Environmental Decision Making

EDM

User's manual

A BioQUEST Collection Module by

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A BioQUEST Collection Simulation Module
(version 3.02)

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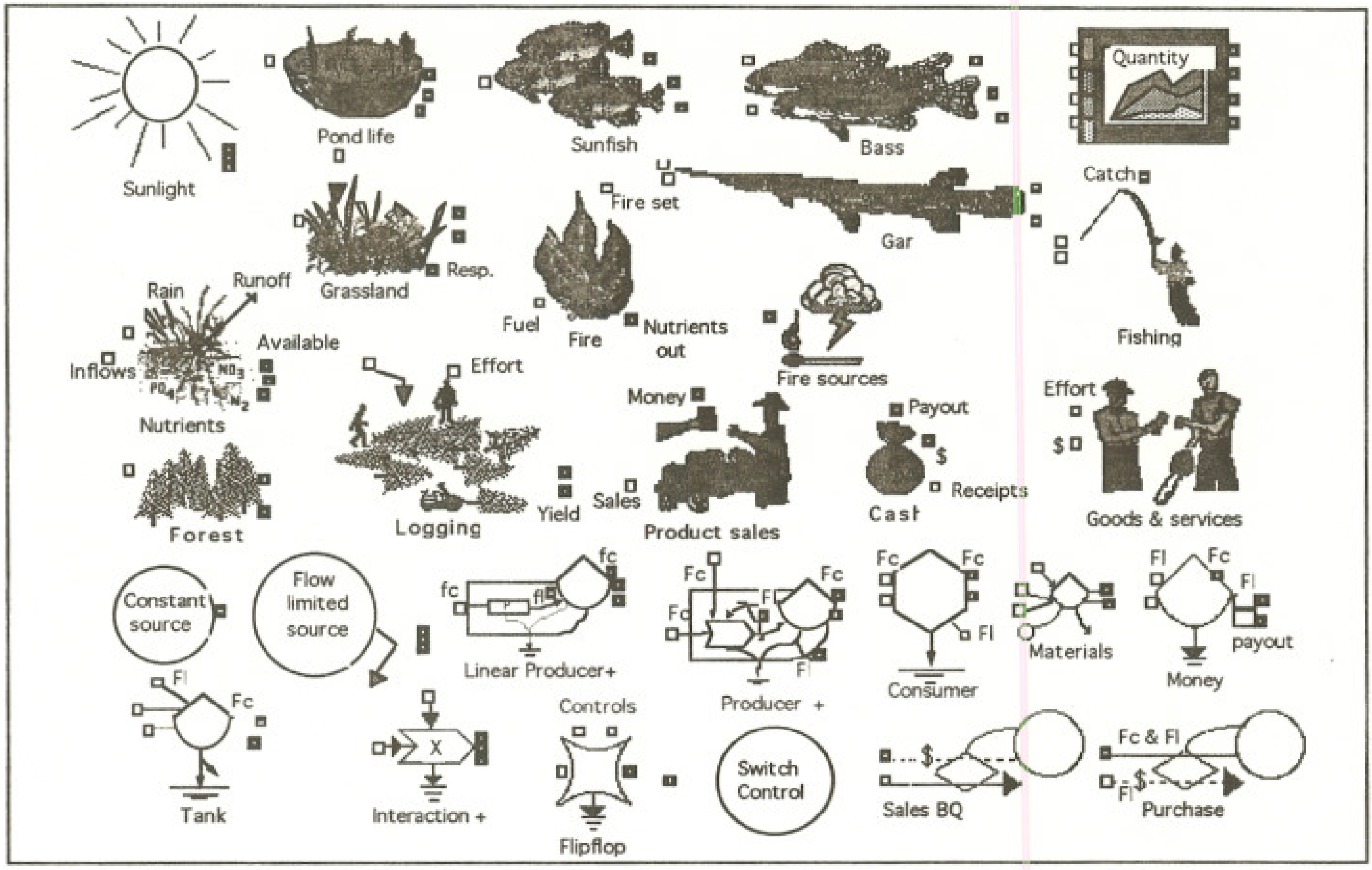

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INTRODUCTION

As human roles on the planet earth increase, the educated public is called on more and more to make decisions about the environmental systems that are the basis for life. To make sensible policies about the environment requires that people understand how the global ecological systems work. Ecological systems (ecosystems for short) include plant producers, animal consumers, storage of resources, cycling of essential materials, transformations of energy, and interactions with the human economy.

Too often educational approaches have taken systems apart, studying each part as if it operated alone. Chemical cycles are often drawn separately without the units and processes that control their flows. Energy is often studied by itself, although it cannot really be understood without the whole system. Systems ecology, on the other hand, encourages the study of all aspects together. Simplification is not done by isolating out parts, but by grouping parts into relatively few units of similar function. Decision-making about real systems requires understanding how everything works together.

Computer Simulation of Ecosystems

Using computer simulation, working with whole systems can be practical and realistic. First, you diagram a model of the system showing parts and connections among them. Each component is linked to the others with a mathematical relationship. Then the system is simulated so that a graph shows what happens over time.

In understanding mathematical models of ecosystems, there are three major considerations. First, there are the outside sources, such as the sun, which is the stimulus for plants to change light energy into chemical energy. Second, there are the relationships among the components, such as the direct connection of the sun to the plants and the indirect relationship of the sun to animals through the plants. Third, specific values are used that characterize the interactions of the components, such as the amount of sunlight used and its efficiency in photosynthesis.

Using an iconic simulation program called Extend™ (see below), it is easy to create an ecosystem model on the screen of a Macintosh computer. Components of the model, such as the sun, are placed on the computer screen. Then the components (called blocks) are connected together to show their relationships, such as the transfer of the sun's energy to plants. Finally, values are entered in the block dialog boxes to characterize the interactions of the components, for example the amount of sunlight at a particular location. When the simulation is run, you can see the growth curves of the various components of the system. By making "what if..." changes in the model, the effects of various proposed decisions about the environment can then be shown.

About the EDM Models

This Environmental Decision Making module (EDM) presents three samples of how models of systems can be built and manipulated: Pond Ecosystem, Grassland Fire System, and Logging a Forest. The models represent interactions of components for each system. For the picture-icon blocks used to build the EDM models, the equations which determine how the components of the model behave are based on expected activity in such ecosystems and have been programmed into each block. For example, such variables as rates of production and consumption are programmed into the blocks. This makes fewer choices for students. The EDM module also contains a set of General System symbol blocks (see Figure 21) which are more general in nature than the picture-icon blocks and can be used to model any system. These have more detailed dialog boxes, so that most variables can be entered rather than having them pre-programmed.

