the time-sharing systems already in schools. A school will be hesitant to spend money on microcomputers when it already is equipped with a large time-sharing system. But this is not a permanent hindrance to the spread of microcomputers. For example, a 1978/79 study done by the Minnesota School District Data Processing Joint Board (ACM Sigcse Bulletin, 1980) culminated in the recommendation to phase out time-sharing in favor of microcomputers in Minnesota schools.

With the sudden popularity of microcomputers, the educational community has been beset by a couple of major problems. Most teachers have little computer knowledge. They do not know how to use computers or what computers can do. This is termed "computer illiteracy" and is one of the most serious problems associated with the educational computer boom (Dickerson and Pritchard, 1981). Another very serious problem is that microcomputer development has far exceeded its software development (Gleason, 1981). Software refers to the programs that can be run on the computer. Many teachers have ideas concerning how to use microcomputers in their classes, but no software has yet been developed for their needs. So although microcomputers are becoming available for use in the classroom, these two
problems, the large number of teachers who are not computer literate and the lack of educational software, limit the microcomputer's use.

In the face of problems such as these, a project was initiated at Michigan Technological University. The two year long SUMIT project (Single-concept User-adaptable Microcomputer-based Instructional Technique), headed by Dr. J. D. Spain and funded by the National Science Foundation, began in the spring of 1980 and produced educational software related to the biological sciences for the Apple II Plus microcomputer. Each microcomputer program, or module, dealt with a single subject in the areas of ecology and general biology.

The modules were designed to be used as a supplement to a biology or ecology laboratory. Experts tend to agree that Computer-Assisted Instruction (CAI) used in addition to laboratories or classroom lectures is the best application of CAI in courses (Alpert and Bitzer, 1970; Clement, 1981; Jenkins, 1976; Tsai and Pohl, 1978; Tsai and Pohl, 1981; Visonhaler and Bass, 1972).

CAI is defined by Oliver and Scott (1978) to be "the direct interaction of a student with a computer through an alphanumeric and/or graphics communications terminal for an instructional purpose." With this in mind, the SUMIT modules could be termed CAI modules because they were written with the idea that they would be run by students.
who would interact with the modules.

User interaction with the microcomputer was felt to be a very important part of the learning experience, so all of the SUMIT modules allowed frequent user-computer interaction through questions and answers. Using the Apple microcomputer's graphics, this was extended to include an interactive graphics situation in which the user would experiment with equation parameters and observe how changes affect various curves and graphs.

SUMIT modules will not only help to alleviate the lack of educational software, but they also were designed to be used by all teachers, regardless of their degree of computer literacy. It requires no computer programming knowledge to run the modules. As an added feature, along with each SUMIT module comes a copy of documentation that explains simple ways that a user can modify the module. Therefore teachers need not be computer experts to run or modify these modules.

Each of the SUMIT modules underwent several formative evaluation procedures. Members of the SUMIT team constantly ran the modules throughout their development and offered suggestions and criticisms. The modules were also run by small groups of students in various ecology and biology courses at MTU. These students would each fill out evaluation forms, which were then used to further improve the modules.
Summative, or final, evaluation took place in animal ecology and general biology laboratories at MTU. The SUMIT modules were incorporated into the laboratory work, where the students would take a pre-test, run the module, and then take a post-test to find if they improved after running the module. They also filled out evaluation forms to give the SUMIT team an idea of their attitudes, likes, and dislikes in relation to the computer work in laboratories.

The SUMIT team desired to evaluate a SUMIT module by comparing it to the traditional method of instruction. Since the modules were written to be part of laboratory experiences, the most relevant summative evaluation would be to use it as part of a laboratory exercise and test students' improvement. The question is, can they teach a student as effectively as traditional instruction (TI) techniques? It was decided to address this question through the summative evaluation of a SUMIT module.

The problem of this study was to determine the effectiveness of CAI using a SUMIT module by comparing it with a traditional method of instruction -- lecture-discussion.
A review of the literature in the area of evaluating CAI revealed very little useful material. A number of individuals expressed the belief that CAI could teach as effectively as TI (Bork, 1980; Cunningham, 1979), but they never conducted any studies on the matter. Others carried out experiments that were very weak. For example, Morrison and Adams (1968) carried out a study on CAI vs. TI in German language classes. They claimed to have found the CAI group to be better in some skills, but no statistical analysis could be performed on the data due to the unstructured nature of their study. Different teachers taught different groups, plus some individuals changed groups midway through the study.

Weistheimer conducted a study of CAI supplemented laboratories vs. traditional laboratories and found that the CAI supplement group did significantly better on material covered on the computer (Jenkins, 1976). But his experimental method was faulty because the CAI supplement group put in four hours "overtime" to look at the CAI modules, while the traditional laboratory group put in no extra time. This gave unfair advantage to the CAI supplement group.

Gershman and Sakamoto (1981) carried out a large-scale study with the Ontario secondary school system. But
students were allowed to move from the CAI group to the TI group and vice versa, so their results were not conclusive.

Better studies with proper experimental design were also found in the literature (Alpert and Bitzer, 1976; Hollen, Bunderson, and Duham, 1971; Lewellen, 1971; Suppes and Morningstar, 1969; Tsai and Pohl, 1978; Tsai and Pohl, 1981; Visonhaler and Bass, 1972), but most were old -- pre-microcomputer era. Educational computing prior to the late 1970's tended to center more around drill & practice. It is questionable if these studies could provide any indication of the teaching effectiveness of the modern CAI simulation modules, because simulations and drill & practice are two very different uses of the computer.

Also, none of the studies found were conducted for a single CAI module. Instead they all were a test of learning over the course of a term or semester. All of these differences made it difficult to predict the results of a SUMIT module vs. TI comparison.

As a final note on this subject, two studies in the literature proved interesting. In 1978, Magidson reviewed the accumulated studies of CAI vs. TI and found that 55% of these resulted in no significant differences. The remaining 45% of the studies resulted in finding the CAI more effective than TI. Three years later, Burns and Bozeman (1981) published a similar review and found 40% resulted in no significant difference, 45% resulted in finding CAI more
effective, and 15% resulted in mixed results.

One should note two points. First, the latter review found 15% of the CAI vs. Tl comparisons getting less than favorable results for CAI. Secondly, the studies were separated by three years, the exact time of the introduction and subsequent popularity of the microcomputer. Possibly in those three years the studies conducted involved microcomputers with more graphics and simulation modules. If this was true, then microcomputer simulations could be responsible for reducing the number of studies that found CAI to be effective, which would imply that either the software for microcomputers was of low quality, the studies were not run well, or that microcomputer simulations are not effective teaching devices.
METHODS AND MATERIALS

(This section outlines the development of the Predator Functional Response module, the lecture to which it was compared, and the posttest for the experiment. The population used, the experimental design for the lecture vs. CAI study, and the statistical methods to analyze the data are also described.)

A. Choice of the module

The SUMIT module entitled Predator Functional Response was chosen for a study comparing the teaching effectiveness of a CAI module and a lecture-discussion. This module concerned the topic of predator functional response and its relationship to prey recruitment. Briefly, predator functional response (PFR) relates the number of prey killed to the prey density in the surrounding environment in which that predator lives. If this is studied in conjunction with prey population growth, or prey recruitment, of an area, many interesting and potentially useful relationships can be discovered. For a more detailed look at prey recruitment-predator functional response, please refer to the PFR module documentation in Appendix A.

This module was chosen because I felt that students would not be familiar with the subject of PFR or the
graphical techniques used to plot the PFR curve. PFR is an important, but not widely taught concept, so most of the students had never been exposed to the material in the module before. New concepts decrease the probability that one student is at an advantage over other students, which is important in the proper evaluation of the effectiveness of a teaching method.

Another reason for using the PFR module was that it was written by the investigator conducting this study; thus he was familiar with the module and the subject matter. This assured that the instruction would be most effective and also eliminated the teacher confounding factor (this occurs when one individual develops teaching materials and another uses them to teach).

B. Development of the module

Initial development of a microcomputer module on PFR involved finding the right approach to the subject. The objective of this module was to take the student further into the predator-prey relationship than the Lotka-Volterra numerical relationships, and also to expose him to ways of graphing relationships other than the standard plot of "population as a function of time".

Many different methods of graphing PFR exist. Examples include plotting the proportion of prey killed per predator.
as a function of prey density (Murdoch, 1973), and plotting the log of the number of prey killed per predator as a function of the log of the prey density (Real, 1979). The simplest method found, and the one used for the PFR module, was to graph the number of prey killed per predator as a function of prey density, a technique made popular by Holling (1959).

A microcomputer program was developed depicting prey recruitment and type III PFR (Holling, 1959) interactions. At this point the module's objectives were formulated for this module:

After running the PFR module the student should be able to:
1. identify and predict stability of prey density equilibrium points resulting from predator functional response.
2. predict and recognize the effect of changes in predator carrying capacity on equilibrium points.
3. compare the relative rates at which different starting prey densities approach a stable equilibrium point.
4. recognize the effect of hunter pressure on prey density equilibrium points.

It should be pointed out that these objectives are not the same as the final performance objectives that were
tested for in the study's posttest (these can be found in Appendix B). The list of objectives was changed and expanded throughout the development of this module as more was learned about PFR and the capabilities of the Apple II Plus microcomputer.

After a module was written and programmed on the Apple, formative evaluation began. This encompassed constant suggestions and subsequent improvements, followed by further suggestions for improvement. The formative evaluation for the PFR module roughly followed the guidelines outlined by Dick and Carey (1978). First the author and SUMIT team reviewed the module. After the suggested improvements were made, the module was run by a small group of students, the BL575 Advanced Animal Ecology class. Their suggestions were used to improve the module. Next a team of three SUMIT members who had a special interest in PFR was assembled. This team met twice weekly to review the module and offer suggestions and criticisms. Following this, a four-member committee created to supervise the graduate work of the PFR module's author ran the module and offered suggestions. Finally, a year after the formative evaluation began, four individuals knowledgeable in the field of predator-prey relationships (two of which could be considered "experts" in the subject of PFR) ran the module to check the accuracy of the material presented. No erroneous material was found, which
ended the formative evaluation of the PPR module.

C. Development of the lecture

A lecture was needed that was comparable to the PFR module in its objectives. Using the list of performance objectives developed for the PFR module (see Appendix B), a lecture-discussion was written by the investigator. This assured that both the lecture and the module covered the same material at the same level.

The lecture was approximately 40 minutes in length and used overhead projections for the graphs. Time was included in the lecture for student questions. After the lecture-discussion was written the author reviewed it to ensure that all of the performance objectives were adequately covered.

To obtain a permanent record, a videotape was made when the lecture-discussion was given to BL340 Animal Ecology. A written transcript was made from this videotape. This can be found in Appendix E.
D. Development of the posttest

A posttest was needed that would measure knowledge on the subject of PFR. The following format for the posttest was chosen:

-- The posttest consisted of multiple choice items because they can be scored objectively, yet have more discriminatory power than true/false items; plus they can be used to test for a variety of cognitive learning levels.

-- The posttest had 20 items. Past posttests used on other SUMIT modules had eight to ten items. For this study a longer test was developed to increase the reliability of the results.

-- A time limit was set for the completion of the posttest by the students. A time limit of 15 minutes was chosen so that it could be administered within the anticipated time constraints on the day of the study.

A posttest with this format was written that tested for the set of performance objectives developed for the module and lecture. Then it was evaluated by the members of the SUMIT team. Suggestions were made, which were used to improve the posttest.

As a final evaluation of the posttest, four individuals knowledgeable in PFR were asked to take the test and look for inaccuracies in the information.
presented. They did this and offered several suggestions for improvement, which were incorporated into the final version of the posttest. A copy of the posttest used in this study can be found in Appendix C.

E. Description of the population

The fall 1981 BL340 Animal Ecology class was used to compare the PFR module to a lecture-discussion. 30 Students were enrolled and attending this course at the time of the experiment. These 30 students were divided randomly into two groups of 15. The random division permitted the assumption to be made that the two groups were representative samples of the population in their prior knowledge of the subject matter to be tested, so a pretest did not have to be given. The randomization was done by associating each student with a random number and then sorting the random numbers from lowest to highest. The students with the 15 lowest random numbers made up the group that would run the PFR module. The remaining 15 students would make up the group that would attend the lecture on PFR. This procedure was conducted on the Apple II Plus microcomputer. A copy of the program and results can be found in Appendix D.
F. Experimental design

One week prior to the experiment the students were informed where to report on the day of testing. On the day of the study, the lecture group attended the 40-minute lecture-discussion on the subject of PFR in their regular lecture room. At the same time, the module group met in their laboratory room and ran the PFR module. Each student used a separate microcomputer and was given 40 minutes to run the module. At the end of the 40 minutes both of the groups were brought together and administered the posttest on PFR.

G. Method of analysis

Each student's posttest score and final course points percentage was collected. Analysis of covariance was applied to this data, using the final course points percentage as the covariate, to test the null hypothesis that the means of the adjusted posttest scores for the two groups were equal. The alternate hypothesis was that the two means were not equal.

In an effort to analyze the effectiveness of the posttest, test and item analyses were run. This was accomplished using a program entitled ITEM ANALYSIS (Fehlberg and Flathmen, 1969) on the UNIVAC computer. This
program calculated a variety of statistics, but the ones most useful to this study were the Kuder-Richardson Formula 20 reliability coefficient (KR-20), the item difficulty indexes, and the item biserial correlation coefficients.

The item difficulty index used was the fraction of students that answered the item correctly. It is a number between zero and one and is calculated by dividing the number of correct responses by the total number of responses for each item.

Item discriminatory power, the "ability to differentiate between students who have achieved well... and those who have achieved poorly" (Ahmann and Glock; 1981), and its difficulty index are related. Items with difficulty indexes around 0.50 generally have the maximum discriminatory power. Therefore a test with items in the range of 0.30 to 0.80 will have a high discriminatory power.

The Kuder-Richardson Formula 20, or KR-20, checks the internal reliability of the entire test. It is calculated using the following formula:

\[
\text{KR-20} = 1 - \frac{\text{SUMMATION} (P(1-P))}{\text{Test Variance}}
\]

where \( P \) = each item's difficulty index.

The KR-20 uses item difficulty indexes to estimate consistency of student performance from item to item. The
KR-20 has a possible range of zero to one, but should be greater than 0.50 for any given test (Tinari, 1979). A value lower than this indicates that the test may be internally inconsistent.

The item biserial correlation coefficient has a possible range of minus one to one. It is calculated using the following formula:

\[
BCC = \frac{P(Mr - Mw)}{Z(\text{Test Variance})}
\]

where Mr is the mean of the students answering the item correctly.

Mw is the mean of the students answering the item incorrectly.

P is the item difficulty index.

Z is the ordinate in the unit normal distribution corresponding to the proportion P.

Like the difficulty index, the biserial correlation coefficient is also related to item discriminatory power. It measures how well an item separated the good students from the poor ones. If an item is discriminating well, the mean test score of the students choosing the correct answer should be greater than the mean test scores of students who chose distracters (wrong answers). When this happens the biserial correlation coefficient for that item is high. If,
on the other hand, the poorer students chose the correct answer and the better students chose the distracters, that item is not operating properly, and the biserial correlation coefficient would be negative.

The lecture and module groups were compared item-by-item using a 2X2 contingency table with the rows equalling module and lecture, and the columns equalling the number that responded with the right answer and the number with the wrong answer. Chi-square values were calculated from these contingency tables.
RESULTs

30 students were enrolled in BL340 Animal Ecology at the time of the experiment. It was hoped that sample sizes of 15 for each group, lecture and module, would occur, but several factors reduced this number. Two students from the module-group were absent, reducing the module sample size to 13. In lecture, three students arrived late and missed enough material to possibly lower their posttest scores, so these students' scores were dropped from the data set, leaving 12 scores from the lecture group to be analyzed.

To use analysis of covariance to compare the lecture and module group means, a covariate was needed. The final course points percentages for the students in the study were used. At the end of the term the list of final points percentages was collected, and it was found that one student who had participated in the module group had later dropped the course. Thus he had no final points percentage, so his posttest score had to be dropped from the data analysis.

This left 12 students' data in each group. The complete final data set can be found in Appendix F. The posttest scores for the lecture and module groups were plotted on frequency histograms in Figure 1. Analysis of covariance was applied to the data collected (see Appendix F). The calculated F-value was less than one, so the null
FIGURE 1. Frequency histograms for the posttest scores of the module and the lecture groups.

MODULE GROUP HISTOGRAM

LECTURE GROUP HISTOGRAM
hypothesis was accepted; the means of the adjusted posttest scores for the lecture and module group are not significantly different.

Table 1 summarizes the results of the test and item analyses. One will recall that the KR-20 formula measures the internal consistency of the test and should be greater than 0.50. The KR-20 formula for the class posttest results was 0.80, which indicates a test with high internal consistency.

The difficulty indexes are listed by item in Table 1. One can see that half of the items in the class's posttest were within the acceptable range of 0.30 to 0.80.

Biserial correlation coefficients are also listed by item in Table 1. Tinari (1979) suggested that items should have biserial correlation coefficients greater than 0.30 to be useful. Scanning the class data in Table 1, it can be seen that 16 items pass this criterion, which is a greater number than the number of items with the proper difficulty index. This means that for some items the difficulty index was not within the optimum range, but the item was still functioning by discriminating good students from poor.

When the lecture and module groups were compared item-by-item using a contingency table (Figure 2), it was found by calculating chi-square values that the two groups were not significantly different on any single item of the posttest.
TABLE 1. Posttest statistics. This table includes test means, standard deviations, and KR-20 values; plus item difficulty indexes and biserial correlation coefficients (BCC's).

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<th>Diff Ind</th>
<th>BCC</th>
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FIGURE 2. An example of the two-by-two contingency table that was used to compare the module and lecture groups by item. The data in this figure is from item #4 of the posttest.

<table>
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A study comparing a CAI module and a lecture was conducted, and it was found by analysis of the data that there was no significant difference between the two in their teaching effectiveness. Although the results are limited to the population of this study, they can be used to consider some other aspects of microcomputers and their use in teaching.

First, how are the results of this study important to manufacturers of microcomputers? Microcomputers have been experiencing a boom in education without any evidence that they could be useful. All that existed were the "feelings" of a limited number of teachers that they could be used somehow. This study provides some evidence that microcomputer CAI modules can teach students as effectively as a class lecture. With this evidence more educational institutions may be willing to make purchases and thus make microcomputers more popular in the classroom. With their increased availability in educational institutions, their use will also increase with more teachers using them in more different ways.

An already existing problem that may temporarily become more acute is the lack of high quality educational software. If a sudden increase in microcomputer popularity in education occurs, the software problem will get worse.
large number of teachers will be exposed to microcomputers and will want to use them, but the software will be limited. CAI simulation modules take hundreds of hours to write, develop, and program. The lag time involved in developing educational software may put a severe pinch on the expanding needs of the educational computing community. Possibly, though, more teachers will develop their own software, and that may be the ultimate answer to the problem.

The next issue to be addressed is the significance of the PFR study to teachers. In the past many teachers were hesitant about using CAI in their classes, partially because they had no way of knowing if it was a useful means of teaching. The PFR study provides evidence that CAI modules can be effective in teaching certain topics (i.e., those that are simulation- and graphics-oriented). With this evidence possibly teachers will begin to make use of CAI modules to replace some lectures and/or to supplement others. The microcomputer has shown that it can be an effective instructional tool, so it should be used as such. The use of the microcomputer in a class will add variety to the learning experience, which will aid the student in understanding and recall.

One curriculum that has a wealth of simulation- and graphics-oriented topics is biology. Thus it is surprising that biology is one of the least frequent users of
computers in education (Magidson, 1978). In his text "BASIC Computer Models in Biology" (1981), Spain covers at least 50 mathematical models related to some aspect of biology, each of which could be the basis of a CAI module. Probably the main problems are related to computer illiteracy among biology teachers and a lack of educational software in the subject of biology. But with the SUMIT project and other similar courseware development programs, biology teachers will have more software to make use of in their courses, which may help alleviate the problem.

Does this study support the view that microcomputers can replace teachers? McCredie (1981) pointed out that the computer has decreased greatly in price at a time when the cost of supporting a faculty member has gone up significantly. He believes that the inexpensive price of computers in teaching will make them much more popular in the near future. But will they replace teachers?

