DEPARTMENTS

Technological Tools

Note: Dr. David Inouye is the editor of the **Technological Tools** section. Anyone wishing to contribute articles or reviews to this section should contact him at the Department of Zoology, University of Maryland, College Park, MD 20742, E-mail: di5@umail.umd.edu.

FIRE ECOLOGY AND MANAGEMENT DATABASE NOW ONLINE

Tall Timbers Research Station is pleased to announce that our Fire Ecology Data Base is now available on the World Wide Web. This database consists of key-worded citations to nearly 11,000 scientific publications and commentaries that pertain to fire ecology and management throughout the world. New citations are added to regular updates. Many citations are of research publications that pertain directly to basic aspects of ecology and management of vegetation, habitats, and landscapes using prescribed fire. There is also an extensive thesaurus of key words for the database that may be read or printed directly from the website.

There is no charge for use of this database. Support for database compilation has been provided by Tall Timbers and the U.S. Fish and Wildlife Service. A special grant from the Education Program of the International Association of Fish and Wildlife Agencies supported the format changes and additional compilation tasks required to post this database on the web. To access the database, go to the Tall Timbers web site <www.talltimbers.org>; click on the Fire Ecology Data Base button on the homepage, and then look for the "click here to use the data base" hot text within the introductory descriptive material.

Send comments to:

Leonard A. Brennan
Director of Research
Tall Timbers Research Station
Route 1, Box 678, County Road 12
Tallahassee, FL 32312
(850) 893-4153, Ext. 229
Fax: (850) 668-7781
E-mail: brennan@ttrs.org

Ecology 101

Note: Dr. Harold Ornes is the editor of Ecology 101. Anyone wishing to contribute articles or reviews to this section should contact him at the Department of Biology and Geology, University of South Carolina–Aiken, 471 University Parkway, Aiken, SC 29801; phone (803) 641-3299; fax (803) 641-3251; e-mail: haroldo@aiken.sc.edu.

Perhaps the best trick one can use to engage students in an ecology class is to take them to the field on the first or second day of the course. Once in the field, of course, one should have engaging activities, as contrasted to demonstrations. Such engagement may take the form of making observations and measurements (collecting data). Then the rubber hits the road, so to speak, when we ask students to present and discuss their data. The following article by Professor Charles W. Welden of Southern Oregon University provides us with useful techniques to model ecological processes, using one of the popular spreadsheets found on most PCs. After your students find success in modeling and graphing from the *spreadsheet, you may want to ask them to make a presentation using one of the popular computer packages. Through presentations, students find rewards from the full cycle of learning, practicing what they learned, and then communicating their findings that may contribute to new learning.—Ed.*

USING SPREADSHEETS TO TEACH ECOLOGICAL MODELING

Mathematical models of phenomena such as population growth, interspecific competition, and predation make up important components of many introductory ecology courses. In my experience, students often struggle with models and modeling, and teaching models with lectures alone or in concert with prewritten computer programs meets with mixed success. After trying a number of teaching methods, I stumbled upon the idea of having students build models in spreadsheet programs such as Excel or QuattroPro. I have refined my use of spreadsheets over several years, and continue to discover new ways to use them as teaching tools.

Using spreadsheets to teach modeling has several advantages. First, it requires students to do modeling, as opposed to passively understanding existing models. This teaches them not only about particular models, but also about the reasoning processes behind models, about exploring the behaviors of models as they change parameter values, and about quantitative reasoning in general. Second, it requires no knowledge of a computer language, and yet requires thinking on a level of rigor comparable to introductory computer programming. Third, it presents models in a discrete-time framework, which more realistically describes many ecological processes, such as seasonal breeding, and avoids the need for calculus. Discrete-time models also easily produce chaotic behavior, which captures many students' interest. Fourth, many colleges and universities have site licenses for spreadsheet programs, and many students own personal copies of such programs, reducing their need to purchase new software. Finally, the spreadsheet skills students learn in these modeling exercises carry over into other contexts, such as senior research projects and employment.