How the System Models are Organized

For each system you build and simulate a simple model with the sun and one producer. When the producer grows up to a steady state, you add another component and run the simulation to record the results of the change. At each stage you make variations in the quantities, predict their effects and then run simulations to check your predictions. You repaeat this until you have built a complete system and can answer questions about how it works. There are three model files already prepared for each ecosystem section: ...*worksheet* (it has only a plotter in it to start); ...*system* (shows the final model of the ecosystem); and ...*general symbols* (shows the same model as the final system, except uses the General System symbols). For example, there are three models already done for the Pond Ecosystem: Pond worksheet; Fishing system; and Pond, general symbols.

Objectives for the EDM Module

The objectives for the EDM learning module are for you to:

1. Learn to identify important components in an ecosystem and assemble them into a model.
2. Collect data in the field to calibrate the model.
3. Refine your ecosystem model to match observed data.
4. Communicate your observations and learning about the components, as well as about the behavior of an ecosystem.
5. Generalize from your experience to behaviors of other ecosystems.
6. Analyze the consequences of human decisions affecting ecosystems.
7. Become creative by synthesizing new systems models.

About Extend™

Extend is a multi-purpose simulation application which allows users to build iconic models of systems in any discipline. For example, Extend is used for modeling in science (biology, chemistry, medical), engineering (electronic, mechanical, industrial), and business (operations research, manufacturing, enterprise modeling).

When you build models in this EDM module, you are using a *student* version of the Extend simulation program (see References) and a custom library of blocks created by the EDM authors. The EDM authors used the *full* version of Extend to program blocks (the components of the models), including custom dialog boxes and icons. These blocks are contained in the BioQUEST library you use as you build the models. The BioQUEST library contains both picture-icon type blocks and General System symbol blocks, all of which were created by the authors.

Since the Extend version which comes with this module is a student version, you cannot modify the programs in the blocks, and you are limited to models which are 25 blocks or less. The full Extend program allows an unlimited number of blocks in a model. It also has an authoring environment for creating custom blocks. In addition, the full Extend program has many features not used in this EDM module such as animation, model Notebook, QuickTime movies, interactive controls, and hierarchy (the ability to encapsulate sections of a model as one block). The student version of Extend is non-FPU, so it does not run as fast as the full version.

Extend can be used at many levels:

· Users unfamiliar with simulation can gain insight into a specific discipline by using models assembled by others (such as instructors). These users can enter and change the data in block dialogs, and run the simulation to observe the results.

· Entry-level users can build models using the extensive libraries of pre-built blocks included with Extend, or by using blocks supplied by third parties (such as the blocks included in the EDM module).

· Intermediate-level users can create custom effects by entering equations or formulas into Extend's equation block, or by using hierarchy to combine the function of several blocks into one.

· Advanced users can modify Extend's blocks, or create new blocks, using Extend's built-in C-like language, dialog editor, and icon drawing tools.

PART I: A POND ECOSYSTEM

Getting Started

To show how to get started with modeling and simulation, we present you with a series of exercises using the example of a pond ecosystem. You will progress from the creation of the model and its simulation, to "what if" questions about how it can change, to the larger questions of environmental decision making about global over-fishing.

Suppose you are asked to work on a pond in Pennsylvania of about one hectare (a measure of an area equal to about 2 1/2 football fields). Right now it has a variety of plant life and small creatures, but no fish. The owner has asked you to turn it into a bass-fishing pond. What can you do to get bass fishing as soon as possible? You know you need to put in small fish and bass, but you want to know when and how many.

Figure 1 gives you a general idea of what you want to have in the pond when you are finished. For now, assume that the pond has everything in Figure 1 except the Sunfish and Bass. Someone has been sampling the **biomass** (weight of living and dead organisms) and made a graph of that data (Figure 2). The first measurement indicates that there is 1 kilogram of biomass. Then the pond's biomass increases rapidly until it reaches a **steady state** or **equilibrium** of approximately 5800 kilograms.

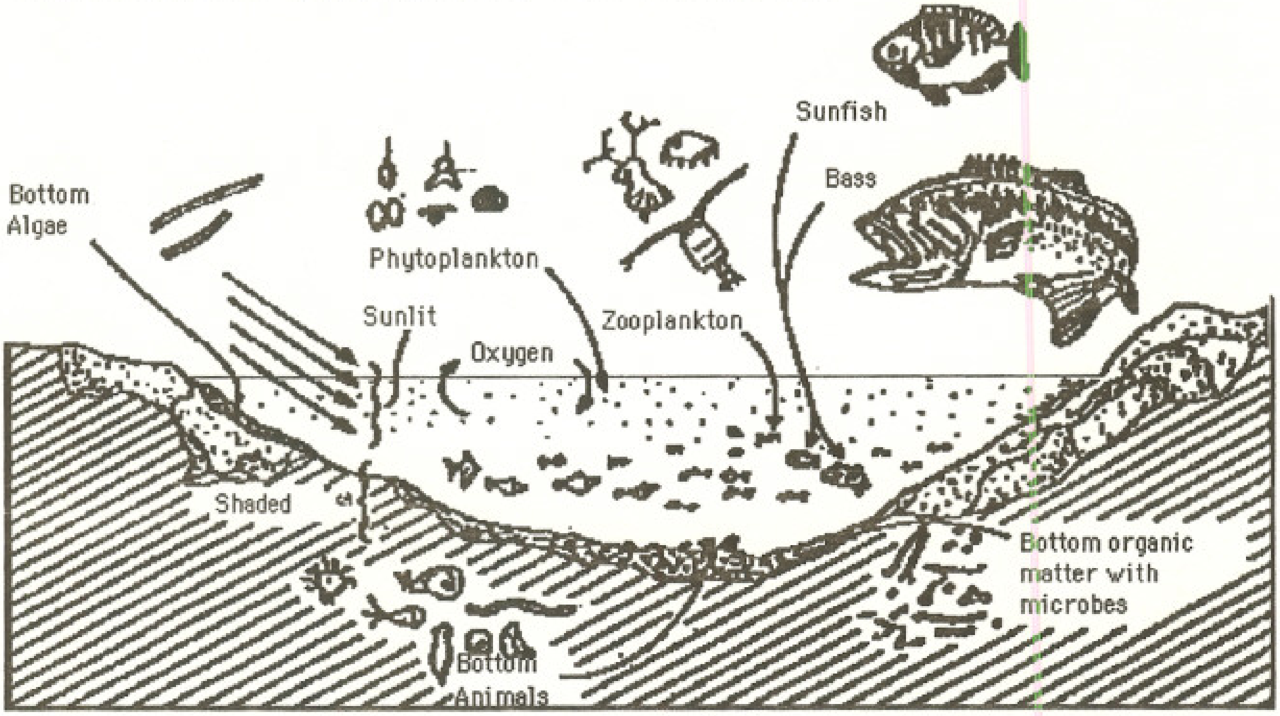


Figure 1. Picture of the one-hectare pond showing phytoplankton, zooplankton, plants, small bottom animals, sunfish, bass and microbes.