The evidence is against it. Tsai and Pohl (1978) conducted studies in 1978 and 1981 comparing the teaching effectiveness of TI, CAI, and CAI supplemented TI. These were some of the first studies that included all three of the most important contrasts concerning CAI learning: TI vs. CAI, TI vs. CAI supplemented TI, and CAI vs. CAI supplemented TI. The results were that they found no significant difference between CAI and TI, but they also found that TI supplemented with CAI was significantly more
effective than either alone.

Some may argue that these studies prove that computers will replace teachers soon. But more evidence exists that this will not occur. Possibly the closest thing to a completely computer-instructed course that exists in the United States at this time is located at the University of California at Irvine (Bork, 1980). There an introductory physics course is taught through a series of PLATO simulation modules. But even this does not eliminate teachers because a summary lecture is given at the end of each week, plus if students consistently have problems on certain material in the CAI module, they are locked out of the module until they discuss the problem with the course instructor. So even with maximal use of CAI, teachers are needed to answer questions and pull together the material for the students.

That is the extreme case of CAI. Most investigators agree that totally computer-instructed courses are not the most effective use of computers in education; rather, CAI used to supplement laboratories and lectures is the best application (Alpert and Bitzer, 1981; Clement, 1981; Jenkins, 1976; Tsai and Pohl, 1978; Tsai and Pohl, 1981; Visonhaler and Bass, 1972). SUMIT modules were designed with this application in mind, and, although this study found the PFR module to be as effective as a lecture, the module was not designed to replace a lecture. CAI modules
may prove to be effective on their own, but any attempt to fit presently available modules together to completely replace a series of lectures would result in an unrelated set of subjects being taught with no connection among them. Therefore, microcomputers and their existing software do not threaten to replace teachers at this time.

In the opinion of this researcher teachers should look at the microcomputer as another learning device to be used to enhance their courses. Microcomputers provide the graphics and interactivity necessary to teach some difficult-to-convey topics and should be used in conjunction with related laboratories and lectures.

The microcomputer is an effective learning aid, but it should not be looked to as an answer to all educational problems. It has its areas of application, like any other teaching aid. But several problems have to be avoided. I was involved with CAI modules from both a student and an instructor's viewpoint in the past year. From my experiences I have found that there is a danger of overusing CAI modules. This was also found by Tsai and Pöhl (1978). It seems that any more than one module a week results in a severe loss in student interest. Therefore, possibly the most effective use of microcomputers would be as part of a multi-media exposure for the student, including such things as overheads, films, slides, videotapes, and field trips. In this way the microcomputer
could add to the richness of a course without becoming a hindrance through overuse.

For future research the module vs. lecture comparison could be improved in several ways. First, it could be repeated with larger sample sizes, which would strengthen the results and also provide possible replication of the results. Further development of the posttest would also be helpful. The posttest in this study contained many multiple-choice items with weak distracters. Better distracters would raise the reliability and discriminatory power of the test.

Also, an interesting addition to the experiment would be the testing of long-term retention of the material learned. By testing the students a week or more after the experiment, long-term retention of the material could be tested. This would be especially interesting, because past studies on retention of CAI learned material have found conflicting results (Alpert and Bitzer, 1970; Hollen, Bunderson, and Duham, 1971; Tsai and Pohl, 1981).

To conclude, a CAI module dealing with predator functional response was developed for the Apple II Plus microcomputer as part of the SUMIT microcomputer software development project. This module was used in an experiment comparing the teaching effectiveness of a CAI module and a class lecture. The 30 students in BL340 Animal Ecology at Michigan Technological University were randomly split into
two groups for the experiment. One group ran the PFR module, the other group attended a lecture on PFR. Immediately afterwards, the students took a posttest on the subject of PFR. The results of this posttest were analyzed, and no significant difference was found between the scores of the two groups. This indicates that CAI modules are useful devices for teaching.
LITERATURE CITED


Spain, J. D. 1981. BASIC computer models in biology. Addison-Wesley.


APPENDIX A

Predator Functional Response
Module Documentation

Following is a copy of the documentation that was written for the PFR module.
PREDATOR FUNCTIONAL RESPONSE

ABSTRACT

This module explores the interrelationships between prey recruitment and predator functional response curves. Equilibrium points are examined with respect to their numbers and stability. The effects of varying predator population size are explored. A method for estimating the relative time required for reaching equilibrium is discussed. The effects of hunter pressure on the predator-prey system are examined and discussed.

PREREQUISITES

Familiarity with S-shaped growth curves (such as the logistic equation). Previous exposure to predator-prey models, such as the SUMIT module entitled PREDATOR-PREY DYNAMICS.

OBJECTIVES

After running this program, the user will be able to:

a) identify and predict stability of prey density equilibrium points resulting from predator functional response.

b) predict and observe the effect of changes in the predator carrying capacity on equilibrium points.

c) compare the relative rates at which different starting prey densities approach a stable equilibrium point.

d) observe the effect of hunter pressure on prey density equilibrium points.
5. BACKGROUND

Solomon (1949) defined two categories of interaction between predators and their prey. He defined the predator NUMERICAL RESPONSE as the change in predator density in response to a change in the prey density. This would be exemplified in the Lotka-Volterra predator-prey models (Wangersky, 1978) where the predator population fluctuates in response to the number of prey (see Figure 1).

![Figure 1](image-url)

Figure 1. Example of a Lotka-Volterra predator-prey graph. A graph showing the cycling nature of the fluctuations of the predator population in response to changes in the prey population. This graph is an example of output from the SUMIT module entitled PREDATOR-PREY DYNAMICS.

Solomon hypothesized that predator eating habits also changed. He defined the predator FUNCTIONAL RESPONSE as the change in the number of prey consumed by individual predators in response to a change in prey density. Predator functional responses are not as well studied as numerical responses, but play an important role in stabilizing prey density. Many times the numerical response of a predator may occur more slowly and also be dependent on the predator's functional response (Oaten and Murdoch, 1975).

There are three basic types of predator functional response curves, when the number of prey eaten by a constant number of predators is plotted versus prey density. The curves have the shapes shown in Figure 2 as defined by Holling (1959).
Figure 2. The three basic shapes of predator functional response curves.

All three curves in Figure 2 tend to level off. This is due to predator satiation. Satiation refers to the maximum number of prey that a constant number of predators can consume in a given time interval.

The type I curve represents a predator with a random search pattern and a rate of searching that remains constant at all prey densities. The number of prey consumed, then, would be directly proportional to the prey density, and a straight line graph would result.

The type II curve represents a predator whose rate of searching progressively decreases as prey density increases.
Possibly the most interesting is the type III predator response curve. One explanation that has been put forward for the sigmoid shape of the curve is that the predators are exposed to multiple prey species. The 'S' part of the curve is due to predator switching; that is, the predators consume a disproportionately larger number of the more abundant prey (Oaten and Murdoch, 1975). When one species of prey is scarce the predators concentrate on other sources of food. But as the density of that prey species increases, the predators recognize and consume a much larger number of them, which is reflected in the steep part of the curve.

Investigations done on type II and type III predator functional responses include Holling's work with predation on the pine saw-fly (1959); Manly, Miller, and Cook's experiments with Quail (1972); and Murdoch, Avery, and Smyth's guppies (1975).

Looking at the prey in the absence of any predators is helpful later in finding relationships between predators and prey. The growth curve of the prey population under such conditions will generally be S-shaped (Horn, 1968). Figure 3a shows a typical prey population growth curve.

Figure 3. Example of an S-shaped growth curve (a) and the resulting recruitment curve (b) for a prey population. These graphs are an example of output from the SUMIT module entitled PREDATOR FUNCTIONAL RESPONSE.
To compare the growth of the prey with the predator functional response, the prey population growth must be graphed on the same axes as the functional response curve. When this is done, the graph in Figure 3b is the result. The curve in Figure 3b is called a prey, RECRUITMENT CURVE. It represents prey births minus prey deaths that are non-predator related. It records the additions to the prey population graphed as a function of prey density.

If the predator of this prey species displayed a type III functional response, the curve plotted on the same graph as prey recruitment could look like that of Figure 4.

Figure 4. Prey recruitment and a predator type III functional response curve plotted on the same graph. This graph is an example of output from the SUMIT module entitled PREDATOR FUNCTIONAL RESPONSE.

Because the prey recruitment curve represents additions to the prey population and the predator functional response curve represents losses from the population, the points where the two curves intersect describe equilibria where the prey density will neither increase nor decrease. Where the prey recruitment curve is
APPLICATIONS

The SUMIT program entitled PREDATOR FUNCTIONAL RESPONSE is useful for showing some relationships between predator and prey. The number and stability of equilibrium prey densities can be studied using this program. PREDATOR FUNCTIONAL RESPONSE introduces the user to different ways of representing predator-prey interactions.

Questions

1. The program discusses predator-prey relationships where three equilibrium points exist and also where one equilibrium point exists. Why do you think a two equilibrium point relationship was not discussed or simulated?

2. Hunter pressure is an example of what shape (type) of predator functional response curve?

3. Here is an example of a prey growth curve:

   ![Graph of Prey Density vs Time]

   Given this curve, come up with the general shape of the prey recruitment curve for this population.

4. Would you think that predator functional response is usually a faster or slower process than predator numerical response? Why?

5. In the hunter pressure section of the program, the prey density ended up at the lower stable equilibrium point. Suggest how the prey density might be brought back up to the upper stable equilibrium point. Do you think that any of these suggestions are feasible for use in real life situations? Can you come up with examples where your suggestions are already being used?
LITERATURE CITED


MODELS USED IN THE PROGRAM

This module is divided into four subprograms.

PRED FUNCT INTRO serves as an introduction and covers
the transition from the S-shaped growth curve to the prey
recruitment curve. Specifically, the standard logistic
equation was used to plot the S-shaped curve.

\[
\frac{dN}{dT} = R * N * (1 - N/K)
\]

where:
- \( R \) = intrinsic rate of natural increase
- \( N \) = prey population size
- \( K \) = prey carrying capacity
- \( \frac{dN}{dT} \) = the change in the number of prey per unit time

The parameters used in this program are:

\( R = 0.1 \quad K = 50 \quad N = 0.5 \)

The logistic curve is a plot of prey population size
\((N)\) as a function of time. The prey recruitment plot is the
change in prey density \((dN)\) as a function of prey density
\((N)\).

PRED FUNCT1 introduces the predator functional
response curve and plots it on the same graph as its prey's
recruitment curve. The recruitment curve is again
calculated with the logistic equation, using the following
parameters:

\( R = .01, \quad K = .100. \)

The predator functional response in this program is a
type III curve. The equation used was obtained from Real
(1979).

\[ f = \frac{(KF * N^E)}{(N^E + DD)} \]

where:
- \( f \) = feeding rate
- \( KF \) = maximum feeding rate
- \( N \) = prey density
- \( DD \) = density of feed items that generate half-
maximal feeding
- \( E \) = exponent associated with the amount of increase
in the rate of detection of a food item with an
increase in food density.

The parameters used in this equation are:

\( KF = 110 \quad E = 2.5 \quad DD = 300 \)

The points generated from these two equations at prey
densities of 0 to 100 were placed in data statements to
increase the speed of plotting.
Next this program covers equilibrium points and their stability, and also allows changes in predator carrying capacity. Predator carrying capacity, in this program, is equivalent to $K$ in the equation for the type III response curve (Real, 1979). The reason is that the maximum feeding rate will change as a function of predator carrying capacity and the resulting number of predators in the system. Also, in this equation the predator carrying capacity is unrelated to the prey density. This means that the predator carrying capacity is determined by restrictions other than prey density, such as territoriality.

.PRED FUNCT2 estimates the time for a prey density to equilibrate. It does this by taking the difference between the prey recruitment curve and the predator functional response curve, and subtracting this difference from the prey density to obtain the density at various time intervals.

.PRED FUNCT3 demonstrates the effect of adding hunter pressure to this simple predator-prey system. Because hunter pressure tends to take a percentage of the prey population regardless of population size, the graph of change in density as a function of prey density is a straight line. The equation for hunter pressure used was:

$$Y = (0.01 \times HP \times N)$$

where:
- $Y$ = the number of prey killed
- $N$ = the prey density
- $HP$ = hunter pressure expressed as a percentage of the prey density.

The variable $HP$ can be changed by the user in the hunter pressure simulation. The effect of this is to raise or lower the prey recruitment curve.
PRED FUNCT INTRO

Line Numbers

5 - 28  REMARKS containing module name, program name, credits, and NSF grant number.
100 - 300  title and credits.
370 - 830  logistic growth curve is introduced and plotted.
840 - 1210  a question is asked regarding the graph displayed.
1220 - 1560  prey recruitment is introduced.
1570 - 1920  prey recruitment and logistic growth are plotted simultaneously.
2270 - 2340  the relationship of the predator is introduced.
2350 - 2390  the subroutine PRED FUNCT1 is run.

SUBROUTINES

5000 - 5065  PAUSE subroutine.
5080 - 5130  press RETURN subroutine.
5750 - 5880  HGR block erasing subroutine.
6240 - 6481  HGR string drawing subroutine.
30600 - 31000  variable size graph drawing subroutine.
31010 - 31080  point scaling and plotting subroutine for variable size graph.
REMARK statements.

5 - 25 the graph is drawn and labelled.
160 - 290 the prey recruitment curve is drawn.
300 - 460 predator functional response curve is introduced.
470 - 710 predator functional response curve is plotted.
720 - 890 positive and negative curves are discussed.
976 - 1140 a question on the number of equilibrium points is asked.
1150 - 1320 equilibrium point #1 is used in a simulation on stability.
1520 - 2285 a question regarding other stable equilibrium points is asked.
2286 - 2360 predator carrying capacity is introduced as a parameter.
2470 - 2830 the predator carrying capacity is changed by the user.
2840 - 3030 the possibility of a different number of equilibrium points is brought up.
3040 - 3250 the predator carrying capacity is changed by the user.
3260 - 3470 the number of equilibrium points is checked.
3480 - 3690 the next section of the module is set up.
3700 - 3910 the subprogram PRED FUNCT2 is run.

SUBROUTINES
4000 - 4070 subroutine that flashes spaces between curves.
4100 - 4310 subroutine that alternately colors and darkens spaces between two curves.
5000 - 5070 PAUSE subroutine.
5080 - 5130 press RETURN subroutine.
5140 - 5270 HGR block erasing subroutine.
5280 - 5600 graph drawing subroutine.
5610 - 5680 point scaling and plotting subroutine.
10000 - 10330 DATA statements containing X and Y coordinates for prey recruitment and predator functional response curves.
PRED FUNCT2
Line numbers

5 - 30  REMARK statements.
160 - 500  a change in scale is introduced.
510 - 610  the prey recruitment curve is plotted.
620 - 780  predator functional response curve is plotted.
790 - 990  the concept of subtracting curves is introduced.
1000 - 1790 simulation that subtracts curves.
1800 - 2010 the simulation is repeated using a new starting prey density.
2020 - 2100 the concept of additional parameters is brought up.
2110 - 2140 the subprogram PRED FUNCT3 is run.

SUBROUTINES
5000 - 5070  PAUSE subroutine.
5080 - 5130  press -RETURN- subroutine.
5140 - 5270  HGR block erasing subroutine.
5280 - 5600  graph drawing and labelling subroutine.
5610 - 5680  point scaling and plotting subroutine.

PRED FUNCT3
Line numbers

5 - 25  REMARK statements.
140 - 370  hunter pressure is introduced.
380 - 500  prey recruitment curve is plotted.
510 - 650  hunter pressure is plotted.
660 - 780  the concept of positive and negative curves is applied.
790 - 890  the two curves are subtracted.
900 - 1000 predator functional response is plotted.
1010 - 1210 a hypothetical situation is introduced.
1220 - 1490 hunter pressure is input by the user.
1500 - 1660 the prey recruitment curve is lowered to account for hunter pressure.
1670 - 1830 the user increases hunter pressure.
1840 - 2110 the loss of a stable equilibrium due to hunter pressure is demonstrated.
2120 - 2430 hunter pressure is taken away.
2440 - 2730 conclusion for the entire module.

SUBROUTINES
4000 - 4080  PAUSE, RETURN, PAUSE; VTAB subroutine.
4100 - 4300  subroutine that erases one curve while plotting another.
4400 - 4480  subroutine that plots predator functional response.
5000 - 5130  press -RETURN- subroutine.
5140 - 5270  HGR block erasing subroutine.
5280 - 5600  graph drawing and labelling subroutine.
5610 - 5680  point scaling and plotting subroutine.
DATA statements containing X and Y coordinates for prey recruitment curve and predator functional response curve.
VARIABLE LIST

'PRED FUNCT INTRO

COUNT - flag variable used to ask a question twice.
D$ - Disk Operating System variable.
D1 - change in prey population with change in time.
FLAG - flag in HGR string drawing subroutine.
K - prey carrying capacity.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
LXA - axes drawing subroutine. Length of X-axis.
LYA - axes drawing subroutine. Length of Y-axis.
N - prey population number.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
R - intrinsic rate of growth of prey population.
T - loop variable representing time interval.
TA - HGR block erasing subroutine. Loop variable.
X - graphing subroutine. X coordinate.
X$ - axes labelling subroutine. X-axis label.
X0 - axes labelling subroutine. X-axis label starting X coordinate.
X1 - axes drawing subroutine. Starting X coordinate.
X8 - storage variable for X coordinate of previous prey recruitment point.
X9 - storage variable for X coordinate of previous logistic curve point.
XA - HGR string drawing subroutine. Starting X coordinate.
XM - graph subroutine. Maximum X value.
XZ - HGR block erasing subroutine. Width along X-axis to be erased.
Y - graphing subroutine. Y coordinate.
Y0 - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1 - axes drawing subroutine. Starting Y coordinate.
Y8 - storage for Y coordinate of previous prey recruitment point.
Y9 - storage for Y coordinate of previous logistic curve point.
YA - HGR string drawing subroutine. Starting Y coordinate.
YM - graphing subroutine. Maximum Y value.
YM$ - graphing subroutine. Maximum Y value.
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
Z$ - graph labelling subroutine. String to be drawn.
Z0 - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.
ZF - graphing subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.
ZX - HGR string drawing subroutine.

VARIABLE LIST

PRED FUNCT1
A - space flashing subroutine. Starting X value.
B - space flashing subroutine. Ending X value.
CA - multiple space flashing subroutine. Counter for first space to be colored.
CB - multiple space flashing subroutine. Counter for second space to be colored.
CC - multiple space flashing subroutine. Counter for third space to be colored.
CD - multiple space flashing subroutine. Counter for fourth space to be colored.
CE - multiple space flashing subroutine. Flag used to flash all four spaces or just two.
COUNT - flag to replot predator functional response curve.
D$ - Disk Operating System variable.
DD - density of prey that generate half-maximal feeding.
E - parameter associated with the amount of increase in the rate of detection of a prey individual with an increase in food density.
H1 - multiple space flashing subroutine. HCOLOR of first space.
H2 - multiple space flashing subroutine. HCOLOR of second space.
H3 - multiple space flashing subroutine. HCOLOR of third space.
H4 - multiple space flashing subroutine. HCOLOR of fourth space.
HC - space flashing subroutine. HCOLOR of space.
I - loop variable.
KF - predator carrying capacity.
KK - temporary storage for previous predator carrying capacity.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
LG - multiple space flashing subroutine. Loop size.
N - prey population number.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
R - intrinsic rate of growth of prey population.
SC - graph labelling subroutine. Scaling variable.
ST - space flashing subroutine. Loop step size.
T - loop variable representing time interval.
TA - HGR block erasing subroutine. Loop variable.
WRITE - graph labelling subroutine. Flag for text statements.
X - graphing subroutine. X coordinate.
HX block erasing subroutine. Starting X coordinate.
X$ - axes labelling subroutine. X-axis label.
X0 - axes labelling subroutine. Starting X coordinate of X-axis label.
X2( - X coordinates for the two curves.
XM - graphing subroutine. Maximum X value.
XZ - HGR block erasing subroutine. Width along X-axis to be erased.
Y - graphing subroutine. Y coordinate.
YO - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1( - Y coordinates for prey recruitment curve.
Y2( - Y coordinates for predator functional response curve.
YE - equilibrium point #3.
YM - graphing subroutine. Maximum Y value.
YS - equilibrium point #1.
YU - equilibrium point #2.
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
ZO - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.
ZF - graph subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.