Teaching models in spreadsheets obviously requires some facility in the use of these programs, by students and instructor alike. Many students come to class already familiar with the basics of spreadsheets, but I begin with a preliminary exercise to teach (or refresh) such concepts as relative and absolute cell addresses, formulae, and graphs (charts, in spreadsheet jargon). In this first exercise, students program linear, exponential, and power functions, and observe their appearances on linear, semilog, and log–log plots. Later exercises explore models of exponential and logistic population growth, interspecific competition, predator–prey dynamics, island biogeography, and metapopulation dynamics. I have also used spreadsheets to teach life tables, fixed-quota harvesting, microevolutionary changes in allele frequencies, and stage-specific matrix models of population growth, as well as basics of statistical data analysis.

As an example of spreadsheet modeling, here I show the Lotka-Volterra model of interspecific competition (Lotka 1932, Begon et al. 1990:247–250). Prior to doing this exercise, students have modeled exponential and logistic population growth, and have heard a lecture on the Lotka-Volterra model. In the lecture, I emphasize the logic of the equations and the derivation of the zero isoclines, without delving into the classic four cases and their outcomes. I try to guide students to discover these for themselves in the modeling exercise that follows, and then reinforce and clarify main points in a subsequent lecture.

Here, I show a convenient arrangement of the spreadsheet (Fig. 1), and the formulae to perform the necessary calculations (Fig. 2). These formulae work in Excel and should work in other spreadsheets, perhaps with minor modification. Many spreadsheets allow one to format subscripts and Greek letters, as in standard notation for the model, but I omit these frills, which require considerable time and

	A	B	C	D	E	F
1	Lotka-Volterra Model of Interspecific Competition					
2						
3		Isocline End Points			Model Parameters	
4		N1	N2		r1 ->	1
5	N1=0 ->	0	500	<- N2=K2	K1 ->	1000
6	N1=K2/a21 ->	2000	0	<- N2=0	a12 ->	1
7	N1=K1 ->	1000	0	<- N2=0	r2 ->	1
8	N1=0 ->	0	1333	<- N2=K1/a12	K2 ->	500
9					a21 ->	0
10	Time					
11	0	100	200	<- Initial Population Densities		
12	1	156	283			
13	2	230	358			
14	3	317	403			
15	4	407	414			
16	5	494	404			
17	6	569	387			
18	7	629	370			
19	8	673	355			
20	9	704	343			
21	10	724	333			

Fig. 1. Appearance of part of a spreadsheet Lotka-Volterra model of interspecific competition. Gray cells contain model parameters, for which students can enter values of their own choosing.

	A	B	C
1	Lotka-Volterra Model of Interspecific Competition		
2			
3		Isocline End Points	
4		N1	N2
5	N1=0 ->	0	=F8
6	N1=K2/a21 ->	=F8/F9	0
7	N1=K1 ->	=F5	0
8	N1=0 ->	0	=F5/F6
9			
10	Time		
11	0	100	200
12	=a11+1	=B11+F$4*B11*(F$5-B11-F$6*C11)/F$5	=C11+F$7*C11*(F$8-C11-F$9*B11)/F$8
13	=a12+1	=B12+F$4*B12*(F$5-B12-F$6*C12)/F$5	=C12+F$7*C12*(F$8-C12-F$9*B12)/F$8
14	=a13+1	=B13+F$4*B13*(F$5-B13-F$6*C13)/F$5	=C13+F$7*C13*(F$8-C13-F$9*B13)/F$8

Fig. 2. Formulae for calculating the spreadsheet values shown in Fig. 1. Column widths differ from those in Fig.1 to accommodate the display of cell formulae.

add greatly to student frustration. For clarity, I have shown cells into which students may enter values ad lib. in gray (Fig. 1), but I do not ask them to shade cells, for the reasons above. Students need not arrange the spreadsheet exactly as shown, but if they arrange it differently, they will have to modify the formulae (Fig. 2) accordingly.

Students may enter any values for model parameters r_1, K_1, α_{12}, r_2, K_2, and α_{21} and initial population sizes. I find it best to suggest starting values of parameters and population sizes because extreme values can cause negative population sizes, overflow errors, or other problems. One can also eliminate these problems by embedding cell formulae in "if... then...else" constructions, but as with Greek letters and subscripts, this greatly complicates the process of building the spreadsheet model.

The formulae in cells B6, B7, C5, and C8 (Fig. 2) and fixed values of zero in cells B5, B8, C6, and C7 represent coordinates of the end points of the zero isoclines for the two competing populations.