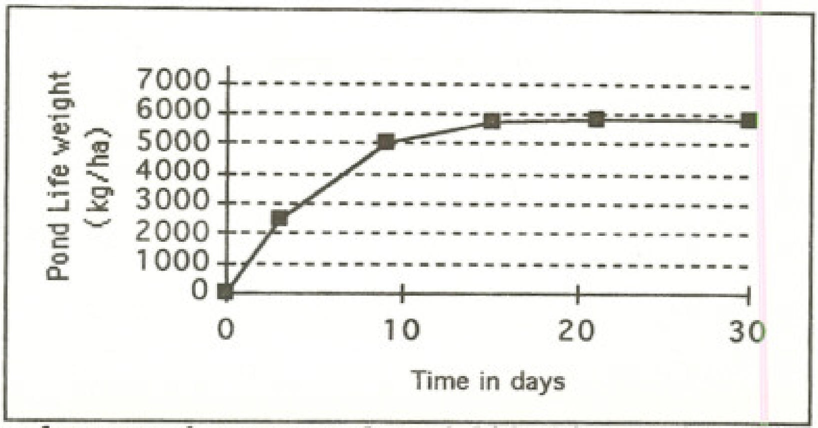


Figure 2. Graph of measured amounts of pond life biomass in the 1 hectare pond. The first measurement gave 1 kilogram of biomass.

Record Keeping, Assignments

In your Extend notebook keep records of this project: your diagrams, data, graphs, text for notes and reports, and especially your ideas. Your assignment may be a scientific report which will include all these parts.

Take a Trip to a Pond

If possible, take a field trip to a real pond. You can sketch it and record the plants and animals you see. Some of the small pond life biomass is in the plankton (suspended organisms), both phytoplankton (plant plankton) and zooplankton (animal plankton). To see them, you need to pull a plankton net through the water and look at the creatures you capture under a microscope. If you don't have a plankton net, it is easy to make one with a stocking (one leg of panty hose), a small plastic vial and a coat hanger. Put the vial in the bottom of the stocking, secure it with a rubber band, and attach the top of the stocking to the hanger so as to keep the top open. Drag it several times through the water. Put the contents into a flat dish to observe and then make slides to study under a low power microscope.

To study the small life biomass in the bottom of the pond, press a plastic tube into the bottom (out from the edge) and pull it out so a core of bottom sediment is withdrawn. Then push the core out of the tube into a white pan. Although most of the dark sediment is dead biomass from previous production, there will probably be some tiny bottom animals present.

Model the System: Production and Consumption

To model this system, you'll need to consider the sunlight and the various plants and animals living in the pond. Energy from the sun which flows into the pond is used to produce plant life, some of which is consumed by animals and microbes. Biomass in the pond increases until consumption equals production. In this example, the leveling off can be seen in the graph in Figure 2. Although yearly production and consumption in a pond may be nearly equal on the average, they vary over a year with the seasons.

Computer Modeling of Pond System with Extend

To construct a model using the program Extend, follow these directions.

1. Double-click on EDM. Load the **Extend BioQUEST** application by double-clicking on its icon.
2. In the **File** menu, select **Open Model.** Then click the mouse and hold it down to **Pond worksheet** and let it go. The Pond worksheet will contain the Plotter block already calibrated for this model (Figure 3).

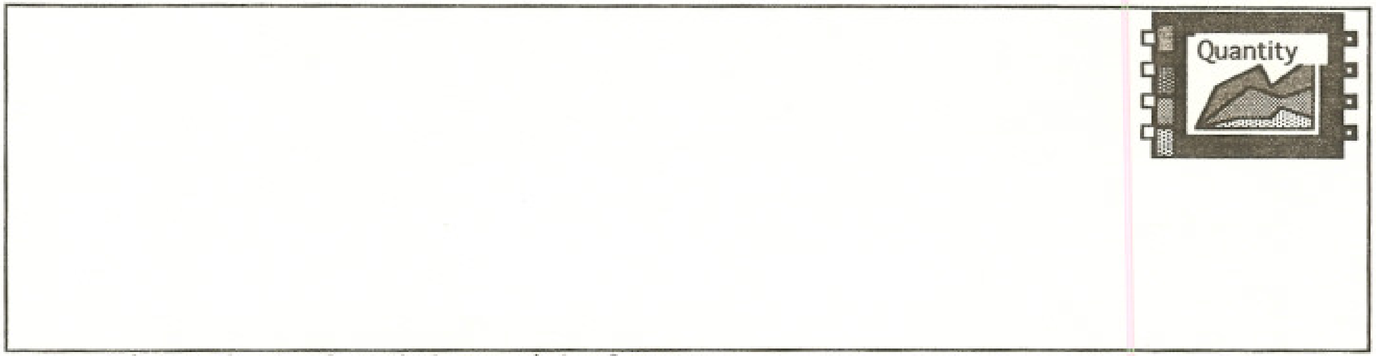
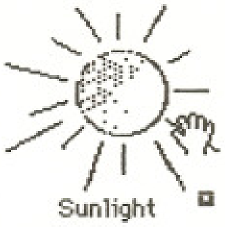


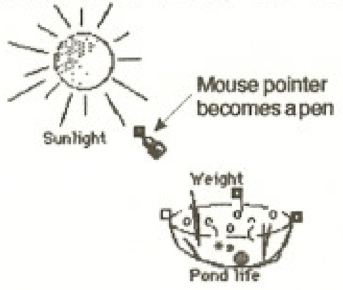
Figure 3. Pond worksheet with Plotter.

3. To get the blocks which are part of this pond ecosystem, you need to access the BioQUEST library. To do this, move the mouse pointer to the **Library** menu at the top of the computer screen.
4. Click the mouse button and hold it down so that you see the commands in the Library menu.
5. Then pull the mouse down until the arrow highlights **BioQUEST library v3**. (This uses Extend version 3.)
6. While still holding the button down, move the arrow to the right and down the list to **Sunlight** and let it go.
7. The Sunlight block will appear on your Pond worksheet. Hold down the mouse on the icon to move it to the upper left of the screen.