VARIABLE LIST
PRED FUNCT2
COUNT - counter of time intervals to reach equilibrium.
CT - flag to skip mandatory input of new starting prey density.
D$ - Disk Operating System variable.
DD - density of prey that generate half-maximal feeding.
E - parameter associated with the amount of increase in the rate of detection of a food item with an increase in food density.
H - Loop variable.
I - loop variable.
J - storage for previous I value.
KF - predator carrying capacity.
L - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$ - axes labelling subroutine. Axis label.
PAUSE - PAUSE subroutine. Pause length.
PS - PAUSE subroutine. Pause loop variable.
R - intrinsic rate of growth of prey population.
SC - graph labelling subroutine. Scaling variable.
TA - HGR block erasing subroutine. Loop variable.
TP - temporary storage of previous Y coordinate of predator functional response curve point.
X - graphing subroutine. X coordinate.
X$  - axes labelling subroutine. X-axis label.
X0  - axes labelling subroutine. Starting X coordinate for X-axis label.
X2( - X coordinates for the two curves.
XM  - graphing subroutine. Maximum X value.
XX  - storage of difference between the two curves, subtracted from the X-axis.
XZ  - HGR block erasing subroutine. Width along X-axis to be erased.
Y   - graphing subroutine. Y coordinate.
YO  - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1() - Y coordinates for prey recruitment curve.
Y2() - Y coordinates for predator functional response curve.
YE  - equilibrium point #3.
YM  - graphing subroutine. Maximum Y value.
YS  - equilibrium point #1.
YU  - equilibrium point #2
Z   - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
ZO  - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3  - graph labelling subroutine. Variable equal to numbers along axes.
ZF  - graphing subroutine. Flag to plot line or dot graph.
ZG  - graphing subroutine. Flag to start plotting line or dot graph.

VARIABLE LIST

PRED FUNCT3

FLAG - curve erasing, curve plotting subroutine. Flag to erase hunter pressure line.
HC  - curve erasing, curve plotting subroutine. HCOLOR of to be plotted.
HO  - storage variable for previous hunter pressure.
HP  - hunter pressure as a percentage of prey density.
HTEMP - storage for hunter pressure.
I   - loop variable.
L   - HGR block erasing subroutine. Length along Y-axis of block to be erased.
L$  - axes labelling subroutine. Axis label.
N   - prey population number.
PAUSE - PAUSE subroutine. Pause length.
PS  - PAUSE subroutine. Pause loop variable.
Q$  - press RETURN subroutine. Input variable.
SC  - graph labelling subroutine. Scaling variable.
TA  - HGR block erasing subroutine. Loop variable.
WRITE - graph labelling subroutine. Flag text statements.
X   - graphing subroutine. X coordinate.
X$  - axes labelling subroutine. X-axis label.
X0  - axes labelling subroutine. X-axis label starting X coordinate.
X2() - X coordinates for the two curves.
X7 - storage variable for previous recruitment curve minus HP X coordinate.
X8 - storage variable for previous HP X coordinate.
X9 - storage variable for previous recruitment curve X coordinate.
Y - graphing subroutine: Y coordinate.
Y0 - axes labelling subroutine. Starting coordinate for Y-axis label.
Y1() - Y coordinates for prey recruitment curve.
Y2() - Y coordinates for predator functional response curve.
Y7 - storage variable for previous recruitment curve minus HP Y coordinate.
Y8 - storage variable for previous HP Y coordinate.
Y9 - storage variable for previous recruitment curve Y coordinate.
Z - HGR string drawing subroutine. Loop variable equal to the length of the string to be drawn.
Z0 - graph labelling subroutine. Flag for printing horizontally or vertically.
Z3 - graph labelling subroutine. Variable equal to numbers along axes.
ZF - graphing subroutine. Flag to plot line or dot graph.
ZG - graphing subroutine. Flag to start plotting line or dot graph.
APPENDIX B

Predator Functional Response

Module Performance Objectives

Following is a list of the 19 performance objectives developed for the PFR module. The numbers in parentheses preceding each objective refer to the posttest items that test for that particular objective.
PFR Performance Objectives

After running the PFR module the student should be able to:

(1) recognize the definition of prey recruitment.

(2) correlate predator functional response with prey losses.

(3) predict the effect of different predator carrying capacities.

(4) identify by recognition the shape of a hunter pressure curve.

(5) predict the shape of the prey recruitment curve, given the prey growth curve.

(18) identify equilibrium points on a prey recruitment-predator functional response graph.

(6,7) identify the stability of equilibrium points on a prey recruitment-predator functional response graph.

(8,9) predict the direction that a chosen prey density will go to approach equilibrium.

(8) predict the time interval involved for a chosen prey to approach equilibrium.

(9) predict the changes in the system due to a change in the number of predators.

(10) identify equivalent points on a prey growth curve and a prey recruitment curve.

(11) predict which point on the prey recruitment curve represents prey carrying capacity.
(12) Identify the point of maximum prey growth on the prey recruitment curve.

(13) Recognize the definition of a stable equilibrium point.

(14) Recognize the effect of hunter pressure.

(15) Recognize the definition of predator functional response.

(16) Identify the curve that is affected by satiation.

(17, 20) Identify the reasons for the shape of the predator functional response curve.

(19) Recognize how hunter pressure affects prey recruitment.
Following is a copy of the posttest used in the PFR module vs. lecture comparison. For the correct responses, please refer to page C8. Appendix B contains the list of performance objectives which this posttest tested for.
1. Which of the following best describes prey recruitment?
   Prey births minus:
   a) prey deaths as a function of time.
   b) prey deaths as a function of prey density.
   c) nonpredator related deaths as a function of time.
   d) nonpredator related deaths as a function of
   prey density.
   e) predator related deaths as a function of prey
   density.

2. Which one of the following curves represents
   subtractions from the prey population?
   a) prey recruitment curve.
   b) predator functional response curve.
   c) predator numerical response curve.
   d) prey growth curve.
   e) none of the above.

3. Which of the following would result in the predator
   functional response curve leveling off at a higher level?
   a) a decrease in the number of hunters.
   b) a decrease in the number of prey.
   c) an increase in predator carrying capacity.
   d) an increase in the number of hunters.
   e) an increase in the number of prey.

4. Studies have shown that the shape of a hunter pressure
   curve tends to be
   a) sigmoid.
   b) hyperbolic.
   c) logistic.
   d) exponential.
   e) linear.
5. Which one of the following prey recruitment curves corresponds to the given prey population growth curve?

a)

b)

c)

d)

e) None of the above.

6. When only one equilibrium point exists in a prey recruitment-predator functional response graph, that equilibrium point is:

a) neutral.
b) transitory.
c) stable.
d) unstable.
e) none of the above.
Items 7 - 9 pertain to the following graph.

7. Point A is
   a) stable.
   b) unstable.
   c) neutral.
   d) transitory.
   e) none of the above.

8. If the prey density of an area is starting at point F, it would approach a stable equilibrium point in a
   a) shorter time than a prey density starting at point G.
   b) longer time than a prey density starting at point G.
   c) time interval about equal to that which a prey density starting at point G would.
   d) time that cannot be compared to that of the prey density starting at point G.

9. If the prey density is at equilibrium point J, what would be the result of removal of all predators?
   The prey density would:
   a) decrease to a lower stable equilibrium point.
   b) decrease to an unstable equilibrium point.
   c) stay at point J because it is a stable equilibrium.
   d) increase greatly due to lack of predators.
   e) increase slightly to the prey carrying capacity.
10. Point T on the prey growth curve is equivalent to which point on the prey recruitment curve?
- a) A
- b) B
- c) C
- d) D
- e) The two curves are not related.

11. Which point on the given prey recruitment curve represents growth at the prey carrying capacity?
- a) A
- b) B
- c) C
- d) D
- e) Cannot be determined from the prey recruitment curve.

12. Which point on the above prey recruitment curve most closely represents maximum prey population growth rate?
- a) A
- b) B
- c) C
- d) D
- e) Cannot be determined from the prey recruitment curve.
13. An equilibrium point is said to be stable when the prey density will
   a) NOT move from that point.
   b) change at a single, stable rate.
   c) tend to move away from that point when disturbed.
   d) tend to move toward a neutral point when disturbed.
   e) tend to return to that point when disturbed.

14. Increasing hunter pressure has the effect of
   a) lowering the predator functional response curve.
   b) lowering the prey recruitment curve.
   c) raising the predator functional response curve.
   d) raising the prey recruitment curve.
   e) none of the above.

15. The predator functional response curve represents the growth of
   a) the predator population.
   b) an individual predator.
   c) the prey population.
   d) hunter pressure.
   e) none of the above.

16. Satiation affects which of the following?
   a) the predator functional response curve.
   b) the prey recruitment curve.
   c) the prey growth curve.
   d) the predator population growth curve.
   e) none of the above.

17. The predator functional response curve levels off because
   a) the prey population can grow no larger.
   b) the predator population can grow no larger.
   c) the prey response is limited.
   d) the predator can eat only so many prey.
   e) none of the above.
Item 18 pertains to the following graph.

18. On the above graph, how many equilibrium points are there in this predator-prey system?
   a) 1
   b) 2
   c) 3
   d) 4
   e) more than 4.

19. To account for hunter pressure:
   a) divide hunter pressure by prey recruitment.
   b) divide prey recruitment by hunter pressure.
   c) add prey recruitment to hunter pressure.
   d) subtract prey recruitment from hunter pressure.
   e) none of the above.

Item 20 pertains to the following graph.

20. The predator functional response curve rises rapidly between point A and point B because
   a) there is a rapid increase in prey density.
   b) there is a rapid increase in predator density.
   c) the predators switch to the prey studied.
   d) the predators switch away from the prey studied.
   e) none of the above.
APPENDIX D
Random Division Program

Following is a copy of the Apple microcomputer program that was used to randomly divide the BL340 Animal Ecology students into two groups. It worked by associating each student's name with a random number between zero and one, then ranking these numbers from lowest to highest. By a flip of a coin it was decided that students associated with the lowest 15 random numbers were to be the module group, and the remaining students would make up the lecture group.
50 REM RANDOM DIVISION
60 REM THIS PROGRAM IS DESIGNED TO DIVIDE THE BL340
CLASS INTO HALF RANDOMLY.
100 DIM ST$(30),NUMBER(30)
105 HOME
110 FOR I = 1 TO 30
120 READ ST$(I)
130 NUMBER(I) = RND(I)
140 NEXT
150 FOR I = 1 TO 29
160 FOR J = I+1 TO 30
170 IF NUMBER(I) < NUMBER(J) GOTO 240
180 X$ = ST$(I)
190 Y = NUMBER(I)
200 ST$(I) = ST$(J)
210 NUMBER(I) = NUMBER(J)
220 ST$(J) = X$
230 NUMBER(J) = Y
240 NEXT
250 NEXT
251 PRINT "THESE STUDENTS WILL REPORT TO ROOM 1105 ON WEDNESDAY AT 11 A.M."
THESE STUDENTS WILL REPORT TO ROOM 1195 ON WEDNESDAY AT 11 A.M.

BROOKS
HUNT
DIMEUSE
SANCH
LINSE
HEALEY
NOH
ZETYE
MALCHON
MHITIRE
LINTON
RICHARDS
ROSICK
TAPANINEN
MOHRING

THESE STUDENTS WILL REPORT TO ROOM 406 ON WEDNESDAY AT 11 A.M.

KINDSBERG
ONEILL
NISOL
HOLMES
HRIGHT
AMPA
LIGHRAD
BARNEY
LEDGETTER
TRENNAINE
HOG
DALE
WHRD
VAUGHT
HUTCHINGS

This is the official division that was used.
Following is a written transcript of the lecture given to the Animal Ecology lecture group. This was made from a videotape of the lecture, which is available upon request.
Wow, only three people skipped out.

What I've got to do today is talk to you about my research for the past few months. We're doing a test, as you know, where half the class is looking at functional response disks, or modules, upstairs, and the other half of the class is you lucky people who get to listen to me talk for approximately 40 to 45 minutes, I don't know. I'll talk until about 20 to or someplace in there and then try and get some questions in; and then the rest of the class is going to come down here, and you all are going to take a posttest. It will be timed from quarter to until noon, right on. You should get done in plenty of time, though.

OK, my topic today is predator functional response and its relationships to prey recruitment, and since many people haven't heard of either one of those things, I have to start from the beginning. First I'd like to start by talking about a prey population growth curve. You've all seen prey population growth curves, but I thought I'd draw one out for you anyway, just to give you a good start on my fantastic drawings.

This is a prey population growth curve. As you can see at the beginning here it starts out with exponential growth of the population. (NOTE: The first part of the curve is pointed to.) And at the top it levels off because environmental carrying capacity takes over. (NOTE: The part of the curve that levels off is pointed to.)

Now, if you look at this curve, can anyone tell where the population growth is the highest? And that means where the most prey are added to the population. At what prey density would that be at? Yell out something. (NOTE: Several students respond with the correct answer.)

OK, alot of people might not notice that, but where the slope is the steepest, that's where the prey population growth is the highest. Sometimes it's a hard concept to catch, so some fantastic person came up with the idea of a prey recruitment curve (NOTE: The prey recruitment curve axes on overhead #1 are revealed) where they graph prey density as the independent variable along the bottom (NOTE: The x-axis is pointed to) and along the side they put prey growth per time, which is the number of prey added per a unit of time.

I'll show you how these prey recruitment curves come about. If you start at a low prey density, say here (NOTE: a point of low prey density was pointed to on the prey population growth curve) and you went for one unit time, and say one unit time is half an inch along this axis; if...
PREY POPULATION GROWTH CURVE

PREY RECRUITMENT CURVE

PREY RECRUITMENT

All prey births minus nonpredator related deaths per unit time.
you went across, then up, you’re only going up a little bit, (NOTE: This is drawn on the overhead with a marker) like so. Hope that looks OK. My hand’s a little shakey today, excuse me.

So that means at low prey density the prey growth per time is also low, so the point would be somewhere in there (NOTE: The corresponding point is plotted on the prey recruitment curve) on your prey recruitment curve.

Now if you went into where the prey growth is really high, like in here somewhere (NOTE: The steep part of the prey population growth curve is pointed to), you’re going to go up a long ways (NOTE: Lines over one time unit, then up to the curve are drawn).

So if you go to a medium prey density here (NOTE: medium prey density on the prey recruitment curve is pointed to) it’s going to be very high growth, so we’ll put a point right here (NOTE: this point is plotted on the prey recruitment curve).

And then if you go up by the carrying capacity and do the same thing you'll have very low growth again (NOTE: this point is plotted on the prey recruitment axes).

The whole effect is that a prey recruitment curve is shaped something like this, (NOTE: a prey recruitment curve is drawn using the axes and plotted points on the overhead.) OK?

Not bad, I hit every point. This is a prey recruitment curve. What we’re talking about is that, I forgot to tell you, this prey population growth curve is in the absence of predators at this time. So this prey recruitment curve is also calculated with no predators around. This is how they'd grow if there were no predators in the area.

With this in mind we could define prey recruitment as all prey births minus nonpredator related deaths per unit time.

That makes sense because the prey recruitment is the number of prey added to the population at different prey densities. If you’re taking all the prey births per unit time at that prey density and subtracting all the nonpredator related deaths, then you’ll come up with the net gain at different prey densities.

So now you know what a prey recruitment curve is. Next we go to the predators and start looking at them. You've all seen predator numerical response. That's when the predators respond to a change in prey density by changing their numbers. Like with the lynx-hare populations, when the hare population goes really high, the lynx population starts to follow it. That's predator numerical response.

For today we're interested in predator functional response. What that is is the change in predator behavior in response to prey density. Predator functional response is graphed on these axes (NOTE: overhead #2 is displayed - PFR axes with PFR definition written below). These are the axes that predator functional response is usually graphed on.
PREDATOR FUNCTIONAL RESPONSE CURVE

PREY KILLED PER PREDATOR / TIME

PREY DENSITY

PREDATOR FUNCTIONAL RESPONSE

A change in predator behavior in response to prey density.
It is the prey killed per predator, this is for a SINGLE predator, per unit of time, and it's as a function of prey density.

I said that predator functional response is a change in predator behavior in response to prey density. That predator behavior is the number of prey that predator eats.

To draw out a general shape of a predator functional response curve, what you do is think about it for a minute. At really low prey densities the predator's got to live, so he has to kill nearly every prey he runs into because he's got to survive. So the curve is going to be generally increasing at first (NOTE: this was plotted on the axes on the overhead) and then once you get up a little ways in the prey density the predator can only eat so much. Like, if he can only eat five prey it doesn't matter if there are five prey per acre or 50 prey per acre. He's only going to kill five and eat them. So the curve levels off at higher prey densities. (NOTE: This section of the PFR curve is plotted on the overhead.)

That's generally the shape of a predator functional response curve. It's constantly increasing until it hits where predators are satiated. That's the term: predator satiation. Then the curve levels off.

This curve is for a single predator. If you had a study area, like Isle Royale for example, where you had 10 wolves instead of one wolf. Instead of a single predator you had multiple predators, a bunch of them. And you still wanted to see the predator functional response curve for this. You can so that, too. Next I'll show you an example of that. I'll draw that on the board.

We use about the same axes. You have prey density along the bottom again. (NOTE: axes are drawn on the blackboard: The X-axis is labelled: "prey density".) The only difference in the axes is that this (NOTE: the Y-axis is pointed at) is prey killed by a fixed number of predators, say 10 wolves, instead of a single predator. That's the difference in this. Plus we're going to make an assumption to show you a different kind of predator functional response curve. We'll make the assumption that these predators have an alternate food source so that when prey density is really low they can live on something else. (NOTE: a student walks in late.)

So at low prey densities the predator is living on something else, so they don't have to worry about this prey at all. In fact, they don't even go searching for them or anything. So the curve doesn't go up very quickly, just slow and easy. (NOTE: the low prey density section of the curve is drawn on the blackboard.)

But at a certain prey density the predators start to notice these prey and they say, "These look good." They learn how to hunt them and they learn that they taste good and everything. So they sort of learn how to kill these prey and how to eat them. And hunt them. So the curve goes
up very rapidly at a very small increase in prey density. 
(NOTE: the mid-prey density section of the curve is plotted on the blackboard.) 
(NOTE: a second student walks in late.) 

At the top, again predator satiation comes into effect, so the curve levels off, like that. (NOTE: the rest of the PFR curve is drawn on the blackboard.) 

This is another type of predator functional response curve, and this is for a fixed number of predators. I drew a neater example of this on the overhead. (NOTE: overhead #3 is displayed.) Here's the same type of thing. Now if we study the predator and the prey for this area, we can put the prey recruitment curve on about the same graph and look at some relationships. (NOTE: overlay overhead #4 on #3.) 

This is with prey recruitment and predator functional response on the same graph. Notice the Y-axis for the blue line, which is the prey recruitment curve, is prey growth per time, which is prey added to the population. The red line, the predator functional response curve, is prey killed per time, or prey subtracted from the prey density per unit time. 

If you look at this as a positive line (NOTE: the prey recruitment curve is pointed at) and a negative line (NOTE: the PFR curve is pointed at), you can find some relationships in the curves. I'd like to talk to you about some of them. 

The first one I'd like to talk about are equilibrium points. Equilibrium points are when the prey additions to the population and prey subtractions are equal. So the prey density will stay at one point; it will not change. We have equilibrium points wherever the two curves intersect. I'll number these. (NOTE: the three equilibrium points on the overheads were numbered.) We have three equilibrium points in this predator-prey relationship. If the prey density is at any of these three equilibrium points, it's not going to move away from that equilibrium point. It will tend to stay there. At least if something doesn't come along and screw it up. 

Next I'd like to talk about stability of equilibrium points. For that I'll use equilibrium point number one as an example. If prey density is right on that point, that means prey additions and prey subtractions from the population are equal; so it's going to stay right there. But if the prey density is a little bit below equilibrium point number one, then you'll see that the blue line, which is additions to the population, is higher than subtractions from the population, or the functional response curve. So if additions to the population are higher than subtractions from it, then you can expect the prey density to move up because you're adding to the population and the prey density. If the prey density is in this area, it's going to move up to equilibrium point number one and then stop. If the prey density was above equilibrium point number one, in
this area right-here (NOTE: the area of the graph between equilibrium points #1 and 2 is pointed to), then you can see that the functional response curve is higher. That means that subtractions from the population are higher than additions. So the prey density is going to move down. So if the prey density is in this area, it is going to tend to move down to equilibrium point number one.