The formula in cell A12, when copied down column A for the desired number of time intervals, will produce a series of integers representing discrete time-steps in the model. I find that 50 iterations usually suffice to reach equilibrium, but students can easily extend the time sequence by copying the formula farther down the column. Some spreadsheets provide more convenient tools for generating a series of integers, and students may use various shortcuts, but I show this formula for the sake of generality.

The formulae in cells B12 and C12 express the Lotka-Volterra equations:

$$N_{1,t+1} = N_{1,t} + r_1 N_{1,t}([K_1 - N_{1,t} - \alpha_{12} N_{2,t}]/K_1)$$

$$N_{2,t+1} = N_{2,t} + r_2 N_{2,t}([K_2 - N_{2,t} - \alpha_{21} N_{1,t}]/K_2).$$

Students must use absolute and relative cell addresses as shown (Fig. 2). As they then copy these formulae down their columns as far as desired, the program automatically adjusts relative cell addresses, keeping absolute addresses unchanged. The program calculates each population size at time $t + 1$ from the sizes of both populations at time t and from the model parameters.

Students can and should make two kinds of graphs from the population sizes calculated in columns B and C (Fig. 1). Most will spontaneously choose to graph both populations against time (Fig. 3). Usually, I must prompt them to graph N_2 against N_1 (Fig. 4), as in the standard depiction of the model.

At this point, we encounter the only tricky aspect of this spreadsheet implementation. To produce this last graph (Fig. 4), students must graph the endpoints of the zero isoclines as well as the population sizes (cells C5–C61 vs. cells B5–B61), and they must have left at least one blank line (cells B9, B10, C9, and C10 in Figs. 1 and 2) between the block of endpoints and the start of the time series of population sizes.

The program draws a line from each endpoint to the next, and thus draws the zero isoclines. In the layout shown here, the program begins at the point (0, K_2) and draws a line to the point (K_2/α_{21}, 0), drawing the zero isocline for population 2. Then the program draws a line (hidden by the X axis) from (K_2/α_{21}, 0) to (K_1, 0). Next, the program draws a line from (K_1, 0) to (0, K_1/α_{12}), the zero isocline for population 1. You can use other orders for these points, but test them first, because some will cause the program to draw extraneous lines across the graph.

If the students have left a blank line after the endpoints, the program will start a separate line for the sequence of population sizes. If they have not, it will connect the last isocline endpoint to the first joint population point, producing an extraneous, misleading line.

The program labels neither isocline endpoints nor endpoints of the trajec-

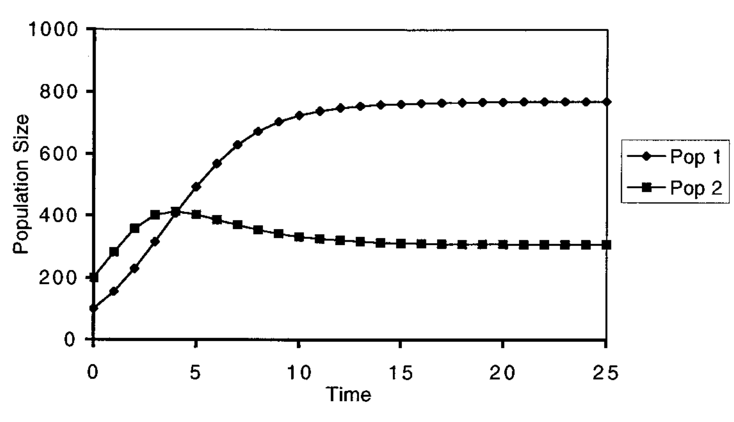

Fig. 3. Population sizes vs. time.

tory of population sizes, forcing students to identify these themselves. I find this beneficial, as it focuses attention on these points and increases the likelihood that they will perceive the relationships determining model outcomes. I have not given detailed instructions on how to label axes, legends, and other graph features, because the steps vary widely between spreadsheet programs and between versions of the same program. Students will have learned these details in earlier exercises.