The mouse becomes a hand over the icon so you can mouse-down and drag it.

8. Now click to the right of the Sunlight block to indicate where you want the next block to be. Then add the **Pond life** block to the worksheet by selecting it from the Libraries above.
The Pond life block includes the small life in the pond: phytoplankton, plants, zooplankton, small bottom animals, and microbes.
9. To arrange the icons for your model, hold down the mouse to move the picture icons around the screen, putting the pond life icon to the right of the sunlight.
It is an important convention to start with the sun at the left, as energy is flowing from left to right: from the sun to producers to small consumers, to larger consumers. This practice makes the screen always represent the natural hierarchy of size and energy flows.
10. You can see small boxes attached to the picture icons. These are connectors to transfer data from one block to others in your system. The output connectors (dark boxes) on the right of a block send flows out. The input connectors (open boxes) on the left of a block take flows in. One of the dark boxes at the right of the picture is to be connected to the plotter to keep a record of changes of biomass. The Plotter has four boxes; it can keep track of four sets of changes in different units and draw four lines on the graph.
11. Now draw a line with your mouse held down to connect the flow from the Sunlight to the Pond life. The line goes from the ouput box to the right of the Sunlight icon to the left box of the Pond life icon. When the mouse is held over a connector box, it becomes a "pen" for drawing.



The mouse becomes a pen for drawing connecting lines.

12. When you have successfully drawn a line between two connectors, it will become thick as you are drawing it. Release the mouse. The line will be dashed if the connection is not complete.
To erase an icon move the mouse over it until the mouse arrow becomes a hand. Click once and it will become highlighted. Then press the delete key on the keyboard.
To erase a line, move the point of the mouse arrow to the line and click. When the line becomes thick, press the delete key on the keyboard.
15. To make the program graph the changes in the weight of pond life, you need to connect the output of the Pond life block to the Plotter. Draw a line from an output box of the Pond life icon to the top open box of the plotter Your screen will look like the picture in Figure 4.

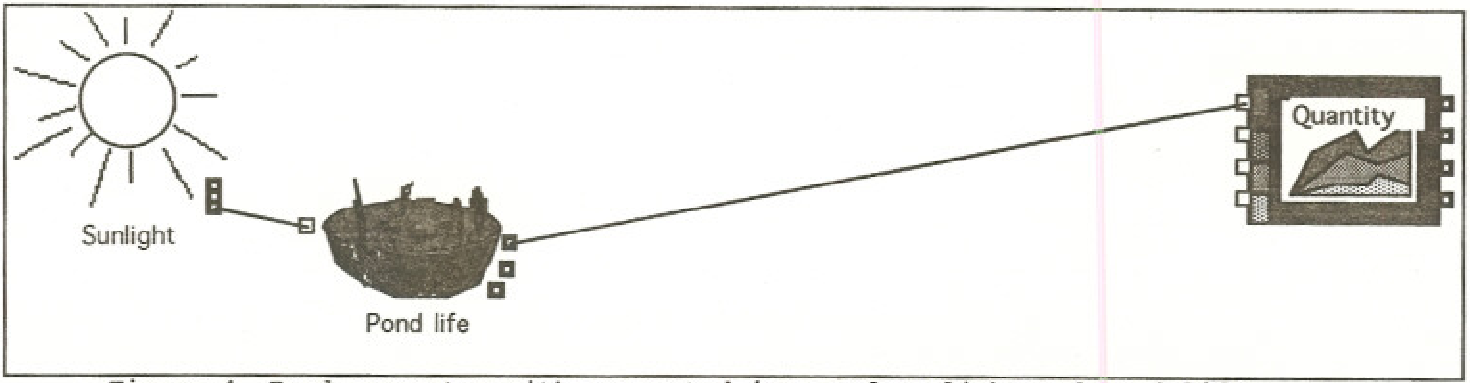


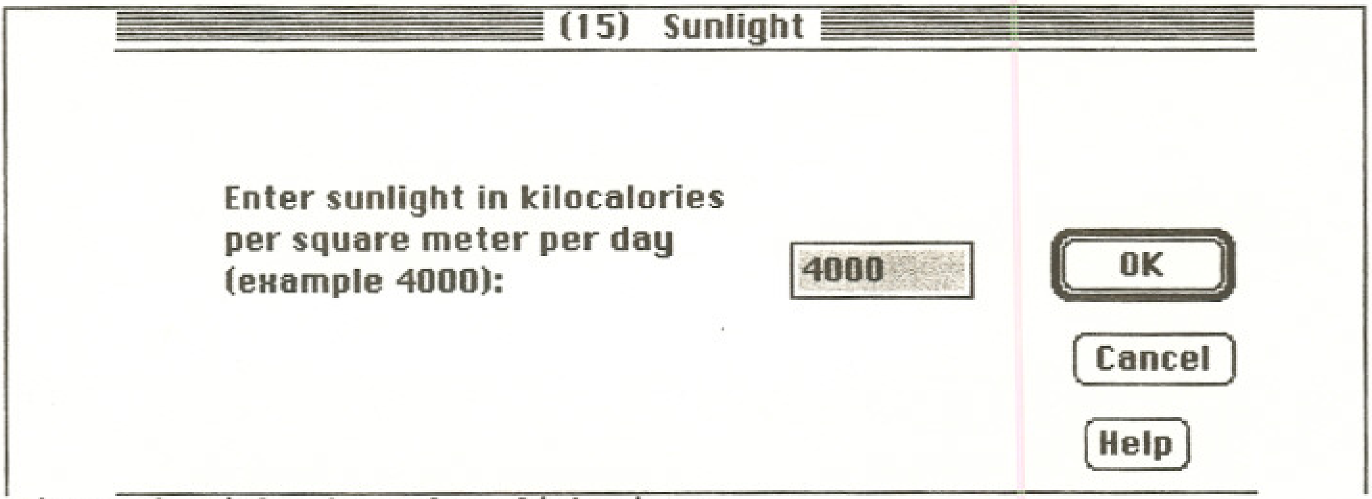
Figure 4. Pond ecosystem with connected icons of sunlight and pond life.

You have now accomplished your first objective - to identify components in the pond ecosystem and assemble them into a model.

Setting Values

You need data to run your model. The process of putting numerical data in the model is called **calibration.**

1. Double-click on the sun icon. You will see a dialog box which asks you for the amount of sun falling on the pond.
2. Figure 5, on the next page, is a map of the sun's energy received over the United States. Check back to remind yourself that the location of your pond is in Pennsylvania and type the appropriate kilocalories of sunlight into the sun's dialog box (Figure 6).