So if the prey density is in the area of equilibrium point number one, it is going to tend to move to that point. If it moves to that point, that means we call equilibrium point number one stable.

If equilibrium point number one is stable, then by the same reasoning equilibrium point number three is also stable, because if the prey density is anywhere in that area, it will tend to move toward equilibrium point number three. And equilibrium point number two is unstable by the same reasoning because if anything is in that area it will move toward one or three, not towards two. So that's what stability means for these points.

Another thing we can look at is how quickly prey density moves to the equilibrium point, or the stable point. I guess I'll do that on the board. (NOTE: the graphs for prey recruitment and type II PFR are drawn on the blackboard.)

This is our prey recruitment-predator functional response curves. A little messy, but...

If we're at any prey density you can figure out which way the prey density is going to move and how fast it's going to move.

(NOTE: a third student arrives late.)

So let's just pick a prey density, say right there. (NOTE: a prey density was chosen on the blackboard graph.)

We want to see which way it's going to move first. Is it going to go up or is it going to go down? If we're there, then we're there, then we're here on the curves. Since this is the prey recruitment curve on top, that means additions are more than subtractions again. So the prey density is going to tend to increase.

We know the direction. Now we're wondering how fast it's going to move to the stable equilibrium point number three. To do that you have to reason this out a little bit. You think about it, and you say that this difference between prey recruitment and predator functional response is the change in prey density in a unit of time. This is how much prey density is going to be added in a unit of time. If this is prey density (NOTE: the X-axis, prey density, was pointed to) then all you have to do is add it to the prey density, the X-axis, to figure out where you'll be for your next unit of time. So if we just take this section and lay it on its side, we'll see where we'll be for the next unit of time. (NOTE: this is drawn on the blackboard.) And if we keep doing that, laying this one over, and again, and keep going until you get to the stable point number three.
equilibrium point, you get a general idea of how long it's going to take for the prey to get from here (NOTE: the original starting prey density) to the stable equilibrium point. You can do that using any prey density and compare. Like if you were here (NOTE: another starting prey density is pointed to) you could figure it out how long it would take to go that way. That's what I wanted to show you with that.

The next thing I've got to talk about is the effect of predator carrying capacity on this whole system. If we have a fixed number of predators in an area -- that's what we're studying right now with these curves -- and some environmental change occurs that allows more predators to live in that area, so we'll still be studying a fixed number of predators, but the number will be higher than before. What that does is move this curve up farther because more predators can eat more prey and so the subtractions from the prey density are going to be more.

I have an example of that. (NOTE: overhead #5 is displayed.) Here is a rather radical example of that. Again the red curve is the predator functional response curve and if you increase the predator carrying capacity quite a ways then the curve is going to go up so high that you're going to lose your two equilibrium points that were right down there. Can anyone tell me if that's a stable or unstable equilibrium point?

(Note: several students volunteer the correct response.)

Very good! It's stable because down here the prey recruitment curve is higher than the predator functional response curve, so additions are higher, so it's going to move up towards the point if it's down in this area. And if it's up in here, anywhere up in here, the predator functional response curve is higher. That means subtractions are higher than additions and so the prey density is going to move down until it hits that point.

(Note: the equilibrium point is pointed to.)

So that equilibrium point is stable. That's pretty much what I wanted to talk about for carrying capacity.

There's another parameter... This is a pretty simple, and theoretical system. There are a lot of things you could add to it. One of the things I've studied is the addition of human hunting pressure on the whole system and seeing what happens.

I'll do this on the board. If we have a prey recruitment curve for an area (NOTE: a prey recruitment curve is drawn on the blackboard) and we want to model in human hunting pressure on the prey; studies have been made on this and they've found that human hunting pressure pretty much is a linear function of prey density. If we wanted to graph human hunting pressure, say 2% of the prey population, we'd come up with something like this. (NOTE: a straight line graph is drawn over the prey recruitment curve.)
curve). Now, the prey recruitment curve, if it's prey births minus nonpredator related deaths, and we say that the human harvest are nonpredator related deaths, that means that this subtraction could be taken out from up here, and the whole prey recruitment curve would be moved down a little bit. We'd have a new prey recruitment curve that takes into account hunting pressure. So if we take a few points for example... This whole curve would just move down, and we'd have a new prey recruitment curve that took into account hunter pressure. While all of this is going on the predator functional response curve is completely unrelated to hunter pressure, so that thing is unchanged no matter what. (NOTE: a type III predator functional response curve is drawn over the new prey recruitment curve.) That just looks like this all along. So that doesn't move; no matter what you do, the predator functional response curve stays the same.

I was going to talk about improper management. Now I'd like to show you an example of game management, and how it can be improperly done, and what the consequences can be to the prey density of an area. Let's say, back to the overheads, that you're managing an area with prey recruitment - predator functional response curves that look like this. (NOTE: the upper half of overhead #6 is displayed.) Let's say your prey density with no hunting pressure at all is at the upper point here. (NOTE: equilibrium point #3 is pointed to.) So you have really high prey density for the area and everything's going along nicely. It's at a stable equilibrium point and everything. But you want to get some hunters into your area because hunters bring in money, and you always need some money in the area, it seems like. So, to help the financial outlook of your district you think about it and say that you'll allow 3% of the prey to be taken out by hunter harvest. If you do that, the curves would look like this. (NOTE: the bottom half of overhead #6 is uncovered.) The dotted blue line is the original prey recruitment curve with no human hunting taken into account. And the solid blue curve is the curve with the 3% hunter pressure taken into account. That doesn't mean you're killing the hunters! It means the hunters are killing 3% of the prey.

If you look at this you can see that 3% wasn't too bad because your stable equilibrium was there. It's only moved a little bit. So your prey density moves down to here and then stops again. Your prey density hasn't gone down very much.

But let's say that you make a mistake and say to take out 15% because things look pretty good. What could happen is this curve. (NOTE: the upper half of overhead #7 is displayed.) If this dotted line is prey recruitment with no hunter pressure figured in, and this solid blue curve is the prey recruitment curve with 15% of the prey population being taken out by hunters. You see that you've lost your...
upper stable equilibrium point completely. You've lost your unstable equilibrium point. So if your prey density was up there (NOTE: equilibrium point #3 is pointed to) and suddenly switched to this curve, what would happen to the prey density?

(NOTE: a student gives the correct response.)

It's going to move down because predator functional response, subtractions, are so high from the population compared to additions, that the prey density will move along that line until it finally gets down to this equilibrium point. You can see that this equilibrium point is at a low density, extremely low. That could make it possible for a Hard winter, or anything, to knock off the prey completely in an area.

If something like this happens, the first thing that most wildlife managers would do would be to take away the hunting pressure and let the prey density move back up to the upper stable equilibrium point. Then you'd have lots of prey again. Then you could have better management.

But if you do that, there's a problem because...

(NOTE: the lower half of overhead #7 is uncovered) if this was your old curve, and you took all hunting away, you'd have this new curve. But the problem is that your old equilibrium point was here, and that's where your prey density was, and suddenly you change things around again, your prey density is only going to move up to the first stable equilibrium and it's not going to move beyond there. So you're not going to get your original system back by removing hunting pressure on the prey. That's been a problem. That may be a problem with wildlife management now. They might be able to use these curves someday, once they've developed a little better.

(NOTE: a student raises his hand.)

Yeah, Kyle?

(NOTE: a question is asked concerning habitat improvement to raise the prey recruitment curve.)

That's a possibility. But most wildlife managers don't believe in curves like this or use them or even know about them. This is just one theory on how prey density can move down and suddenly can't move back up for some reason after excessive hunting. The thing is, now, if you have a system with an equilibrium point there (NOTE: the lower equilibrium point is pointed to) it's not going to move up naturally. If you leave it to nature it's just going to stay there because everything is at a stable equilibrium, humming along nicely. But there are other ways of getting the point back up, but you have to intervene and change habitat and things of that sort, like Kyle said.

Any more questions?

I'll throw in a little conclusion because I'm ahead of schedule. What we've talked about, then, is the prey population growth curve and how we got the prey recruitment curve from that. Then we talked about the predator
functional response curve and how that came about; the
general shape of it, showing that it's generally increasing
until it levels off due to predator satiation.

We talked about how fast the prey density will
approach an equilibrium point. We talked about equilibrium
points, if they're stable or unstable. We talked about
 predator carrying capacity and how that changed the
functional response curve, moves it up or down. And we also
talked about human hunting pressure. Other than that, if
there aren't any questions we can relax for seven or eight
minutes until the rest of the class comes down. Then we'll
take a posttest.

(NOTE: a student raises his hand.)
Got a question, Dale?

(NOTE: a question is asked concerning the theoretical
nature of the curves.)

These are quite theoretical right now. The curves
themselves are accepted, but when you put them together,
there is still a lot of theory involved and a lot of
argument. Like these started in the 1950's, but since then
these curves have not been more developed. People have
accepted them from back then and worked with that. But then
they don't put predator and prey together, usually. There's
got to be a lot of work done before this is accepted.

(NOTE: a question is asked concerning the simplicity
of the model.)

There are a lot of environmental parameters that
aren't in this model, like hard winters and things of that
sort, and different years for vegetative growth. That would
move these curves all over the place. There are a lot of
studies to be done yet.

Anybody else?

(NOTE: a question is asked concerning why the prey
density remains at the lower equilibrium point after
hunting pressure is removed.)

The curve itself is the same; it's just that the prey
density is stuck down here because when you put on all that
hunting pressure the prey density was forced to drop all
the way down to this equilibrium point, right? So that
means that equilibrium point is right there when you take
the hunting pressure off, and these two original curves
come about again. So that means that this prey density can
only move up to that stable equilibrium point. It can't get-
up to the upper stable equilibrium. It's kind of caught in
the big change there. That's the problem.

(NOTE: the instructor is asked to cover the speed of
prey density movement again.)

(NOTE: the axes and curves are drawn on the
blackboard.)

You have the two curves. If this is the change in
density per time, the predator functional response curve is
the negative change. The prey recruitment curve is the
positive change. Then if you take the difference...
the two curves, like right here, you have a section that is the net change. So if you have this net change in prey density, then you already know it's going to go in this direction because prey recruitment is the higher curve. Take that length and lay it on its side on the X-axis, and add it to the prey density. If this is the change in the prey density, then you can add that to what the prey density was and get the next time interval's prey density. Like if this time unit is per year, then that would be the change in the prey density per year. So you'd take that much, and for the next year you'd be adding this; taking the whole thing and laying it on its side. You'd come out there, and the next year your prey density would be up this high.

These curves have been developed from Alaska, the caribou, moose herds, and also in Canada.

(Note: hallway noise is heard.)

I gather everyone's here, so if there aren't any more questions, we can get this posttest going.

(Note: the module group comes in.)

(Note: the tests and computer answer sheets are handed out.)

Please don't start the test until I tell you to. Take one copy of the test and one copy of the answer sheet. I'd like it done in pencil if you could get one. The first thing you can do is put your name on the answer sheet and also what you did — if you were up looking at a module or here.

There are 20 questions; you'll have until on the hour to do this. And please answer on the answer sheet; don't write on the test itself. And notice that the answer sheet goes across with the numbers, not down.

You can start now.
APPENDIX F

Analysis of Covariance

The data to be analyzed consisted of the posttest scores and final course percentages for 24 students. These scores are listed in Table F1.

The Olmstead-Tukey's Corner Test was applied to the data for each group, lecture and module, to check for a relationship between the X (final course percentages) and the Y (posttest scores) variables. A relationship was indicated by the corner test.

Analysis of covariance was applied to the data to compare the lecture and module group posttest scores. This data analysis procedure adjusts the Y variable to the X variable (covariate), then compares the mean of these adjusted Y values. Table F2 summarizes the analysis of covariance results. The calculated F-value was less than one, which indicated no significant difference between the means of the adjusted posttest scores for the lecture and module groups.
TABLE F1. The raw scores for the module and lecture groups.

<table>
<thead>
<tr>
<th>Module</th>
<th>Lecture</th>
<th>Module</th>
<th>Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>76</td>
<td>87</td>
<td>16</td>
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<td>90</td>
<td>19</td>
<td>11</td>
</tr>
<tr>
<td>81</td>
<td>93</td>
<td>17</td>
<td>20</td>
</tr>
</tbody>
</table>

TABLE F2. Analysis of covariance table. SS(Y'), MS, and F are calculated from the means of the adjusted posttest scores.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS(X)</th>
<th>SS(Y)</th>
<th>SP</th>
<th>SS(Y')</th>
<th>MS</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trtmt</td>
<td>1</td>
<td>126.04</td>
<td>0.00</td>
<td>0.00</td>
<td>8.23</td>
<td>8.23</td>
<td>0.98</td>
</tr>
<tr>
<td>Error</td>
<td>22(21)</td>
<td>1541.92</td>
<td>285.33</td>
<td>409.83</td>
<td>176.40</td>
<td>8.40</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>23(22)</td>
<td>1667.96</td>
<td>285.33</td>
<td>409.83</td>
<td>184.63</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Following are the Applesoft program listings for the PFR module. This module consists of four subprograms: PRED FUNCT INTRO, PRED FUNCT1, PRED FUNCT2, and PRED FUNCT3.

Page G1
REM PRED FUNCT INTRO IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.

REM DESIGNED BY MARK SHALTZ, DR. J. D. SPAIN, AND DR. KENNETH KRAMER.

REM PROGRAMMED BY MARK SHALTZ.

REM THIS PROGRAM HAS DEVELOPED BY THE SUMIT I COURSEWARE DEVELOPMENT PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UNIVERSITY, HOUGHTON 49931.

REM THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENCE FOUNDATION UNDER GRANT NUMBER SED-7919051.

REM ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRESSED IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSARILY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.

REM POKE 232,0: POKE 233,08: SCALE = 1: ROT = 0: HCOLOR = 3

REM PRINT D$: "BLOAD SMALL CHARACTERS AT 800"

REM TITLE AND CREDITS ARE DISPLAYED.

REM HOME : HGR

REM SCALE = 4: HCOLOR = 3: ROT = 0

REM "PREDICTOR FUNCTIONAL RESPONSE"

REM XA = 31: YA = 50: GOSUB 6340

REM SCALE = 2

REM "FUNCTIONAL RESPONSE"

REM XA = 11: YA = 90: GOSUB 6340

REM HOME : HGR : TEXT : PAUSE = 500: GOSUB 5000

REM UTAB 7

REM "THIS MODULE WAS DEVELOPED FOR"

REM UTAB 9

REM "THE SUMIT I PROJECT"

REM PRINT "DEPARTMENT OF BIOLOGICAL SCIENCES"

REM PRINT "MICHIGAN TECHNOLOGICAL UNIVERSITY"

REM PRINT "HOUGHTON, MICHIGAN 49931: PAUSE = 600: GOSUB 5000

REM GOSUB 4050: UTAB 10

REM "PREDATORS DEPEND ON AN ACTIVELY GROWING PREY POPULATION FOR THEIR SURVIVAL. IF TOO FEW PREY ARE BORN, PREDATORS CANNOT SURVIVE."

REM "TO STUDY THIS RELATIONSHIP OF PREDATORS TO PREY, WE MUST FIRST LOOK AT THE PREY IN THE ABSENCE OF PREDATORS."

REM "PAUSE = 1000: GOSUB 5000: UTAB 10"

REM "PRINT "TO STUDY THIS RELATIONSHIP OF PREDATORS TO PREY, WE MUST FIRST LOOK AT THE PREY IN THE ABSENCE OF PREDATORS."

REM "PAUSE = 500: GOSUB 5000: GOSUB 5000"

REM
370 REM THE LOGISTIC GROWTH CURVE IS INTRODUCED.
380 REM

390 X$ = "TIME"
400 Y$ = " "
410 YH$ = "50"
420 Y1$ = VAL (YH$)
430 XH$ = 100
440 XL$ = 30
450 Y1 = 109
460 LYA = 70
470 LXA = 80
480 HOME : HGR:
490 PAUSE = 500: GOSUB 5000
500 GOSUB 30600
510 Z0 = 1: X0 = 12: Y0 = 94: L$ = "PREY": GOSUB 30780
520 Z0 = 1: X0 = 22: Y0 = 101: L$ = "DENSITY": GOSUB 30780
530 XA = 96: YA = 112
540 Z$ = "HERE IS AN EXAMPLE"
550 GOSUB 6340
560 Z$ = "OF A POSSIBLE PREY"
570 GOSUB 6340
580 XA = 141: YA = 60
590 Z$ = "GROWTH CURVE."
600 GOSUB 6340
610 XA = 141: YA = 70
620 Z$ = "GROWTH CURVE."
630 GOSUB 6340
640 REM

650 REM THE LOGISTIC GROWTH CURVE IS PLOTTED.
660 REM

670 ZF = 1
680 R = .1
690 K = 50
700 N = .5
710 FOR T = 0 TO 100
720 D1 = R * N * (1 - N / K)
730 N = N + D1
740 X = T: Y = N
750 GOSUB 31000
760 NEXT
770 XA = 0: YA = 129
780 Z$ = " THE POPULATION GROWS UNTIL IT LEVELS OFF AT SOME CARRYING CAPACITY."

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REM A QUESTION IS ASKED CONCERNING THE CURVE ON THE SCREEN.

790 GOSUB 6340
800 GOSUB 5080: HOME
810 X = 141: Y = 50: XZ = 138: L = 30: GOSUB 5750
820 HOME: X = 0: Y = 129: XZ = 279: L = 20: GOSUB 5750
830 REM

840 REM  "GROWTH RATE?": GOSUB 6340
850 REM

860 XA = 140: YA = 50: IF COUNT = 1 THEN XA = 0
870 Z$ = "..LOOKING AT THIS"
880 GOSUB 6340

890 XA = 140: YA = 60: IF COUNT = 1 THEN XA = 0
900 Z$ = "GRAPH WHERE DOES": GOSUB 6340
910 XA = 140: YA = 70: IF COUNT = 1 THEN XA = 0
920 Z$ = "THE PREY POPULATION": GOSUB 6340
930 XA = 140: YA = 80: IF COUNT = 1 THEN XA = 0
940 Z$ = "HAVE THE HIGHEST": GOSUB 6340
950 XA = 140: YA = 90: IF COUNT = 1 THEN XA = 0
960 Z$ = "GROWTH RATE": GOSUB 6340
970 XA = 0: YA = 129
980 Z$ = "A. AT A LOW PREY DENSITY.": GOSUB 6340
1000 XA = 0: YA = 139
1020 Z$ = "B. AT A HIGH PREY DENSITY.": GOSUB 6340
1040 XA = 0: YA = 149
1050 Z$ = "C. SOMEWHERE IN BETWEEN.": GOSUB 6340
1060 VTAB 23
1070 POKE -16368,0
1080 INPUT Q$ 
1090 HOME
1100 IF LEFT$(Q$,1) = "A" OR LEFT$(Q$,1) = "B" GOTO 1164 
1101 IF LEFT$(Q$,1) = "C" GOTO 1162
1110 PAUSE = 500: GOSUB 5000: VTAB 22
1120 PRINT " .PLEASE CHOOSE A, B, OR C ."
1140 GOTO 1070
1162 IF COUNT = 1 THEN HOME: RETURN
1163 HOME: VTAB 21: PRINT "VERY GOOD!": GOTO 1168
1164 IF COUNT = 1 THEN HOME: RETURN 
1165 HOME: VTAB 21: PRINT "INCORRECT."
1168 PAUSE = 500: GOSUB 5000
1170 PAUSE = 500: GOSUB 5000: VTAB 21
1180 PRINT " THE PREY POPULATION HAS THE HIGHEST GROWTH RATE AT MEDI
1190 PREY DENSITIES." 
1200 PAUSE = 500: GOSUB 5000
1210 HOME
PREY RECRUITMENT IS INTRODUCED.

TO BETTER SHOW THIS CHANGE IN GROWTH RATE AT DIFFERENT DENSITIES, A GRAPH WITH THE FOLLOWING AXES CAN BE USED.