I have given much more explicit instructions here than I give to students. Because certain details of layout matter, I show students a sample spreadsheet (e.g., Fig. 1) but not the formulae. I remind them how we calculated isocline endpoints in the lecture and that they have modeled logistic population growth before. Most students have little difficulty finding the appropriate formulae, although I must always do some over-the-shoulder troubleshooting. Allowing them to work in pairs and to think aloud often speeds the process and prompts them to teach each other, enhancing their own understanding of the model.

Depending on the order in which students enter formulae, they may see various error messages while building their models and assume they have made a mistake. Most such apparent errors actually result from entering a formula before entering parameter values. In these circumstances, the program cannot evaluate the formula and reports an error. Such errors disappear when students enter appropriate parameter values. Because of the confusion that can result, I ask students to call for help if they see an error message, and help them resolve these problems one-on-one.

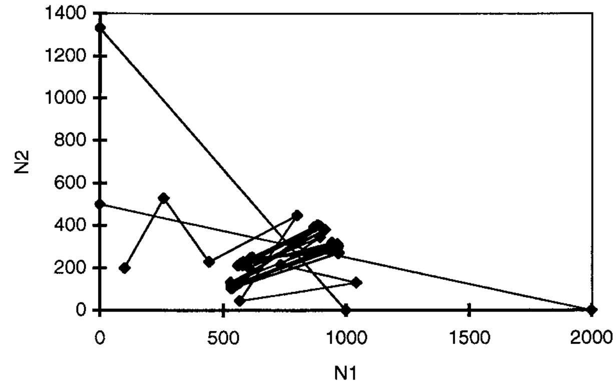

Fig. 5. Size of population 2 vs. size of population 1, showing chaotic behavior.

Two practical tips: push students to make graphs as large as their monitors permit, as small graphs often hide interesting detail; and remind them to use *XY* charts (scatterplots) rather than line charts. Line charts space all data points evenly along the *x* axis regardless of their *x* coordinates, and will not produce satisfactory plots of interval data.

I often require a laboratory report in which students answer questions about outcomes of interspecific competition under various conditions (different carrying capacities, population growth rates, and competition coefficients). For example, by suggesting that students set $K_1 = K_2$, $r_1 = r_2$, and $N_{1,0} = N_{2,0}$, one can lead them to an understanding of the competition coefficients α_{12} and α_{21}.

If the instructor has access to suitable audiovisual equipment, he or she may demonstrate how to explore the model by systematically varying parameter values. I also encourage free exploration of the model, in which students change parameter values ad lib.

Because the spreadsheet program automatically recalculates the entire model with each change in a parameter value, and simultaneously updates all graphs, students can rapidly explore the effects of many changes. Many find that such immediate feedback increases their willingness (if not enthusiasm) to work with and understand models. Many also discover periodic and chaotic behavior when they increase *r* values beyond certain thresholds (Fig. 5), and such surprises also add to their enjoyment of modeling.

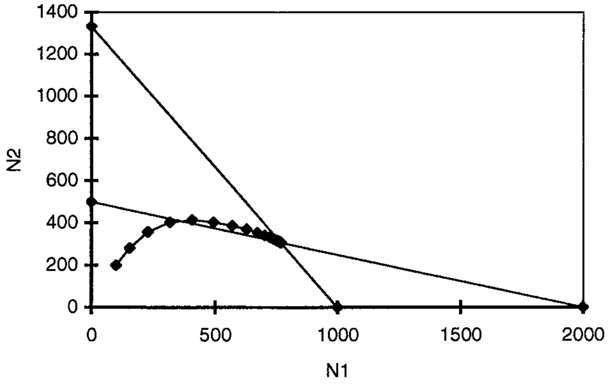

Fig. 4. Size of population 2 vs. size of population 1, showing zero isoclines and equilibrium outcome.

Although I have not formally assessed the effectiveness of teaching models with spreadsheets vs. other methods, I feel that students learn more when they do the spreadsheet exercises. Laboratory sessions always generate animated conversation and students remain on task and engaged, rarely leaving early. Anonymous course evaluations often include comments to the effect that working with spreadsheet models enhanced students' understanding and appreciation of models, reducing their apprehension about them.

Acknowledgment

The author thanks Dr. Joel W. Snodgrass of the Savannah River Ecology Laboratory for his helpful comments in reviewing this manuscript.

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Charles W. Welden
Department of Biology
Southern Oregon University