Enter sunlight in kilocalories per square meter per day (example 4000): 4000

Figure 6. Dialog box of sunlight icon.

3. Double-click on the **Pond life** icon. Its dialog box asks for the initial quantity of biomass in the pond.
4. Check with the graph of the pond life biomass data (Figure 2) for original biomass quantity (1 kg/ha), and type it in the Pond life dialog box.

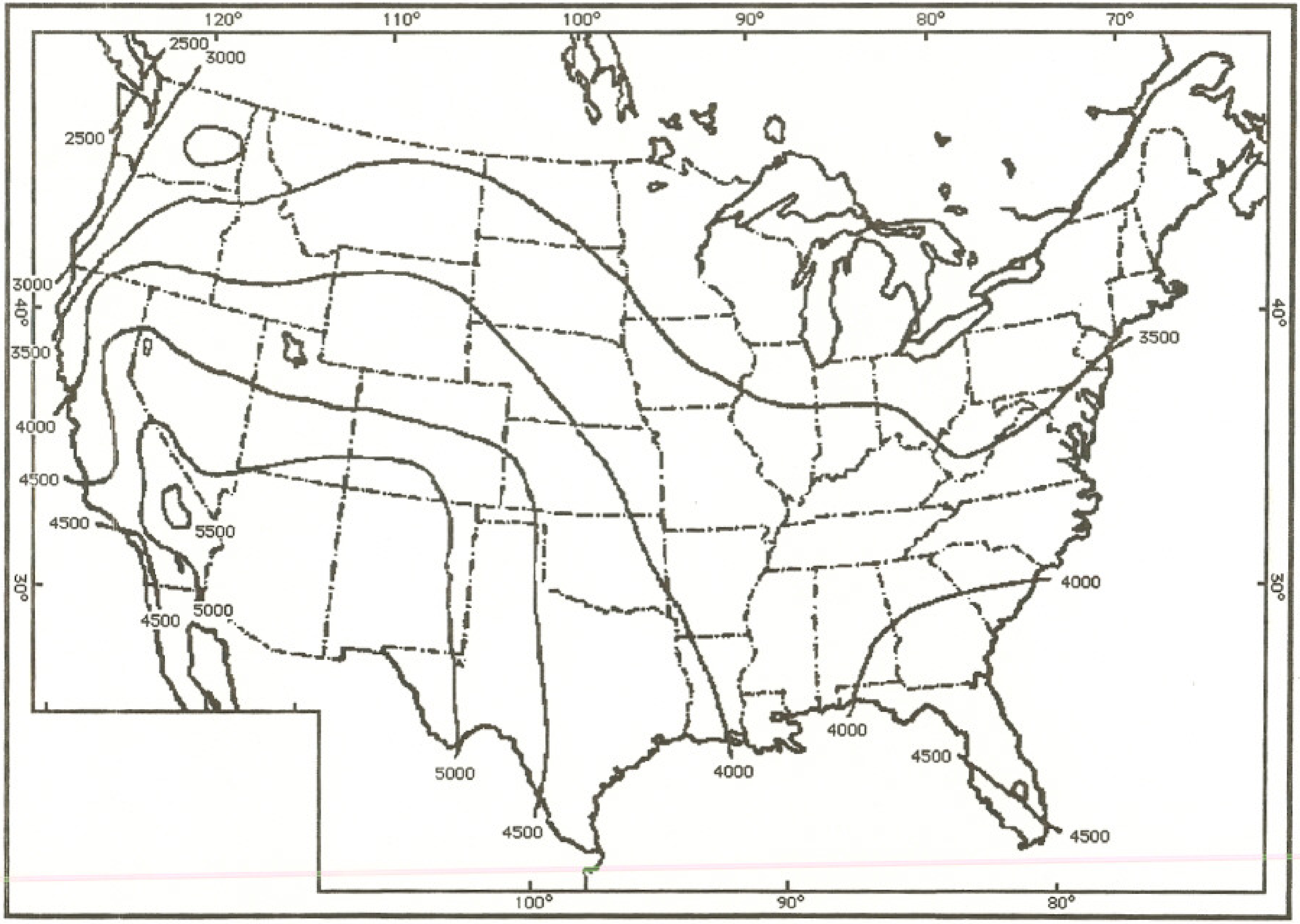


Figure 5. Map of the annual daily average sun's energy received over the United States, in kilocalories per meter squared (Visher 1954).

Simulation of Sun and Pond Life Model

After the calibration is done, you tell the Extend program to make a simulation graph of the change in pond life biomass over time.

1. Pull down **Run Simulation** from the top menu.
2. Just click **OK** on the next screen which already has the details to make a graph. A graph of growth of pond life biomass will appear (Figure 7).
3. Record the quantity of pond life when the graph levels off, to use in the next simulation.

Does your model predict the data that was measured (Figure 2)? Note two important similarities:

a. Starting point is the same.
b. Shape of the curve is similar.

If the graphs are not the same, what hypothesis would you suggest to explain the difference? (Hint: check the quantity of sunlight.) When the graphs are similar, you may conclude that the model represents the biomass production and consumption of the system.