HOME: X = 140; Y = 50; XZ = 139; L = 50: GOSUB 5750
HOME :X = 0:Y = 129;XZ = 279;L = 30: GOSUB 5750
X:A = 0:YA = 131
Z$ = "TO BEATEN SHOW THIS CHANGE IN GROWTH TIES, A GRAPH WITH THE FOLLOWING AXES CAN BE USED."
GOSUB 6340
YM$ = "1.4" - YM = VAL (YM$)
X1 = 180
YM = "PREY": GOSUB 6340
XA = 256:YA = 112
Z$ = "DENSITY": GOSUB 6340
XA = 256:YA = 112
Z$ = "50": GOSUB 6340
GOSUB 5080: HOME : VTAB 21
HOME :X = 0:Y = 129;XZ = 279;L = 30: GOSUB 5750

ARE THE TWO X-AXES THE SAME?

IF LEFT$ (Q$,1) < > "Y" AND LEFT$ (Q$,1) < > "N" THEN VTAB 22: PRINT "PLEASE ANSWER YES OR NO.": GOTO 1410
IF LEFT$ (Q$,1) = "N" THEN PRINT "RIGHT!": GOTO 1420
PRINT "WRONG.";
PRINT "THE X-AXES ARE DIFFERENT."
PAUSE = 500: GOSUB 4000: PRINT "THE POPULATION GROWTH GRAPH HAS TIME ON THE X-AXIS, WHILE THE GRAPH ON THE RIGHT HAS PREY DENSITY."
PAUSE = 500: GOSUB 4000
PRINT "ALSO NOTICE THAT, THE Y-AXES ARE DIFFERENT.

PAUSE = 500: GOSUB 4000.
PRINT "DO YOU UNDERSTAND WHAT 'CHANGE' IS ON THE Y-AXIS OF THE GRAPH ON THE RIGHT?"
VTAB 24: POKE - 16368,0: INPUT Q$: GOSUB 4050
IF LEFT$ (Q$,1) < > "Y" AND LEFT$ (Q$,1) < > "N" THEN PRINT "PLEASE ANSWER YES OR NO.":PAUSE = 2000: GOSUB 5000: GOSUB 4050: GOTO 14
PAUSE = 500: GOSUB 4000
PRINT "WHAT DOES 'CHANGE' REPRESENT?":PAUSE = 1000: GOSUB 5000
PRINT "A. CHANGE IN TIME."
PRINT "B. GAIN IN THE PREY POPULATION."
PRINT "C. LOSS IN THE PREY DENSITY."
4

1445 UTAB 15: POKE -16368,0; INPUT Q$
1446$ IF LEFT$ (Q$,1) < > "A" AND LEFT$ (Q$,1) < > "B" AND LEFT$ (Q$,1) < > "C" THEN UTAB 14: PRINT "PLEASE ANSWER A, B, OR C."; UTAB 15: PRINT "": GOTO 1445
1447 GOSUB 4050: UTAB 5: IF LEFT$ (Q$,1) = "B" THEN PRINT "THAT'S RIGHT. YOU REALLY DID KNOW!": GOTO 1450
1448 PRINT "THAT IS INCORRECT."
1449 UTAB 7: PRINT "'CHANGE' HERE REPRESENTS GAINS IN THE PREY POPULATION."
1450 PRINT; PRINT "FOR EXAMPLE, IF THE POPULATION GREW FROM 60 TO 75 INDIVIDUALS OVER AN INTERVAL OF TIME, WHAT IS THE CHANGE?"
1451 PRINT; POKE /16368,0: INPUT Q$: PRINT; PRINT
1452 IF LEFT$ (Q$,2) = "15" OR LEFT$ (Q$,5) = "FIFTE" THEN PRINT "VERY GOOD!": GOTO 1456
1453 PRINT; PRINT; PRINT "THAT'S NOT CORRECT."
1454 PRINT; PRINT; PRINT "THE CHANGE IS 75 - 60 = 15."
1455 PAUSE = 500: GOSUB 4000: POKE -16304,0: POKE -16297,0
1456 UTAB 10: INPUT Q$
1457 HOME; X = 0; Y = 139; XZ = 279; L = 20: GOSUB 5750
1458 REM; PREY RECRUITMENT AND LOGISTIC GROWTH ARE PLOTTED SIMULTANEOUSLY.

1459 REM

1500 X = 0; Y = 129; XZ = 279; L = 20: GOSUB 5750
1510 XA = 0; YA = 139
1520 Z$ = "TIME": GOSUB 6340
1530 POKE -16368,0
1540 UTAB 10: INPUT Q$
1550 HOME; X = 0; Y = 139; XZ = 279; L = 10: GOSUB 5750
1560 REM;
1570 REM; PREY RECRUITMENT AND LOGISTIC GROWTH ARE PLOTTED SIMULTANEOUSLY.
1580 REM

1590 ZF = 1; ZG = 0
1600 N = .5
1610 X = 31; Y = 39; XZ = 30; L = 69: GOSUB 5750
1620 X = 181; Y = 39; XZ = 30; L = 69: GOSUB 5750
1630 IF COUNT < 0 GOTO 1700
1640 XA = 0; YA = 149
1650 Z$ = "TIME": GOSUB 6340
1660 XA = 100; YA = 149
1670 Z$ = "PREY DENSITY": GOSUB 6340
1680 XA = 230; YA = 149
1690 Z$ = "CHANGE": GOSUB 6340
1700 FOR T = 0 TO 100
1710 D1 = R * N * (1 - N / K)
1720 N = N + D1
1730 VH = 50; X1 = 30; XM = 100
1740 IF T > 0 THEN HPOLR X9; Y9
1750 X = T; Y = N: GOSUB 3100
1760 X9 = X8; Y9 = Y0
1770 IF T = 0 THEN ZG = 0
1780 YM = 1.4: X1 = 180: XM = 50
1790 IF T > 0 THEN HPLTT X8, Y8
1800 X = X: Y = D1: GOSUB 31000
1810 X8 = X0: Y8 = Y0
1820 IF COUNT < > 0 GOTO 1920
1830 IF T = 0 OR INT (T / 25) = 25 GOTO 1920
1840 HOME
1850 UTAB 21: PRINT T, INT (N * 100) / 100, INT (D1 * 100) / 100
1860 PAUSE = 500: GOSUB 5000
1870 IF T = 25 THEN PRINT "NOTICE THAT AT LOW PREY DENSITY THE CHANGE IN PREY DENSITY IS LOW."
1880 IF T = 50 THEN PRINT "THE HIGHEST CHANGE OCCURS AT MEDIUM PREY DENSITY."
1890 IF T = 75 THEN PRINT "AT HIGHER PREY DENSITIES THE CHANGE DECREASES.
1900 PAUSE = 500: GOSUB 5000: GOSUB 5000
1910 HOME
1920 NEXT
1930 PAUSE = 500: GOSUB 5000
1940 HOME: X = 0: Y = 149: XZ = 279: L = 10: GOSUB 5750
1950 GOSUB 4060
1960 PRINT "THE GRAPH ON THE RIGHT REPRESENTS ALL PREY BIRTHS MINUS NON-PREDATOR DEATHS. IT IS CALLED A PREY RECRUITMENT CURVE."
1970 XA = 168: YA = 10
1980 Z$ = "PREY RECRUITMENT": GOSUB 6340
1990 XA = 196: YA = 20
2000 Z$ = "CURVE": GOSUB 6340
2010 PAUSE = 500: GOSUB 4060
2020 PRINT "WOULD YOU LIKE TO SEE THE CURVES PLOTTED AGAIN?"
2030 VTAI 24
2040 INPUT Q$;
2050 HOME: PAUSE = 500: GOSUB 5000
2060 IF LEFT$ (Q$, 1) = "Y" THEN COUNT = 1: GOTO 1590
2070 X = 0: Y = 0: XZ = 140: L = 119: GOSUB 5750
2080 REM
2090 REI THE SAME QUESTION ASKED EARLIER IS NOW ASKED USING A NEW GRAPH.
2100 REM
2110 COUNT = 1: GOSUB 860
2120 VTAI 21
2130 IF LEFT$ (Q$, 1) = "C" THEN PRINT "CORRECT. THE HIGHEST POPULATION GROWTH OCCURS AT THE PEAK IN THE CURVE, SO -C- IS CORRECT."
2140 IF LEFT$ (Q$, 1) = "C" GOTO 2130
2150 PRINT "THAT IS INCORRECT. THE HIGHEST POPULATION GROWTH OCCURS AT THE PEAK IN THE CURVE, SO -C- IS THE CORRECT ANSWER."
2160 PAUSE = 2000: GOSUB 5000: GOSUB 5000: HOME
2170 X = 0: Y = 50: XZ = 139: L = 50: GOSUB 5750
2180 X = 0: Y = 129: XZ = 279: L = 30: GOSUB 5750
2190 XA = 0: YA = 50
IN THIS MODULE WE WILL BE WORKING WITH RECRUITMENT CURVES.

THE RELATIONSHIP OF THE PREDATOR IS INTRODUCED.

THE PREDATOR WOULD LIKE TO EAT AS MANY PREY AS POSSIBLE.

THE PREDATOR WILL KILL AND EAT A CERTAIN NUMBER OF TST PREY AVAILABLE IN S T GIVEN AMOUNT OF TIME.

THE CURVE AT LOW PREY DENSITIES; THEN, WILL BE CONSTANTLY INCREASING. AS MORE PREY BECOME AVAILABLE, MORE ARE KILLED.
2525 GOTO 2620
2530 PAUSE = 500: GOSUB 4000
2560 PRINT "AS PREY DENSITY INCREASES, THE PREDATOR SPENDS LESS TIME SEARCHING FOR PREY AND MORE TIME EATING ITS KILL."
2570 PAUSE = 500: GOSUB 4000
2580 PRINT "THE EFFECT IS THAT THE CURVE BEGINS TO LEVEL OFF AS THE PREDATOR SPENDS LESS TIME SEARCHING FOR PREY."
2590 PAUSE = 500: GOSUB 5000: GOTO 2510
2600 PRINT "THE CURVE LEVELS OFF AT VERY HIGH PREY DENSITIES DUE TO TWO FACTORS: SATIATION AND PROCESSING TIME."
2610 GOTO 2510
2620 PAUSE = 500: GOSUB 4000
2630 VTAB 10
2640 PRINT "SATIATION REFERS TO THE FACT THAT A PREDATOR CAN EAT ONLY SO MANY PREY, EVEN IF MORE AVAILABLE."
2650 PRINT "(THE PREDATOR GETS FULL.)"
2660 PAUSE = 500: GOSUB 5000: VTAB 23: INPUT "PRESS -RETURN- TO CONTINUE"; @$: VTAB 23: PRINT 
2665 GOSUB 4000: VTAB 17
2670 PRINT "BUT THE CURVE ALSO LEVELS OFF BECAUSE THE PREDATOR SPENDS LITTLE TIME SEARCHING. IT IS MAINLY USING ITS TIME CONSUMING EACH KILL IT MAKES."
2680 PAUSE = 500: GOSUB 4000: POKE -16304,0: POKE -16307,0
2690 PRINT "THIS IS CALLED A PREDATOR FUNCTIONAL RESPONSE CURVE."
2700 X$ = "65"; Y$ = 0
2710 Z$ = "PREDATOR FUNCTIONAL": GOSUB 6340
2720 X$ = "82"; Y$ = 10
2730 Z$ = "RESPONSE CURVE": GOSUB 6340
2740 PAUSE = 500: GOSUB 4000
2750 PRINT "IT REPRESENTS THE NUMBER OF PREY KILLED AS A FUNCTION OF PREY DENSITY."
2760 PAUSE = 500: GOSUB 4000: HGR : TEXT : VTAB 7
2770 PRINT "THE PREDATOR FUNCTIONAL RESPONSE CURVES IN THE PREVIOUS EXAMPLES ARE FOR A SINGLE PREDATOR."
2780 PAUSE = 500: GOSUB 5000: VTAB 23: INPUT "PRESS -RETURN- TO CONTINUE"; @$
2785 VTAB 23: PRINT 
2786 VTAB 11
2787 PRINT "BUT IN NATURE WE'RE USUALLY INTERESTED IN A POPULATION OF PREDATORS IN AN AREA NOT JUST A SINGLE PREDATOR."
2790 VTAB 15
2800 PRINT "PREDATOR FUNCTIONAL RESPONSE CURVES CAN ALSO BE LOOKED AT FOR A POPULATION OF PREDATORS."
2810 PAUSE = 500: GOSUB 4000
2820 VTAB 10
2830 PRINT "LET'S LOOK AT THE FUNCTIONAL RESPONSE FOR A POPULATION OF PREDATORS AND THEN EXPLORE THE RELATIONSHIP TO THE PREY RECRUITMENT CURVE."

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2840 UTAB 21: PRINT " (PLEASE BE PATIENT. PROGRAM LOADING.)
3800 REM
3810 REM THE SUBPROGRAM PRED FUNCT1 IS RUN.
3820 REM
3830 D$ = CHR$(6)
3840 PRINT D$; "RUN PRED FUNCT1"
3850 END
4000 REM
4010 REM PAUSE. RETURN. PAUSE. UTAB SUBROUTINE.
4020 REM
4030 GOTO 5000
4040 UTAB 5000
4050 HOME
4060 PAUSE = 500: GOSUB 5000
4070 UTAB 21
4080 RETURN
4090 REM
4100 REM ***********
4110 REM *** SUBROUTINES ***
4120 REM ***********
5000 REM
5010 REM PAUSE SUBROUTINE.
5020 REM VARIABLES TO BE PROVIDED:
5030 REM D = LENGTH OF PAUSE.
5040 REM
5050 FOR PS = 1 TO PAUSE
5060 NEXT
5070 RETURN
5080 REM
5090 REM PRESS -RETURN- SUBROUTINE.
5100 REM
5105 POKE -16388, 0
5110 UTAB 24
5115 INPUT " PRESS -RETURN- TO CONTINUE", D$
SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.

- VARIABLES THAT MUST BE PROVIDED -
X = STARTING X COORDINATE
Y = STARTING Y COORDINATE
XZ = LENGTH OF RECTANGLE ALONG THE X AXIS.
L = WIDTH OF RECTANGLE ALONG THE Y AXIS.

HCOLOR = 0
FOR TA = 0 TO L
HPLOT X, TA + Y TO X + XZ, TA + Y
NEXT TA
HCOLOR = 3
RETURN

SUBROUTINE THAT DRAWS A STRING ON THE HGR SCREEN.

- VARIABLES THAT MUST BE PROVIDED -
X9 = INITIAL X POSITION
YA = INITIAL Y POSITION
Z$ = STRING IN QUOTATION MARKS

YA = 0: HOME : HGR
X9 = 0:YA = YA + 10
FOR Z = 1 TO LEN (Z$)
IF Z = 1 THEN 6360
X9 = X9 + 7
ZZ = ASC ( MID$ (Z$, Z-1))
IF ZZ > 32 THEN 6420
IF ZZ < 2 THEN 6410
IF X9 < 279 THEN 6470
X9 = 0:YA = YA + 10: GOTO 6470
FLAG = FLAG + 1:XA = X9 - 7: GOTO 6470
IF INT (FLAG / 2) = FLAG / 2 THEN 6440
ZZ = ZZ - 64
IF X9 < 279 THEN 6460
X9 = 0:YA = YA + 10
DRAW ZZ AT X9, YA
NEXT Z
RETURN

AXES AND UNITS FOR GR

SUBROUTINE DEVELOPED BY J. SPAIN ... MICHIGAN TECH UNIV.
DEFINE XS=UNITS ON THE X AXIS
DEFINE YS=UNITS ON THE Y AXIS
DEFINE YS=MAXIMUM UNITS ON THE Y AXIS
COLOR = 3
HPLT X1,Y1 - LYA TO X1,Y1 TO X1 + LXA + 9,Y1
REM LABEL X AXIS AS REQ. 36 CHAR. MAX
REM X$ = "0" - X AXIS 100" ETC.
Z0 = 0: LS$ = X$: X0 = X1 + 7: Y0 = Y1 + 8
GOSUB 30780
REM LABEL Y AXIS AS REQUIRED
Z0 = 1: LS$ = Y$: X0 = X1 - 8: Y0 = Y1 - 2
GOSUB 30780
IF CHART = 1 GOTO 30755
REM UNITS ON, THE Y AXIS.. YM = Y MAX.
Z0 = 0: X0 = X1 - LEN (YM$) * 7: Y0 = (Y1 - LYA) + 10: LS$ = YM$
GOSUB 30850
IF CHART = 1 GOTO 30770
DRAW 48 AT X1 - 10, Y1 - 4
RETURN
REM ALPHANUMERIC CHARACTERS FOR HR
REM THE FOLLOWING MUST BE DEFINED
REM PRI$ = "CHARACTER STRING"
REM Y0 = THE INITIAL Y POSITION
REM X0 = THE INITIAL X POSITION
REM SET Z0 = 0 IF PRINTING HORIZONTAL
REM SET Z0 = 1 IF PRINTING VERTICALLY
FOR Z = 1 TO LEN (LS$): Z3 = ASC (MID$ (LS$, Z, 1))
IF Z0 < > 0 THEN GOTO 30800
IF Z3 > 64 THEN DRAW Z3 - 64 AT X0 + (Z - 1) * 7, Y0 - 5: GOTO 30930
DRAW Z3 AT X0 + (Z - 1) * 7, Y0 - 5: GOTO 30930
IF Z3 < 33 THEN GOTO 30830
DRAW Z3 AT X0 - 5, Y0 - (Z - 1) * 7
ROT = 0: NEXT Z
RETURN
REM SCALE AND PLOT POINT FOR DEFINED X AND Y
REM FOR LINE PLOT MAKE ZF=1
X0 = X1 + X * LXA / XM
Y0 = Y1 + Y * LYA / YM
IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 GOTO 31080
IF Z6 = 1 THEN HPLT TO X0, Y0: GOTO 31080
HPLT X0,Y0: IF ZF = 1 THEN Z6 = 1
RETURN
5 REM PRED FUNCTION.
10 REM PRED FUNCTION IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.
12 REM PROGRAMMED BY MARK SHALTZ.
15 REM THIS PROGRAM WAS DEVELOPED BY THE SUNIT I COURSEWARE DEVELOPMENT
16 REM PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UNI-
17 REM VERSITY, Houghton, MI 49931.
20 REM THIS MATERIAL IS BASED UPON WORK SUPPORTED BY THE NATIONAL SCIENC
21 REM E FOUNDATION UNDER GRANT NUMBER SED-7919051.
25 REM ANY OPINIONS, FINDINGS, AND CONCLUSIONS OR RECOMMENDATIONS EXPRES
26 REM IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSARI-
27 REM REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.
100 DIM Y1(101),X2(101),Y2(101)
110 X$ = "DENSITY OF PREY POPULATION"
120 Y$ = "PREY GROWTH / TIME"
125 VTAB 21: PRINT "---:
130 PAUSE = 0.500: GOSUB 4500
132 HGR
134 PRINT " FIRST WE'LL GRAPH THE PREY RECRUITMENT CURVE FOR THE PREY OF
135 AN AREA."
150 REM
160 REM THE GRAPH IS DRAWN AND LABELLED.
170 REM
180 GOSUB 5280
190 WRITE = 0
260 ZF = 1
290 REM
300 REM THE PREY RECRUITMENT CURVE IS DRAWN.
310 REM
320 HCOLOR = 3
330 HPL0T 23,149
340 FOR I = 0 TO 100
350 READ X2(I),Y1(I),Y2(I)
360 HPL0T TO X2(I),Y1(I)
370 NEXT
380 PAUSE = 1: GOSUB 4500
420 PRINT " THIS CURVE REPRESENTS THE CHANGE IN PREY DENSITY RESULTING
430 FROM ALL PREY BIRTHS MINUS ALL NON-PREDATOR DEATHS."
430 PAUSE = 500: GOSUB 4500
460 REM
470 REM PREDATOR FUNCTIONAL RESPONSE IS INTRODUCED.
480 REM
490 VTAB 22
510 PRINT " NEXT, THE NUMBER OF PREY EATEN BY A FIXED NUMBER OF PREDAT
ORS IS GRAPHED."

Page G13
FOR THIS GRAPH THE Y-AXIS IS THE NUMBER OF PREY EATEN BY THE PREDATORS.

FOR THIS GRAPH THE Y-AXIS IS THE NUMBER OF PREY EATEN BY THE PREDATORS.

THE PREDATOR FUNCTIONAL RESPONSE CURVE IS PLOTTED.

THE PREDATOR FUNCTIONAL RESPONSE CURVE IS PLOTTED.

RECALL THAT THIS FUNCTIONAL RESPONSE CURVE IS FOR A FIXED NUMBER OF PREDATORS.
REM

* THE IDEA OF POSITIVE AND NEGATIVE GRAPHS IS DISCUSSED. *

970 REM

980 TEXT : HOME : PAUSE = 500: GOSUB 5000
990 VTab 7

1000 PRINT " BOTH OF THE CURVES JUST GRAPHED EXPRESS CHANGE IN THE

PREY DENSITY."
1010 PAUSE = 1000: GOSUB 5000: UTab 10

1020 PRINT " THE PREY RECRUITMENT CURVE IS POSITIVE BECAUSE IT R

PRESENTS ADDITIONS TO THE PREY POPULATION."
1030 PAUSE = 1000: GOSUB 5000: UTab 14

1040 PRINT " THE PREDATOR FUNCTIONAL RESPONSE CURVE IS NEGATIVE BECA

USE IT REPRESENTS SUBTRACTIONS FROM THE PREY POPULATION."
1050 PAUSE = 500: GOSUB 4500: POKE 16304,0: POKE 16297,0
1060 PRINT "IN THIS PROGRAM, POSITIVE CHANGES WILL BE GRAPHED AS A WHITE

LINE, AND NEGATIVE CHANGES WILL BE COLORED (OR DOTTED)."
1070 PAUSE = 1000: GOSUB 5000: VTAB 22: POKE 16368,0
1080 HOME : UTab 21

1100 REM

1150 REM A QUESTION REGARDING THE NUMBER OF EQUILIBRIUM POINTS IS ASK

ED.
1160 REM

1165 INPUT " THIS IS AN EXAMPLE OF A MULTI-EQUILIBRIA SYST

EH. HOW MANY EQUILIBRIUM POINTS ARE THERE?": Q$
1170 IF LEFT$ (Q$,1) = "4" OR LEFT$ (Q$,2) = "FO" GOTO 1172
1171 GOTO 1180
1172 GOSUB 4550
1173 PRINT "YOU ANSWERED 4, BUT 3 IS THE CORRECT ANSWER."
1174 PAUSE = 1000: GOSUB 4500
1175 PRINT "POSSIBLY YOU COUNTED (0,0) AS AN EQUILIBRIUM POINT. (0

,0) IS NOT USUALLY INCLUDED."
1176 GOTO 1210
1180 IF LEFT$ (Q$,1) = "3" OR LEFT$ (Q$,3) = "THR" GOTO 1230
1190 GOSUB 4550: UTab 22
1200 PRINT " EQUILIBRIUM POINTS OCCUR WHERE THE TWO CURVES INTERSECT."
1210 PAUSE = 1000: GOSUB 5000: GOSUB 5000
1220 GOTO 1110
1230 GOSUB 4550
1240 PRINT " THAT'S CORRECT. THERE ARE THREE EQUILIBRIUM POINTS, 0

WE AT EACH INTERSECTION."
1250 PAUSE = 1000: GOSUB 5000
1260 HCOLOR = 3
1270 DRAW 49 AT 39,113
1280 DRAW 50 AT 88,43
1290 DRAW 51 AT 198,36
1300 DRAW 52 AT 39,113
1310 DRAW AT 35,113
1320 PAUSE = 500: GOSUB 4500: UTab 22
1330 PRINT " AN EQUILIBRIUM POINT CAN BE STABLE OR UNSTABLE."
EQUILIBRIUM POINT #1

AS AN EXAMPLE, LET'S LOOK AT EQUILIBRIUM POINT #1.

PAUSE = 1000: GOSUB 5000
FOR I = 1 TO 6
HCOLOR = 0
DRAW 49 AT 30,113
PAUSE = 500: GOSUB 5000
HCOLOR = 3
DRAW 49 AT 30,113
GOSUB 5000
NEXT

REM EQUILIBRIUM POINT #1 IS USED IN A SIMULATION REGARDING STABILITY.

PAUSE = 500: GOSUB 4500: UTAB 22
PRINT "IF THE PREY DENSITY IS BELOW POINT #1, ADDITIONS TO THE PREY DENSITY (WHITE CURVE) ARE GREATER THAN SUBTRACTIONS FROM IT (COLOR CURVE)."
FOR I = 1 TO YS
HCOLOR = 3
HPLT X2(I),Y1(I) TO X2(I),Y2(I)
NEXT
HCOLOR = 5
HPLT 23,149
FOR I = 0 TO YS
HPLT TO X2(I),Y2(I)
NEXT
HCOLOR = 3
PAUSE = 1: GOSUB 4500
PRINT "THE NET RESULT IS THAT THE PREY DENSITY INCREASES UNTIL IT REACHES EQUILIBRIUM POINT #1."
PAUSE = 500: GOSUB 5000
A = 0: B = YS: ST = 1
GOSUB 4000
HCOLOR = 5
HPLT 25,149
FOR I = 0 TO YS
HPLT TO X2(I),Y2(I)
NEXT
HCOLOR = 3
PAUSE = 1: GOSUB 4500
PRINT "IF THE PREY DENSITY IS JUST ABOVE POINT #1, SUBTRACTION OF (COLORED CURVE) ARE GREATER THAN ADDITIONS TO (WHITE CURVE)."
FOR I = YU TO YS: STEP = 1
HCOLOR = 3
HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
NEXT
HCOLOR = 5
HPLOT X2(YU),Y2(YU)
FOR I = YU TO YS STEP -1
HPLOT TO X2(I),Y2(I)
NEXT
HCOLOR = 3
PAUSE = 1000: GOSUB 5000
POKE 16368,0
INPUT "PRESS RETURN":Q$
GOSUB 4550
PRINT "A PREY DENSITY IN THIS AREA, THEN, WILL TEND TO DECREASE UNTIL IT REACHES EQUILIBRIUM POINT #1."
A = YU: B = YS: ST = -1
GOSUB 4000
HCOLOR = 5
HPLOT X2(YU),Y2(YU)
FOR I = YU TO YS STEP -1
HPLOT TO X2(I),Y2(I)
NEXT
HCOLOR = 3
PAUSE = 1: GOSUB 4500
PRINT "THE NET EFFECT IS THAT ANY PREY DENSITY IN THESE REGIONS WILL TEND TO MOVE TO THE EQUILIBRIUM POINT #1."
LG = 150
CE = 1
GOSUB 4100
HCOLOR = 5: HPLOT 25,149
FOR I = 0 TO YU
HPLOT TO X2(I),Y2(I)
NEXT
PAUSE = 1: GOSUB 4500
PRINT "BECAUSE ANY PREY DENSITY IN THE AREA OF POINT #1 WILL MOVE TO THAT POINT, IT IS CALLED A STABLE EQUILIBRIUM POINT."
PAUSE = 1000: GOSUB 4500
REH
REM A QUESTION REGARDING OTHER STABLE EQUILIBRIUM POINTS IS ASKED.
REH
PRINT "EQUILIBRIUM POINT #1 IS STABLE.":PAUSE = 1000: GOSUB 5000
POKE 16368,0
VTAB 23
INPUT "WHICH OTHER EQUILIBRIUM POINT IS STABLE?":Q$
GOSUB 4550
IF LEFT$(Q$,1) = "3" OR LEFT$(Q$,3) = "THR" THEN PRINT "VERY GOOD!": GOTO 2360
PRINT "NO:"
PRINT "EQUILIBRIUM POINT #3 IS ALSO STABLE."
PAUSE = 500: GOSUB 4500

VTAB 21: PRINT "WATCH THE GRAPH TO GET THE OVERALL IDEA OF WHERE PREY DENSITY WILL GO."
PAUSE = 1000: GOSUB 5000

PRINT "PRESS RETURN WHEN THROUGH."
CE = 0: LG = 100000: GOSUB 4100
GOSUB 4550: VTAB 22
IF PEEK (- 16384) = 141 THEN POKE - 16368, 0
REH

REH 'PREDATOR CARRYING CAPACITY IS USED AS A PARAMETER TO BE VARI ED.'
REH
HOM E: HGR = TEXT: VTAB 1
PRINT "THE SHAPE OF THE PREDATOR FUNCTIONAL RESPONSE CURVE IS INFLUENCED BY THE PREDATOR CARRYING CAPACITY"
60SUB 5200
HCOLOR = 5
L$ = "PREY EATEN / YR": X0 = 0: Y0 = 140: GOSUB 5450
X0 = 1: GOSUB 5450
HCOLOR = 3
VTAB 3
HPLOT 25, 149
XM = 100: YM = .3
REH

REH THE PREY RECRUITMENT CURVE IS DRAWN.
REH
R = .01
K = 100
FOR N = 0 TO 100
IF N = 60 THEN VTAB 7: PRINT "WILL THE PREDATOR FUNCTIONAL RESPONSE CURVE GO UP OR DOWN WHEN THE PREDATOR CARRYING CAPACITY IS RAISED?"
IF N = 90 THEN PRINT: POKE - 16368, 0: INPUT Q$
H PLOT TO X2(N), Y1(N)
NEXT
VTAB 13
IF LEFT$(Q$, 1) = "U" THEN PRINT "THAT'S RIGHT!": GOTO 2700
PRINT "THAT'S NOT RIGHT."
K = 110
YM = 150
HCOLOR = 5
HPLOT 25, 149
FOR N = 0 TO 100
IF COUNT > 0 THEN HCOLOR = 5: GOTO 2800
IF N = 5 THEN PRINT: PRINT "IT WILL GO UP BECAUSE A HIGHER CARRYING CAPACITY WILL ALLOW MORE PREDATORS TO SURVIVE IN THE SYSTEM.

IF N = '50 THEN PRINT: PRINT "MORE PREDATORS WILL EAT MORE PREY."

PRINT " IT WILL NOT BECAUSE A HIGHER CARRYING CAPACITY WILL ALLOW MORE PREDATORS TO SURVIVE IN THE SYSTEM."

MORE PREDATORS WILL EAT MORE PREY."

THE PREDATOR CARRYING CAPACITY IS CHANGED BY THE USER.

NEXT : IF COUNT < > 0 GOTO 2930

PAUSE = 1: GOSUB 4500

VTAB 10

PRINT "TRY A HIGHER PREDATOR CARRYING CAPACITY TO SEE THIS DEMONSTRATED."

PAUSE = 1000: GOSUB 5000

VTAB 20

PRINT "PRESENT CARRYING CAPACITY = ";K

IF COUNT < > 0 THEN HOME: VTAB 22: INPUT "WOULD YOU LIKE TO CHANGE THE CARRYING CAPACITY AGAIN? "$;

IF LEFT$(Q$,1) = "Y" THEN HOME: VTAB 22: PRINT "FORMER CARRYING CAPACITY = ";KK

IF COUNT < > 0 AND LEFT$(Q$,1) <> "Y" THEN GOTO 3020

VTAB 23: INPUT "ENTER THE NEW CARRYING CAPACITY: ";KK

IF COUNT < > 0 AND KK > 160 OR KK < 110 THEN HOME: GOTO 3020

PLEASE CHOOSE A VALUE BETWEEN 110 AND 160.";PAUSE = 3000: GOSUB 5000: HOME: GOTO 2940

PLEASE CHOOSE A VALUE BETWEEN 110 AND 160.";PAUSE = 3000: GOSUB 5000: HOME: GOTO 2940

K = KK

COUNT = 1

POKE -16304.0: POKE -16297.0

GOTO 2710

PAUSE = 500: GOSUB 5000

THE DIFFERENT POSSIBLE NUMBERS OF EQUILIBRIUM POINTS IS WORKED WITH.

REH

HOME: HGR = TEXT

PAUSE = 500: GOSUB 5000

VTAB 10
YOU'VE EXPERIMENTED WITH THE PREDATOR CARRYING-CAPACITY AND SEEN ITS EFFECTS. YOU MAY ALSO HAVE NOTICED THAT THESE GRAPHS NEED NOT HAVE ALL THREE EQUILIBRIUM POINTS.

X0 = 0: Y0 = 140: GOSUB 5450

HCOLOR = 5: LS = "PREY EATEN / TIME": X0 = 0: Y0 = 140: GOSUB 5450

HCOLOR = 3

HLOT 25, 149

FOR I = 0 TO 100

HLOT TO X2(I), Y1(I)

NEXT

PRINT "BY CHANGING THE PREDATOR CARRYING CAPACITY TRY TO COME UP WITH A SYSTEM THAT HAS ONLY ONE EQUILIBRIUM POINT."

PAUSE = 2000: GOSUB 5000

K = 0

GOSUB 5000: HOME: PAUSE = 500: GOSUB 5000

POKE -16384, 0: POKE -16297, 0

GOTO 3310

THE PREDATOR CARRYING CAPACITY IS CHANGED BY THE USER.

PAUSE = 1000: GOSUB 5000

VTAB 22

PRINT "FORMER CARRYING CAPACITY = "; K

PAUSE = 1000: GOSUB 5000

VTAB 24

INPUT "ENTER A NEW CARRYING CAPACITY: "; KK


K = KK

POKE ORANGE, COLOR.

POKE 28, 213

HCOLOR = 5

HLOT 25, 149

FOR X = 0 TO 100

Y = K * X * E / (X * E + DD)

GOSUB 5610

NEXT

HOME

REM
3480 REM THE NUMBER OF EQUILIBRIUM POINTS IS CHECKED.
3490 REM
3500 PAUSE = 500: GOSUB 5000
3510 VTAB 22
3520 PRINT " IS THERE ONLY ONE EQUILIBRIUM POINT?"
3530 INPUT Q$
3540 HOME : VTAB 22:PAUSE = 500: GOSUB 5000
3550 IF LEFT$(Q$,1) = "Y" AND K > 78 AND K < 128 THEN PRINT " THAT IS INCORRECT. THE SYSTEM HAS MORE THAN ONE EQUILIBRIUM POINT. PLEASE TRY AGAIN.";PAUSE = 1000: GOSUB 5000: GOSUB 5000: HOME : GOTO 3280
3560 IF -LEFT$(Q$,1) < > "Y" AND K < 78 AND K > 128 THEN PRINT " THAT IS INCORRECT. THE SYSTEM HAS MORE THAN ONE EQUILIBRIUM POINT.";PAUSE = 1000: GOSUB 5000: GOSUB 5000: HOME : GOTO 3280
3570 IF -LEFT$(Q$,1) = "Y" AND (K <= 78 OR K >= 128) THEN PRINT " THAT IS INCORRECT. THE SYSTEM HAS ONLY ONE EQUILIBRIUM POINT.";PAUSE = 1000: GOSUB 5000: GOSUB 5000: HOME : GOTO 3590
3580 IF -LEFT$(Q$,1) < > "Y" AND (K <= 78 OR K >= 128) THEN PRINT " THAT IS INCORRECT. THE SYSTEM HAS ONLY ONE EQUILIBRIUM POINT.";PAUSE = 1000: GOSUB 5000: GOSUB 5000: HOME
3590 PAUSE = 500: GOSUB 5000
3600 VTAB 22
3610 PRINT " IS THIS EQUILIBRIUM POINT STABLE OR UNSTABLE?"
3620 INPUT Q$
3630 HOME : VTAB 22:PAUSE = 500: GOSUB 5000
3640 IF LEFT$(Q$,1) = "E" THEN PRINT " THAT IS CORRECT."
3650 IF LEFT$(Q$,1) < > "E" THEN PRINT " THAT IS INCORRECT."
3660 PAUSE = 1000: GOSUB 5000: VTAB 23
3670 PRINT " IT IS A STABLE EQUILIBRIUM POINT.";PAUSE = 1000: GOSUB 5000
3680 GOSUB 5000
3690 REM
3700 REM THE NEXT SECTION OF THE MODULE IS SET UP.
3710 REM
3720 HOME : TEXT
3730 VTAB 22
3740 PRINT " GOING BACK TO THE ORIGINAL GRAPH..."
3750 X = 26:Y = 0:XZ = 253:L = 148: GOSUB 5140
3760 HCOLOR= 3
3770 HPLT 25,149
3780 FOR I = 0 TO 100
3790 HPLT TO XZ(I),Y1(I)
3800 NEXT
3810 POKE -16384,0: POKE -16297,0
3820 REM

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3830 REM POKE ORANGE COLOR.
3840 REM
3850 POKE 28,213
3860 HCOLOR= 5
3870 H PLOT 25,149
3880 FOR I = 0 TO 100
3890 H PLOT TO X2(I),Y2(I)
3900 NEXT
3910 REM
3920 REM THE SUBPROGRAM PRED FUNCT2 IS RUN.
3930 REM
3940 D$ = CHR$ (4)
3950 PRINT D$; "RUN PRED FUNCT2"
3960 END
3970 REM
3980 REM
3990 REM **********************
4000 REM *** SUBROUTINES ***
4010 REM
4001 REM SUBROUTINE TO FLASH SPACES BETWEEN CURVES.
4002 REM
4003 FOR T = 0 TO 21
4004 HC = HC + 3: IF HC > 3 THEN HC = 0
4005 HCOLOR= HC
4006 FOR I = A TO B STEP ST
4007 HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
4008 NEXT
4009 NEXT
4010 RETURN
4011 REM
4012 REM SUBROUTINE THAT ALTERNATELY COLORS AND DARKENS SPACES BETWEEN CURVES.
4013 REM
4014 FOR I = 1 TO L6
4015 H1 = 3:H2 = 3:H3 = 3:H4 = 3
4016 CA = 0:CB = 0:CQ = 0:CD = 0
4017 HC = 3
4018 FOR I = 1 TO L6
4019 CA = CA + 1:CB = CB + 1:CC = CC + 1:CD = CD + 1
4020 IF CA > YS AND H1 = 0 AND L6 - I < = YS THEN GOTO 4183
4021 IF CA > YS THEN CA = 0:H1 = H1 + 3: IF PEAK (< - 16384) = 141 THEN H 1 = 0
4022 IF H1 > 3 THEN H1 = 0
HCOLOR = H1
HPLOT X2(CA), Y1(CA) TO X2(CA), Y2(CA)

IF CB > YU - YS AND H2 = 0 AND LG - I < = YU - YS THEN GOTO 4300

IF CB > YU - YS THEN CB = 0: H2 = H2 + 3: IF PEEK (-16384) = 141 THEN

H2 = 0

IF H2 > 3 THEN H2 = 0

HCOLOR = H2

HPLOT X2(YU - CB), Y1(YU - CB) TO X2(YU - CB), Y2(YU - CB)

IF CE < 0 GOTO 4300

IF CC > YU - YS THEN CC = 0: H3 = H3 + 3: IF PEEK (-16384) = 141 THEN

H3 = 0

IF H3 > 3 THEN H3 = 0

HCOLOR = H3

HPLOT X2(YU + CC), Y1(YU + CC) TO X2(YU + CC), Y2(YU + CC)

IF CD > 101 - YE THEN CD = 0: H4 = H4 + 3: IF PEEK (-16384) = 141 THEN

H4 = 0

IF H4 > 3 THEN H4 = 0

HCOLOR = H4

HPLOT X2(101 - CD), Y1(101 - CD) TO X2(101 - CD), Y2(101 - CD)

GOTO 4300 NEXT

RETURN

REM

REM PAUSE. RETURN. PAUSE. VTAB SUBROUTINE.

REM

GOSUB 5000
GOSUB 5080
HOME
PAUSE = 500: GOSUB 5000
VTAB 21
RETURN

REM

REM VARIABLES TO BE PROVIDED:

D = LENGTH OF PAUSE.

FOR PS = 1 TO PAUSE

NEXT

RETURN

REM

REM 'PRESS -RETURN- SUBROUTINE.

POKE -16368, 0
VTAB 24
INPUT "PRESS -RETURN- TO CONTINUE"; Q$
SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.

VARIABLES THAT MUST BE PROVIDED:

X = STARTING X COORDINATE
Y = STARTING Y COORDINATE
Z = LENGTH OF RECTANGLE ALONG THE X AXIS.
L = WIDTH OF RECTANGLE ALONG THE Y AXIS.