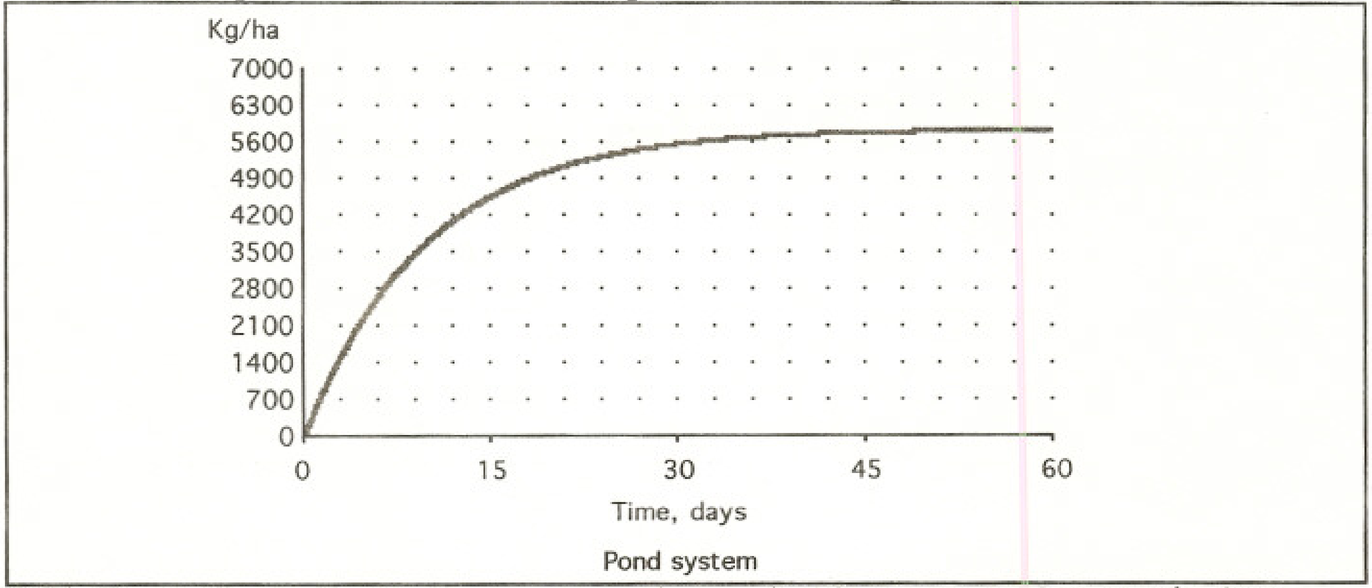


Figure 7. Graph of growth of pond life biomass in kilograms per hectare in days. Sunlight was measured as 3200 kilocalories per meter squared per day for the middle of Pennsylvania.

Saving and Printing

To print, pull down **File** to **Print**, choose what you want to print, and click on Print. (Caution: if you want to print only the graph and not the table, be sure to uncheck the box for **Plotters - data tables**.)

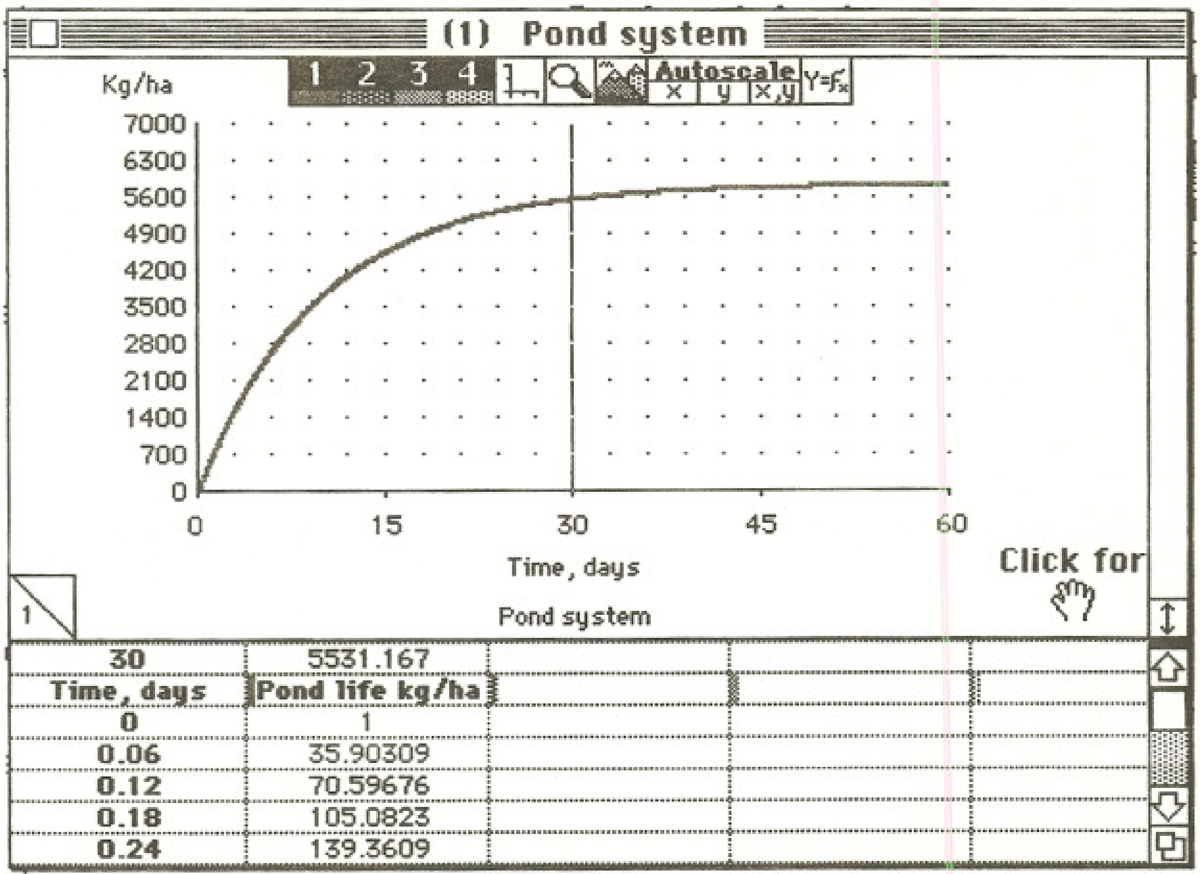
To save a text or model, pull down **File** to **Save As**, name it, and it will be saved. To save something you have already saved with the same name, pull down **File** to **Save**.

To save a graph, on the keyboard press **Control, Shift, 3.** The mouse becomes a + symbol which you use to select (draw around) the area you want to save; whatever you selected will automatically be put into the **Clipboard.** From there you can **Paste** it into any draw or paint program and save it there.

To close without saving a graph or model, select **Close** under **File** or click in the open box in the upper left corner of the screen.

Reading Quantities from a Graph

To read quantities from a graph, move the mouse across the graph to the point you want to read. Stop it, and look at the table at the bottom of the page. You can read the time and various quantities across the top of the table. Figure 8 shows the graph of pond life in Figure 7 with the mouse-line put at 30 days. In the table below you see that at 30 days the pond life weight was 5531 kg/ha (kilograms per hectare).



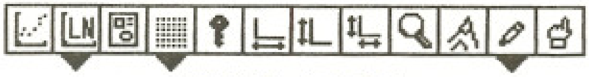
30	5531.167			
Time, days	Pond life kg/ha			
0	1			
0.06	35.90309			
0.12	70.59676			
0.18	105.0823			
0.24	139.3609			

Figure 8. Picture of screen showing on the graph the mouse line at 30 days, and in the table 30 days and 5531 kg/ha of pond life.

Record the quantity of pond life biomass at the time when the pond system comes to steady state (levels). You will need this number for your next graph.

Changing a Graph's Display

If you want to change a number on the graph (quantity or time), click on the graph number and type in the new number in the box which appears. For example, to change the top value for the left axis from 7000 to 75000, click on the 7000 until a text box appears. Then type 7500 and click elsewhere or press Enter.