HCOLOR = 0
FOR TA = 0 TO L
HPLOT X,TA + Y TO X + Z,TA + Y
NEXT TA
HCOLOR = 3
RETURN

AXES AND UNITS FOR GRAPHS

SUBROUTINE DEVELOPED BY J. SPAIN, MICHIGAN TECH UNIV. AND B.J. WINKEL, ALBION COLLEGE

DEFINE X$ = VARIABLE PLOTTED ON X AXIS
DEFINE Y$ = VARIABLE PLOTTED ON Y AXIS
DEFINE XM = MAXIMUM UNITS ON THE X AXIS
DEFINE YM = MAXIMUM UNITS ON THE Y AXIS

HCOLOR = 3; SCALE = 1; SC = 1; ROT = 0
LIST OF RESERVED VARIABLES: X, X0, XM, X$, Y, Y0, YM, Y$, Z, Z0, Z3, L$, SC

HPLOT 23,0 TO 23,149
HPLOT 25,149 TO 279,149
WRITE VARIABLE NAME ON X-AXIS
Z0 = 0; L$ = X$; X0 = 60; Y0 = 150
GOSUB 5450
WRITE VARIABLE NAME ON Y-AXIS
Z0 = 1; L$ = Y$; X0 = 10; Y0 = 140
X0 = 13
GOSUB 5450
GOSUB 5450
RETURN

ALPHANUMERIC CHARACTERS FOR HGR
THE FOLLOWING MUST BE DEFINED
BEFORE ENTERING THE SUBROUTINE
L$ = "CHARACTER STRING"
Y0 = THE INITIAL Y POSITION
X0 = THE INITIAL X POSITION
SET Z0 = 0 IF PRINTING HORIZONTAL
SET Z0 = 1 IF PRINTING VERTICALLY
FOR Z = 1 TO LEN (L$): Z3 = ASC (MID$ (L$,Z,1))
IF Z3 < > 0 THEN GOTO 5570
IF Z3 > 64 THEN DRAW 23 - 64 AT X0 + (Z - 1) * 7 * SC, Y0: GOTO 5590
DRAW Z3 AT X0 + (Z - 1) * 7 * SC, Y0: GOTO 5590
5570 ROT= 48: IF Z3 > 64 THEN DRAW Z3 - 64 AT X0, Y0 - (Z - 1) * 7: GOTO 5590
5580 DRAW Z3 AT X0, Y0 - (Z - 1) * 7
5590 ROT= 0: NEXT Z
5600 RETURN
5605 REM
5610 REM: SCALE AND PLOT POINT FOR DEFINED X AND Y
5620 REM: FOR LINE PLOT MAKE ZF=1
5625 REM
5630 X0 = 23 + X = 256 / XM
5640 Y0 = 149 - Y = 149 / YM
5650 IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 THEN GOTO 5680
5660 IF ZF = 1 THEN HPL T TO X0, Y0: GOTO 5680
5670 HPL T X0, Y0: IF ZF = 1 THEN ZF = 1
5680 RETURN
9995 REM
9996 REM: DATA STATEMENTS CONTAINING THE PREY RECRUITMENT X AND Y POINTS AND THE PREDATOR Y POINTS TO BE PLOTTED.
9997 REM
10000 DATA 23,149,149,25,144,148,28,139,147
10010 DATA 38,135,143,33,131,139,35,126,132
10020 DATA 38,122,125,48,118,118,43,114,119
10030 DATA 46,110,103,48,107,96,51,103,90
10040 DATA 53,99,84,56,96,40,58,32,76
10050 DATA 61,89,72,63,86,69,66,33,66
10060 DATA 69,88,64,71,77,62,74,74,61
10070 DATA 76,71,59,79,68,58,81,66,57
10080 DATA 84,63,56,87,61,55,89,59,54
10090 DATA 92,57,53,94,54,33,97,52,52
10100 DATA 99,51,52,102,49,51,104,47,51
10110 DATA 107,45,51,110,44,50,112,42,50
10120 DATA 115,41,50,117,49,49,120,39,49
10130 DATA 122,37,49,125,37,49,127,36,49
10140 DATA 130,35,48,133,34,48,135,34,46
10150 DATA 138,33,48,146,33,48,143,32,48
10160 DATA 145,32,48,154,32,48,151,32,48
10170 DATA 153,32,47,156,32,47,153,32,47
10180 DATA 161,33,47,163,33,47,166,34,47
10190 DATA 168,34,47,171,35,47,174,36,47
10200 DATA 176,37,47,179,37,47,181,39,47
10210 DATA 184,40,47,186,41,47,189,42,47
10220 DATA 191,44,47,194,45,47,197,47,47
10230 DATA 199,49,47,202,50,47,204,52,47
10240 DATA 207,54,47,209,57,47,212,59,46
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</table>
5 REM PRED FUNCT2
10 REM PRED FUNCT2 IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.
15 REM PROGRAMMED BY MARK SHALTZ
20 REM THIS PROGRAM WAS DEVELOPED BY THE SUMIT 1 COURSEWARE DEVELOPMENT P
25 REM PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UNI
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135 REM IN THIS PUBLICATION ARE THOSE OF THE AUTHORS AND DO NOT NECESSARI
140 REM HOME
145 X$ = "DENSITY OF PREY POPULATION"
150 Y$ = "CHANGE IN DENSITY/yr"
160 REM A CHANGE IN SCALING IS INTRODUCED.
170 REM
180 GOSUB 4050
190 PRINT "FOR THE NEXT DEMONSTRATION IT MIGHT BE BETTER TO LOOK ONLY AT"
200 PAUSE = 3000: GOSUB 4000
210 UTA B 22
220 PRINT ", SO WE'LL IGNORE EVERYTHING TO THE
230 HPL OT 126,0
240 FOR I = 0 TO 148
250 HCOLOR = 3
260 HPL OT 126,1
270 NEXT
280 PAUSE = 1000: GOSUB 5000
290 X = 127: Y = 0: XZ = 152: L = 148: GOSUB 5140
300 PAUSE = 3000: GOSUB 5000
310 GOSUB 4050
320 UTA B 22
330 PRINT ", WHAT REMAINS IS PUT ON A LARGER SCALE SO IT CAN BE EXAMINED"
340 TEXT
350 X = 25: Y = 0: XZ = 102: L = 148: GOSUB 5140
360 POKE - 16304, 0: POKE - 16297, 0
370 ZF = 1
380 UTA B 22
390 HPL OT 25,149
400 YM = 40
410 YM = 225
420 PAUSE = 1000: GOSUB 5000
430 POKE - 16304, 0: POKE - 16297, 0
440 REM
450 REM
460 REM
470 REM
480 REM
490 REM
500 REM
510 REM THE PREY RECRUITMENT CURVE IS DRAWN.
520 REM
530 R = .01
540 K = 100
550 FOR X = 0 TO XM STEP .5
560 Y = R * X * (1 - X / K)
570 IF Y < 0 THEN Y = 0
580 GOSUB 5610
590 Y1(X) = Y0
600 NEXT
610 REM
620 REM PREDATOR RESPONSE IS PLOTTED.
630 REM
640 YM = 112.5
650 HCOLOR= 5
660 HPUT 25, 149
670 K = .110
680 E = 2.5
690 DD = 300
700 VS = 0: Y0 = 0: YE = 0
710 VTAB 22
720 FOR X = 0 TO XM STEP .5
730 Y = K * X * E / (X * E + DD)
740 GOSUB 5610
750 X2(X) = X0: Y2(X) = Y0
760 NEXT
770 PAUSE = 1000: GOSUB 5000: GOSUB 5080
780 REM
790 REM THE CONCEPT OF SUBTRACTING CURVES IS INTRODUCED.
800 REM
810 TEXT: GOSUB 4050
820 VTAB 5
830 PRINT "YOU WILL RECALL THAT THE PREY RECRUITMENT CURVE REPRESENTS THE POSITIVE CHANGE IN THE PREY POPULATION, AND THE PREDATOR FUNCTIONAL RESPONSE CURVE REPRESENTS THE NEGATIVE CHANGE."
840 PAUSE = 1000: GOSUB 5000
850 VTAB 11
860 PRINT "IF THIS IS SO, THEN THE DIFFERENCE BETWEEN THESE TWO CURVES IS THE CHANGE IN PREY DENSITY PER SOME TIME INTERVAL."
870 PAUSE = 1000: GOSUB 5000
880 VTAB 15
890 PRINT "SO THE RELATIVE AMOUNT OF TIME NECESSARY FOR THE PREY DENSITY TO REACH A STABLE EQUILIBRIUM POINT CAN BE ESTIMATED."
900 PAUSE = 1000: GOSUB 5000
910 VTAB 20
920 PRINT "THE PRECISE LENGTH OF TIME CANNOT BE CALCULATED DUE TO SCALE DIFFERENCES."
930 PAUSE = 500: GOSUB 4000
940 POKE -16304,0: POKE -16297,0
950 REM
960 REM SIMULATION THAT SUBTRACTS THE TWO CURVES AND TAKES THIS DIFFERENCE FROM THE X-AXIS.
970 REM
980 COUNT = 0
990 I = 18
1000 GOTO 1240
1010 IF X2(I) < Y2(J) THEN COUNT = COUNT + 1
1020 IF Y1(I) < Y2(I) THEN TP = Y2(I)
1030 FOR H = INT(TP) TO -1 STEP -1
1040 HCOLOR = 0: IF INT(H/3) = H/3 THEN HCOLOR = 3
1050 HPLT X2(I),Y1(I) TO X2(I),Y2(I)
1060 HPLT X2(I) - 2,Y1(I) TO X2(I) - 2,Y2(I)
1070 HCOLOR = 0
1080 HPLT X2(I),Y1(I) TO X2(I),Y2(I)
1090 HPLT X2(J),Y1(J) TO X2(J),Y2(J)
1100 HPLT X2(J) - 2,Y1(J) TO X2(J) - 2,Y2(J)
1110 HPLOT X2(I),Y1(I) TO X2(I),H
1120 YY = H
1130 NEXT I
1140 HCOLOR = 3
1150 HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
1160 HPLOT X2(I) - 2,Y1(I) TO X2(I) - 2,Y2(I)
1170 HCOLOR = 0
1180 HPLOT X2(I),Y1(I) TO X2(I),Y2(I)
1190 HPLOT X2(J),Y1(J) TO X2(J),148
1200 HPLOT X2(J),148 TO X2(I),148
1210 HPLOT X2(J),147 TO X2(I),147
1220 IF X2(J) = X2(I) THEN COUNT = COUNT + 3
1230 IF COUNT < 2 THEN GOSUB 4650
1240 IF COUNT < 2 AND CT = 0 THEN PRINT "THE DIFFERENCE BETWEEN THE TWO CURVES IS THE EFFECT OF PREDATION ON THE PREY DENSITY PER TIME INTERVAL.":PAUSE = 4000: GOSUB 5000
1250 HCOLOR = 3
1260 HPLT X2(I),Y1(I) TO X2(I),Y2(I)
1270 HPLT X2(I) - 2,Y1(I) TO X2(I) - 2,Y2(I)
1280 IF COUNT = 0 AND CT = 0 THEN GOSUB 5800
1290 IF COUNT < 2 THEN HOME
1300 YY = Y1(I)
1310 IF COUNT < 2 AND CT = 0 THEN PRINT "BY SUBTRACTING THIS DIFFERENCE FROM THE X-AXIS, THE PREY DENSITY FOR THE FOLLOWING TIME INTERVAL IS OBTAINED.":PAUSE = 2000: GOSUB 5000
1320 TP = Y1(I)
1330 IF Y1(I) < Y2(I) THEN TP = Y2(I)
1340 FOR I = INT(TP) TO 148
HCOLOR = 0: IF INT (H / 3) = H / 3 THEN HCOLOR = 3
1380 HPLT X2(I), YY TO X2(I), H
1390 YY = H
1400 NEXT
1410 IF X2(J) = X2(I) THEN COUNT = COUNT - 3
1420 J = I
1430 XX = X2(I) - (Y1(I) - Y2(I))
1440 I = (XX - 23) * XM / 256
1450 HCOLOR = 3
1460 IF X2(I) < 279 AND X2(I) > 0 GOTO 1530
1470 HPLT X2(J), 148 TO 279, 148
1480 HPLT X2(J), 147 TO 279, 147
1490 GOSUB 4050
1500 PRINT "PREY DENSITY HAS GONE OFF THE GRAPH TOWARD THE OTHER EQUILIBRIUM POINT."
1510 PAUSE = 2000: GOSUB 5000: GOSUB 5080
1512 HCOLOR = 0
1513 HPLT X2(J), 148 TO 279, 148
1514 HPLT X2(J), 147 TO 279, 147
1515 HCOLOR = 3
1520 HOME: GOTO 1890
1530 HPLT X2(J), 148 TO X2(I), 148
1540 HPLT X2(J), 147 TO X2(I), 147
1550 IF COUNT = 0 AND CT = 0 THEN GOSUB 5080: HOME
1560 IF X2(I) = X2(J) GOTO 1590
1570 GOTO 1650
1580 REH
1590 HOME
1600 UTAB 21
1601 IF I > 28 AND I < 31 THEN HOME: UTAB 21: PRINT "NOTICE THAT THE PREY DENSITY IS ON THE UNSTABLE EQUILIBRIUM POINT. TRY A DEN- ...
1602 IF CHECK > 0 GOTO 1610
1605 IF COUNT > 0 AND CT > 0 THEN COUNT = COUNT - 1
1610 PRINT "IT TOOK " COUNT " TIME INTERVALS FOR"
1615 CHECK = 1
1620 UTAB 22
1630 PRINT "THE PREY DENSITY TO REACH EQUILIBRIUM."
1640 UTAB 23
1650 PRINT "PRESS -RETURN- TO CONTINUE"
1660 IF Peek ( - 16384) = 141 THEN GOTO 1690
1665 GOTO 1690
1670 HCOLOR = 3: HPLT 23, 149: FOR I = 0 TO 40 STEP .5
1680 IF I = 40 GOTO 1730
1690 HPLT TO X2(I),Y1(I)
1700 NEXT
1710 HCOLOR = 5: HPLT 23, 149
1720 FOR I = 0 TO 40 STEP .5
1730 HPLT TO X2(I),Y2(I)
1740 NEXT
1760 IF I > 40 GOTO 1780
1770 NEXT
HOME: CT = CT + 1: IF CT < 17 THEN GOTO 1890
1800 REM THE SIMULATION IS REPEATED WITH A NEW STARTING PREY DENSITY
     (INPUT BY THE USER).
1810 REM
1820 60SUB 4050
1840 PRINT "TRY A DIFFERENT STARTING PREY DENSITY TO COMPARE WITH THE ORIGINAL EXAMPLE.
1850 POKE 16368, 0
1860 PAUSE = 1000: 60SUB 5000: VTAB 24: INPUT "PRESS RETURN TO INPUT NEW DENSITY": Q$ ="
1870 HOME: POKE 16304, 0: POKE 16297, 0
1880 GOTO 1900
1890 VTAB 22: PAUSE = 1000: 60SUB 5000
1900 IF PEEK (-16384) < 0 THEN POKE 16368, 0
1910 INPUT.1. "WOULD YOU LIKE TO TRY AGAIN FROM ANOTHER STARTING PREY DENSITY": Q$ ="
1920 IF LEFT$ (Q$, 1) = "Y" GOTO 2040
1930 PRINT "WHERE WOULD YOU LIKE TO START? (1-35)"
1940 HOME: HGR: TEXT
1950 PAUSE = 1000: 60SUB 5000: VTAB 10
1960 PRINT "FROM THE PREVIOUS SIMULATIONS YOU SAW THAT THERE EXISTS A RELATIONSHIP BETWEEN THE PREY RECRUITMENT AND THE PREDATOR FUNCTIONAL RESPONSE CURVE."
1970 PAUSE = 1000: 60SUB 5000
1980 VTAB 15
1990 PRINT "NEXT YOU WILL SEE THAT A CHANGE IN A SINGLE PARAMETER CAN AFFECT THE ENTIRE SYSTEM."
2000 REM
2010 REM THE CONCEPT OF ADDITIONAL PARAMETERS IS BROUGHT UP.
2020 REM
2040 HOME: HGR: TEXT
2050 PAUSE = 1000: 60SUB 5000: VTAB 10
2060 PRINT "FROM THE PREVIOUS SIMULATIONS YOU SAW THAT THERE EXISTS A RELATIONSHIP BETWEEN THE PREY RECRUITMENT AND THE PREDATOR FUNCTIONAL RESPONSE CURVE."
2070 PAUSE = 1000: 60SUB 5000
2080 VTAB 15
2090 PRINT "NEXT YOU WILL SEE THAT A CHANGE IN A SINGLE PARAMETER CAN AFFECT THE ENTIRE SYSTEM."
2100 REM
2110 REM THE SUBPROGRAM PRED FUNCT3 IS RUN.
2120 REM
2130 D$ = CHR$ (4)
2140 PRINT D$: "RUN PRED FUNCT3"
4000 REM
4010 REM PAUSE, RETURN, HOME, VTAB SUBROUTINE.
4020 REM
4030 GOSUB 5000.
4040 GOSUB 5080
4050 HOME
4060 PAUSE = 500: GOSUB 5000
4070 VTAB 21
4080 RETURN
4090 REM
4095 REM
4096 REM ****************************
4097 REM **** SUBROUTINES ******
4098 REM ****************************
4099 REM
5000 REM PAUSE SUBROUTINE.
5010 REM VARIABLES TO BE PROVIDED:
5020 REM PAUSE = LENGTH OF PAUSE.
5030 REM
5040 5050 FOR PS = 1 TO PAUSE
5060 5070 RETURN
5080 REM
5090 REM PRESS -RETURN- SUBROUTINE.
5100 REM
5105 POKE 16368,0
5110 VTAB 24
5120 INPUT "PRESS -RETURN- TO CONTINUE":Q$ 
5130 RETURN
5140 REM
5150 REM SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HGR SCREEN.
5160 REM VARIABLES THAT MUST BE PROVIDED:
5170 REM X = STARTING X COORDINATE
5180 REM Y = STARTING Y COORDINATE
5190 REM XZ = LENGTH OF RECTANGLE ALONG THE X AXIS.
5200 REM L = WIDTH OF RECTANGLE ALONG THE Y AXIS.
5210 REM
5220 HCOLOR= 0
5230 FOR TA = 0 TO L
5240 HPLOT X,TA + Y TO X + XZ,TA + Y
5250 NEXT TA
5260 HCOLOR = 3
5270 RETURN
5275 REM

5280 REM AXES AND UNITS FOR GRAPHS
5290 REM SUBROUTINE DEVELOPED BY J. SPAIN, MICHIGAN TECH UNIV., AND B. J. HINKEI, ALBION COLLEGE
5300 REM DEFINE X$-VARIABLE PLOTTED ON X AXIS
5310 REM DEFINE Y$-VARIABLE PLOTTED ON Y AXIS
5320 REM DEFINE YM-MAXIMUM UNITS ON THE Y AXIS
5330 REM DEFINE XH-MAXIMUM UNITS ON THE X AXIS
5335 REM

5340 HCOLOR = 3: SCALE = 1: SC = 1: ROT = 0

5360 HPL0T 23,0 TO 23,149
5370 HPL0T 25,149 TO 279,149
5380 REM WRITE VARIABLE NAME ON X-AXIS
5390 Z0 = 0: LS = X$: X$ = 60: Y$ = 150
5400 GOSUB 5450
5410 REM WRITE VARIABLE NAME ON Y-AXIS
5420 Z0 = 1: LS = Y$: X$ = 10: Y$ = 140
5430 GOSUB 5450
5440 RETURN

5450 REM ALPHANUMERIC CHARACTERS FOR HGR
5460 REM THE FOLLOWING MUST BE DEFINED
5470 REM BEFORE ENTERING THE SUBROUTINE
5480 REM L$ = "CHARACTER STRING"
5490 REM Y$ = THE INITIAL Y POSITION
5500 REM X$ = THE INITIAL X POSITION
5510 REM SET Z0 = 0 IF PRINTING HORIZONTAL
5520 REM SET Z0 = 1 IF PRINTING VERTICALLY
5530 REM FOR Z = 1 TO LEN (LS): ZS = ASC ( MID (LS, Z, 1))
5540 REM IF Z0 < > 0 THEN GOTO 5570
5550 REM IF Z3 > 64 THEN DRAW Z3 - 64 AT X$ + (Z - 1) * 7 * SC, Y$: GOTO 5590
5560 DRAW Z3 AT X0 + (Z - 1) * 7 * SC, Y0: GOTO 5590
5570 ROT= 48: IF Z3 > 64 THEN DRAW Z3 - 64 AT X0, Y0 - (Z - 1) * 7: GOTO 5590
5580 DRAW Z3 AT X0, Y0 - (Z - 1) * 7
5590 ROT= 0: NEXT Z
5600 RETURN
5605 REM
5610 REM SCALE AND PLOT POINT FOR DEFINED X AND Y
5620 REM FOR LINE PLOT MAKE ZF=1
5625 REM
5630 X0 = 23.0 + X * 256 / XH
5640 Y0 = 149.0 + Y * 140 / YH
5650 IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 THEN GOTO 5680
5660 IF ZG = 1 THEN HPLT TO X0, Y0: GOTO 5680
5670 HPLT X0, Y0: IF ZF = 1 THEN ZG = 1
5680 RETURN
PRED FUNCT3

PRED FUNCT3 IS A SUBPROGRAM OF PREDATOR FUNCTIONAL RESPONSE.