Graph tools

You can experiment with the graph control tools at the top of the window of the simulation graph. The first tool, ⋰, lets you specify the line type and label. The ∟ and ⇅L tools scale the graph horizontally and vertically; the ⇅∟ tool automatically scales the axes to fit the maximum figures. The 🔍 tool magnifies a specified area of the graph; the A tool zooms out by changing the axes by 2 in each direction.

"What if" Experiments

1. Put the pond in your part of the country. Type in the appropriate sunlight from Figure 5. Would you have more or less biomass in a pond near you than in the Pennsylvania example? Why?

2. Put the sunlight quantity back to Pennsylvania's. Change the amount of initial pond life biomass by making it 7000 kg/ha. How does this change the graph in the next few days? Why doesn't this different starting biomass change the biomass level in the long run?

Summary of the Ecosystem Modeling Process

We can summarize the process from what we have done so far:

1. From the description of the natural system, select the appropriate components for the model.
2. Place the ecosystem components of the model on the screen, starting with the sun on the left, connecting items in the food web to the right as energy is transferred and transformed.
3. Gather data for input to the model - in the field or from previous measurements - and calibrate each icon.
4. Run the simulation.
5. Check the graph results to see how it compares with the real observations.
6. Correct the model or its calibration as needed to improve your model's accuracy in making predictions.

Adding Sunfish to the Model

Now that the model has come to an equilibrium steady state without fish, you can to add sunfish (food for bass), and see what the new pattern will be.

1. To add the sunfish to the model, pull down the **Sunfish** block from the library.
2. Place the **Sunfish** block to the right of the **Pond life** block and attach it by drawing a line from the output connector at the right of the **Pond life** block to the input connector on the left of the **Sunfish** block.
3. Attach an output connector of the **Sunfish** block to the second input connector on the Plotter, so that the changes in Sunfish biomass will be graphed too. Your model should look like Figure 9.

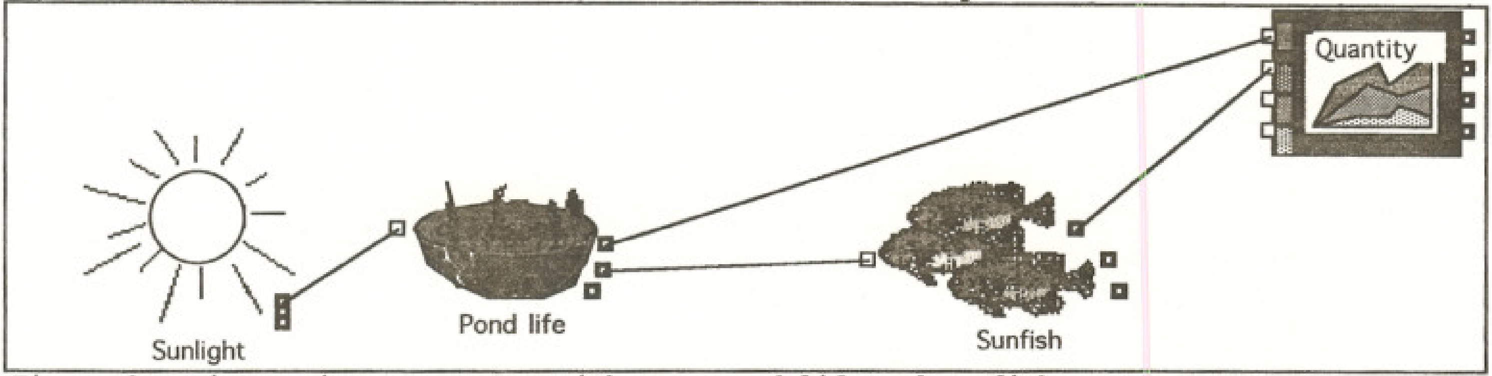


Figure 9. Picture icon ecosystem with sun, pond life and sunfish.

4. A fish pond expert suggested adding 400 juvenile sunfish (there are about 40 small juvenile sunfish in a kilogram). Calculate the number of kilograms and fill in the sunfish dialog box.
5. Since the pond life is already at the level steady state for conditions without fish, you need to set the starting biomass quantity in the pond life dialog box to that level. Fill in the pond life dialog box with the pond life biomass figure from your earlier run (Figure 8).

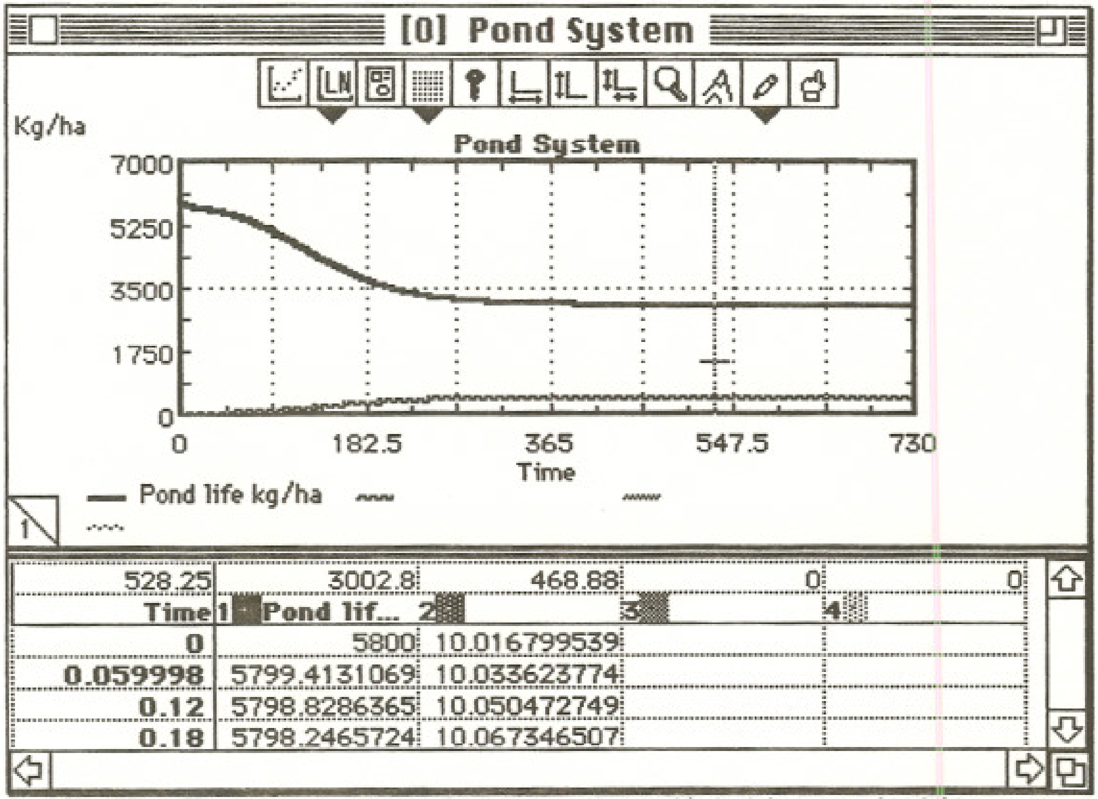
Setting the Simulation Run Time

The model is originally set to run for 60 days, which is a long enough time for growth of small pond life. Now that you are adding fish, you need to see what happens over a longer time.