PROGRAMPED BY MARK SHALTZ

THIS PROGRAM WAS DEVELOPED BY THE SUMIT I COURSEWARE DEVELOPMENT
PROJECT, DEPARTMENT OF BIOLOGICAL SCIENCES, MICHIGAN TECHNOLOGICAL UN
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ILY REFLECT THE VIEWS OF THE NATIONAL SCIENCE FOUNDATION.

DIM Y1(101),X2(101),Y2(101)

X$ = "DENSITY OF PREY POPULATION"

Y$ = "PREY GROWTH / TIME"

HUNTER PRESSURE IS INTRODUCED AS A PARAMETER.

PAUSE = 1: GOSUB 4800

PAUSE = 500: GOSUB 5000

VTAB 7

PRINT " THE PREY RECRUITMENT CURVE IS THE RESULT OF PREY BIRTHS
MINUS NON-PREDATORDEATHS AT DIFFERENT PREY DENSITIES."

PAUSE = 500: GOSUB 5000

HCOLOR= 5: X0 = 1: GOSUB 5450

PRINT " IF THE PREY ARE ALSO HARVESTED BY MAN, THEN YOU MUST CON
SIDER AN ADDITIONAL EFFECT ON PREY RECRUITMENT, THAT OF HUN
TING PRESSURE."

600 GOSUB 5200

PRINT " HUNTING PRESSURE LOWERS THE PREY RECRUITMENT CUR
RUE."

PAUSE = 500: GOSUB 5000

VTAB 20

PRINT " LET'S EXAMINE HOW THIS HAPPENS."

PAUSE = 500: GOSUB 4000

VTAB 22

PRINT " FIRST WE MUST AGAIN GO BACK TO THE ORIGINAL PREY RECRUI
ENT CURVE."

PAUSE = 1000: GOSUB 5000

POKE -16304,0: POKE -16297,0

REH
THE PREY RECRUITMENT CURVE IS PLOTTED.

5F = 1
XM = 100: YM = .3
HPL0T 23, 149
FOR I = 0 TO 100
READ X2(I), Y1(I), Y2(I)
HPL0T TO X2(I), Y1(I)
NEXT
PAUSE = 1000: GOSUB 5000: HOME: GOSUB 5000
PRINT " IT HAS BEEN FOUND THAT PREY LOSS DUE TO HUNTING IS A LINEAR
FUNCTION OF PREY DENSITY."

HUNTER PRESSURE IS PLOTTED.
POKE ORANGE COLOR.
POKE 28, 213
HCOlor = 5
HPL0T 23, 149
HP = .05
FOR N = 0 TO 100
X = N: Y = .25 * HP / 50 * 2 * N
GOSUB 5610
NEXT
PAUSE = 500: GOSUB 4000
PRINT " THIS MEANS THAT HUNTERS TEND TO HARVEST A CERTAIN PERC
ENTAGE OF THE PREY, REGARDLESS OF PREY DENSITY."
PAUSE = 500: GOSUB 4000

THE CONCEPT OF POSITIVE AND NEGATIVE CURVES IS APPLIED TO PREY
RECRUITMENT AND HUNTER PRESSURE.

TEXT: PAUSE = 500: GOSUB 5000
PRINT " THE PREY RECRUITMENT CURVE REPRESENTS PREY ADDED TO THE POPU
LATION, AND THE HUNTING LINE REPRESENTS PREY KILLED."
PAUSE = 500: GOSUB 5000
PRINT " BY SUBTRACTING PREY KILLED DUE TO HUNTING FROM PREY ADDE
D THROUGH RECRUITMENT, A NEW CURVE WOULD RESULT."
PAUSE = 500: GOSUB 5000: VTAB 15
PRINT " THIS NEW PREY RECRUITMENT CURVE WOULD TAKE INTO ACCOUNT
HUNTER PRESSURE."
PAUSE = 500: GOSUB 4000
POKE -16304, 0: POKE -16297, 0

REM THE TWO CURVES ARE SUBTRACTED.

PAUSE = 500: GOSUB 5000

PRINT "SUBTRACTING THE CURVES..."

HP = 0.05: HC = 6: FLAG = 0: GOSUB 4100

PAUSE = 1000: GOSUB 5000: GOSUB 4050

PRINT ", THUS THE PREY RECRUITMENT CURVE IS LOWERED BY HUNTING PRESSURE."

PAUSE = 500: GOSUB 4000

REM

THE PREDATOR FUNCTIONAL RESPONSE CURVE IS PLOTTED.

VTAB 22

PRINT "THE PREDATOR FUNCTIONAL RESPONSE CURVES IS NOT AFFECTED BY HUNTING PRESSURE."

HCOLOR = 5

HPLOT 23, 149

FOR I = 0 TO 100

HPLOT TO X2(I), Y2(I)

NEXT

PAUSE = 500: GOSUB 4000

REM

A HYPOTHETICAL SITUATION IS SET UP.

VTAB 22

PRINT "TO STUDY THE POSSIBLE CONSEQUENCES OF HUNTING PRESSURE ON A SYSTEM, LET'S LOOK AT A HYPOTHETICAL SITUATION."

X = 24: Y = 0: XZ = 255: L = 148: GOSUB 5140

HCOLOR = 3

HPLOT 23, 149

FOR I = 0 TO 100

HPLOT TO X2(I), Y2(I)

NEXT

PAUSE = 1: GOSUB 4000

VTAB 7

PRINT "IF YOU HERE A WILDLIFE MANAGER, ONE OF YOUR CONCERNS MAY BE THAT OF KEEPING A HIGH PREY POPULATION AVAILABLE FOR HUNTING EACH YEAR."

HCOLOR = 5

HPLOT 23, 149

FOR I = 0 TO 100

HPLOT TO X2(I), Y2(I)

NEXT
THE HUNTER PRESSURE IS INPUT BY THE USER.

YOU ARE MANAGING AN AREA WITH 10,000 PREY. HOW MANY OF THESE PREY WOULD YOU ALLOW TO BE HARVESTED BY HUNTERS?

PRINT : PRINT : INPUT HP
HP = INT (HP + .5)
PAUSE = 1: GOSUB 4050
VTAB 2
PRINT "YOU CHOSE "HP" PREY TO BE"
PRINT "HARVESTED."
IF HP < 100 THEN VTAB 15: PRINT "BY ALLOWING SO FEW TO BE HARVESTED, YOUR AREA'S TOWNS COULD LOSE VALUABLE INCOME DUE TO THE LACK OF HUNTERS. TRY A LARGER NUMBER."
IF HP > 600 THEN VTAB 7: PRINT "KILLING THAT MANY COULD STRAIN THE PREY POPULATION. TRY A SMALLER NUMBER."
IF HP >= 100 AND HP < 600 THEN VTAB 11: PRINT "LET'S SEE THE EFFECT OF HUNTERS HARVESTING "HP" PREY."

PAUSE = 4000: GOSUB 5000
IF HP < 100 OR HP > 600 THEN PAUSE = 1: GOSUB 4000: GOTO 1240
POKE -16304,0: POKE -16297,0
VTAB 22
PAUSE = 500: GOSUB 5000
VTAB 22
PRINT "THE PREY DENSITY IN YOUR AREA IS AT THE UPPER STABLE EQUILIBRIUM POINT."
FOR I = 1 TO 12
HCOLOR= 3: IF INT (I / < I / 2 THEN HCOLOR= 0
PAUSE = 500: GOSUB 5000
HPLOT 60.37 TO 200.45 TO 206.39
NEXT
PAUSE = 500: GOSUB 5000
GOSUB 4050
REH

THE PREY RECRUITMENT CURVE IS LOWERED TO ACCOUNT FOR HUNTER PRESSURE.

REM

BY KILLING "HP" PREY, THE PREY RECRUITMENT CURVE IS MOVED DOWN.
HTEMP = HP / 10000
PRINT "RECRUITMENT CURVE IS MOVED DOWN."
HP = HP / 10000: HC = 3: FLAGE = 1: GOSUB 4100
HO = HTEMP
GOSUB 4400
PAUSE = 1: GOSUB 4000
1600 PRINT " NOTICE HOW THE EQUILIBRIUM PREY DENSITY IN YOUR AREA HAS LOWERED SLIGHTLY BY HUNTING PRESSURE."
1610 PAUSE = 500: GOSUB 4000
1620 TEXT:PAUSE = 1000: GOSUB 5000: UTAB 5
1630 PRINT " YOU HAVE A BOSS WHO RAISES MORE HUNTERS IN THE AREA'S 0 AS TO GET MORE INCOME INTO THE LOCAL TOWNS."
1640 PAUSE = 500: GOSUB 5000
1650 UTAB 12
1660 REM
1670 REM THE USER INCREASES HUNTER PRESSURE.
1680 REM
1690 PRINT " OUT OF THE ORIGINAL 10,000, HOW MANY PREY WILL YOU HARVEST NOW?"
1700 PRINT :PRINT ; INPUT: HP
1710 HP = INT (HP + 5)
1720 GOSUB 4050
1730 UTAB 2
1740 PRINT " YOU HAVE CHosen TO HARVEST ";HP
1750 PRINT " PREY."
1760 IF HP < 800 THEN UTAB 15: PRINT " NOT ENOUGH, SAYS YOUR BOSS. HE WANTS MORE HUNTERS (AND MORE INCOME FOR THE TOWNS)."
1770 IF HP > 4000 THEN UTAB 0: PRINT " SUCH A LARGE HARVEST IS TOO RISKY TO YOUR BOSS. TRY A SMALLER NUMBER."
1780 IF HP < 800 OR HP > 4000 THEN PAUSE = 2000: GOSUB 4000: GOTO 1650
1790 UTAB 10: PRINT " LET'S SEE THE EFFECTS OF HUNTERS HARVESTING ";HP;" PREY."
1800 PAUSE = 4000: GOSUB 5000
1810 GOSUB 4050
1820 POKE –16304,0: POKE -16297,0
1830 REM
1840 REM THE LOSS OF A STABLE EQUILIBRIUM POINT DUE TO HUNTER PRESSURE IS SHOWN.
1850 REM
1860 PAUSE = 500: GOSUB 5000
1870 UTAB 22
1880 PRINT " BY HARVESTING ";HP;" PREY, THE GRAPH"
1890 PRINT " WOULD CHANGE TO LOOK LIKE..."
1900 HTEMP = HP / 10000
1910 HP = HP / 10000: HC = 3: FLAG = 1: GOSUB 4100
1920 GOSUB 4050: HD = HTEMP: UTAB 22
1930 PRINT " EXCESSIVE HARVEST CAUSED THE EQUILIBRIUM PREY DENSITY TO MOVE FROM HERE..."
1940 GOSUB 4400
1950 FOR I = 1 TO 13
1960 HCOLOR= 3: IF INT (I / 2) = I / 2 THEN HCOLOR= 0
1970 HPLLOT 200,37 TO 200,45 TO 205,39
1980 PAUSE = 500: GOSUB 5000
1990 NEXT

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2000 PAUSE = 500: GOSUB 4000: UTAB 22
2010 PRINT "... TO HERE."
2020 FOR I = 1 TO 13
2030 HCOLOR = 3: IF INT (I / 2) = I / 2 THEN HCOLOR = 0
2040 HPLT 55.135 TO 47.135 TO 53.141
2050 PAUSE = 500: GOSUB 5000
2060 NEXT
2070 PAUSE = 500: GOSUB 4888
2080 HCOLOR = 0
2090 HPLT 200.37 TO 200.45 TO 206.39
2100 PAUSE = 500: GOSUB 4000
2110 REM
2120 REM HUNTER PRESSURE IS TAKEN AWAY.
2130 REM
2140 HOME: TEXT
2150 PAUSE = 500: GOSUB 5000: UTAB 7
2160 PRINT "NOH BECAUSE OF THE SUDDEN LOW DENSITY OF PREY, YOUR BOSS FEARS THAT HUNTERS WILL WIRE OUT THE PREY COMPLETELY."
2170 PAUSE = 1000: GOSUB 5000
2180 UTAB 12
2190 PRINT "SO HE ORDERS ALL HUNTING TO CEASE, HOPING THAT THE LACK OF HUNTER PRESSURE WILL ALLOW THE PREY TO EVENTUALLY RETURN TO THEIR HIGHER EQUILIBRIUM DENSITY."
2200 PAUSE = 500: GOSUB 4000
2210 PRINT "THE RESULT OF YOUR BOSS'S NEW POLICY IS THE ORIGINAL GRAPH BEFORE HUNTING..."
2220 PAUSE = 500: GOSUB 5000
2230 POKE -16304,0: POKE -16297,0
2240 HP = 0: HC = 3: FLAG = 1: GOSUB 4100
2250 GOSUB 4050
2260 PRINT "ALTHOUGH THE UPPER STABLE EQUILIBRIUM POINT RETURNED, THE PREY DENSITY IS STUCK AT THE LOWER EQUILIBRIUM POINT."
2270 GOSUB 4400: HCOLOR = 3
2280 HPLT 55.118 TO 47.118 TO 53.124
2290 PAUSE = 1000: GOSUB 5000
2300 HCOLOR = 0: HPLT 55.135 TO 47.135 TO 53.141
2310 PAUSE = 1: GOSUB 4000
2320 PRINT "DUE TO EXCESSIVE HUNTER PRESSURE, THE PREY DENSITY DROPPED TO THE LOWER STABLE EQUILIBRIUM POINT."
2330 PAUSE = 1000: GOSUB 5000
2340 FOR I = 1 TO 13
2350 HCOLOR = 3: IF INT (I / 2) = I / 2 THEN HCOLOR = 0
2360 HPLT 55.118 TO 47.118 TO 53.124
2370 PAUSE = 500: GOSUB 5000
2380 NEXT
2390 PAUSE = 500: GOSUB 4000
2400 UTAB 21
2410 PRINT "THE PREY DENSITY WILL STAY AT THIS LOWER EQUILIBRIUM POINT UNTIL OTHER FACTORS INTERVENE."
2420 PAUSE = 500: GOSUB 4000
CONCLUSIONS FROM THE ENTIRE PROGRAM ARE LISTED.

IN THIS MODULE, YOU HAVE:

1. SEEN PREY RECRUITMENT DERIVED FROM LOGISTIC GROWTH.

2. OBSERVED THE PREDATOR FUNCTIONAL RESPONSE CURVE PLOTTED ON THE SAME GRAPH AS THE PREY RECRUITMENT CURVE.

3. IDENTIFIED AND PREDICTED STABILITY OF PREY DENSITY EQUILIBRIUM POINTS.

4. CHANGED THE PREDATOR CARRYING CAPACITY AND OBSERVED ITS EFFECTS.

5. COMPARED RATES AT WHICH DIFFERENTITIES APPROACHED A STABLE EQUILIBRIUM POINT.

6. WORKED WITH A PARAMETER AFFECTING AFFECTING PREY RECRUITMENT, THAT OF HUNTER PRESSURE.

I HOPE THIS MODULE HAS BEEN OF USE TO YOU.

THAT'S IT! BYE.
SUBROUTINE THAT ERASES ONE CURVE WHILE PLOTTING ANOTHER.

SUBROUTINE TO REPLICATION PREDATOR FUNCTIONAL RESPONSE CURVE.
PAUSE SUBROUTINE.

VARIABLES TO BE PROVIDED:

\[ D = \text{LENGTH OF PAUSE}. \]

FOR PS = 1 TO PAUSE
NEXT
RETURN

PRESS -RETURN- SUBROUTINE.

POKE -16368,0
VTAB 24
INPUT "PRESS -RETURN- TO CONTINUE";
RETURN

SUBROUTINE THAT BLACKS OUT A RECTANGLE ON THE HDR SCREEN.

VARIABLES THAT MUST BE PROVIDED:

\[ X = \text{STARTING X COORDINATE}; \]
\[ Y = \text{STARTING Y COORDINATE}; \]
\[ XZ = \text{LENGTH OF RECTANGLE ALONG THE X AXIS}; \]
\[ L = \text{WIDTH OF RECTANGLE ALONG THE Y AXIS}. \]

HCOLOR= 0
FOR TA = 0 TO L
HPILOT \( X + TA \) TO \( X + XZ, TA + Y \)
NEXT TA
HCOLOR=-3
RETURN

AXES AND UNITS FOR GRAPHS

SUBROUTINE DEVELOPED BY J. SPAIN, MICHIGAN TECH UNIV., AND B.J. WINKEL, ALBION COLLEGE

DEFINE X$=VARIABLE PLOTTED ON X AXIS
DEFINE Y$=VARIABLE PLOTTED ON Y AXIS
DEFINE YM =MAXIMUM UNITS ON THE Y AXIS
DEFINE XM =MAXIMUM UNITS ON THE X AXIS

HCOLOR= 3: SCALE= 1: SC = 1: RDT= 0
LIST OF RESERVED VARIABLES:X,X0,XH,X$,Y,Y0,YH,Y$,Z,ZF,Z0,Z3,L$,

Page 043
5360 HPLT 23,0 TO 23,149
5370 HPLT 25,149 TO 279,149
5390 REM WRITE VARIABLE NAME ON X-AXIS
5390 20 = 0; X$ = X; X0 = 60; Y0 = 150
5400 GOSUB 5450
5405 IF WRITE = 1 THEN HOME; PAUSE = 1000; GOSUB 5000; UTAH 22; PRINT "ALONG THE Y-AXIS IS THE GROWTH OF THE PREY DENSITY PER YEAR."; PAUSE = 3000; GOSUB 5000
5410 REM WRITE VARIABLE NAME ON Y-AXIS
5420 Y0 = THE INITIAL Y POSITION
5425 X0 = 10: Y0 = 140
5430 GOSUB 5450
5440 RETURN
5450 REM ALPHANUMERIC CHARACTERS FOR HGR
5460 REM THE FOLLOWING MUST BE DEFINED
5470 REM BEFORE ENTERING THE SUBROUTINE
5480 REM L$ = "CHARACTER STRING"
5490 REM Y0 = THE INITIAL Y POSITION
5500 REM X0 = THE INITIAL X POSITION
5510 REM SET Z0 = 0 IF PRINTING HORIZONTALLY
5520 REM SET Z0 = 1 IF PRINTING VERTICALLY
5530 FOR Z = 1 TO LEN (L$): Z3 = ASC (MID$ (L$, Z, 1))
5540 IF Z0 < 0 THEN GOTO 5570
5550 IF Z3 > 64 THEN DRAW Z3 - 64 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
5560 DRAW Z3 AT X0 + (Z - 1) * 7 * SC,Y0: GOTO 5590
5570 ROT = 48: IF Z3 > 64 THEN DRAW Z3 - 64 AT X0,Y0 - (Z - 1) * 7: GOTO 5590
5580 DRAW Z3 AT X0,Y0 - (Z - 1) * 7
5590 ROT = 0: NEXT Z
5600 RETURN
5601 REM
5610 REM SCALE AND PLOT POINT FOR DEFINED X AND Y
5620 REM FOR LINE PLOT, MAKE ZF=1
5625 REM
5630 X0 = 23 + X * 256 / XM
5640 Y0 = 149 - Y * 140 / YM
5650 IF X0 > 279 OR X0 < 0 OR Y0 > 149 OR Y0 < 0 THEN GOTO 5690
5660 IF Z6 = 1 THEN HPLT TO X0,Y0: GOTO 5680
5670 HPLT X0,Y0: IF ZF = 1 THEN Z6 = 1
5680 RETURN
9995 REM
DATA STATEMENTS FOR COORDINATES OF PREY RECRUITMENT AND PREDATOR FUNCTIONAL RESPONSE CURVE.

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