1. To change the simulation run time to 2 years (730 days), pull down the **Simulation Setup** command from the **Run** menu. This brings up the simulation time dialog where you can change the simulation's duration (how long the simulation runs) and granularity (the time between each calculation step, or delta time). Delta time is discussed in Part IV of this manual.
2. For this model, you do not need to change the delta time, only the ending time for the simulation. Put 730 in the first box labeled **End Simulation at Time**, and click OK to close the dialog box.

A Simulation of the Model with Sunfish

1. Run the simulation by choosing **Run Simulation** in the **Run** menu.
2. If your graph does not match Figure 10 below, hypothesize why and change the values if needed. For example, if the graph line showing change in pond life biomass does not start near the top of the graph, check that you filled in the right starting value in the Pond life dialog box.
3. Record the steady state values: the time it took for the system to come to steady state and how much pond life and sunfish were there at the time of stabilization.



528.25	3002.8	468.88	0	0
Time	1 Pond lif...	2	3	4
0	5800	10.016799539		
0.059998	5799.4131069	10.033623774		
0.12	5798.8286365	10.050472749		
0.18	5798.2465724	10.067346507		

Figure 10. Growth of pond life biomass and sunfish biomass in kilograms per hectare in days.

Adding Labels to the Data Table

You need to add a legend to the data table shown under the graph in Figure 10.

1. Click on the ⊡ tool in the plot window. The window in Figure 11 will appear.

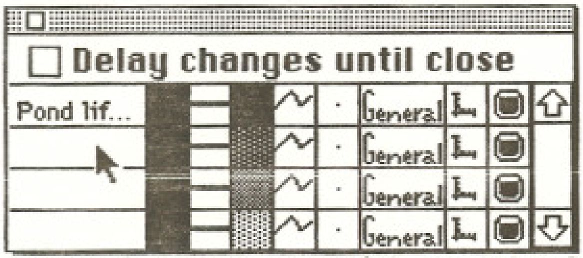
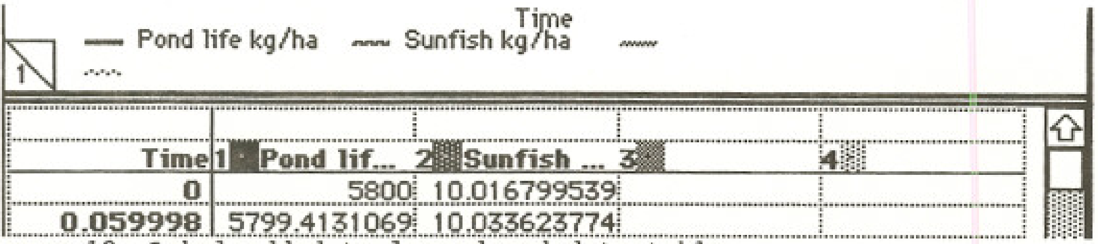


Figure 11. Screen indicating where to click to add a label to the data table.

2. Click in the second box from the top, below "Pond life...". Type "Sunfish kg/ha" in the box.
3. Then click on the box in the upper left corner of this window to close it. The new legend and top of the data table is shown in Figure 12.



Time

— Pond life kg/ha ~~ Sunfish kg/ha

Time	1 Pond lif...	2 Sunfish ...	3	4
0	5800	10.016799539		
0.059998	5799.4131069	10.033623774		

Figure 12. Label added to legend and data table.

Adding Bass to the Model

Now you want to know how many bass (averaging 1 kilogram each) you should put in the pond to get it to its steady level as fast as possible. You can try different stocking amounts in your model to figure out what to recommend.

1. Pull down the **Bass** block from the library and connect it into your model as shown below (Figure 13).

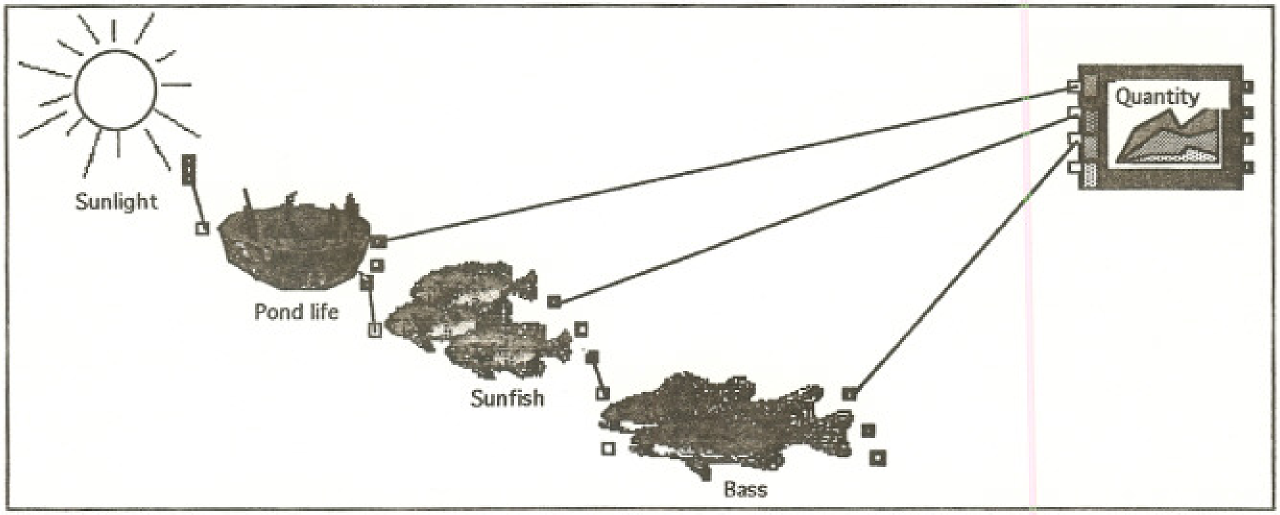


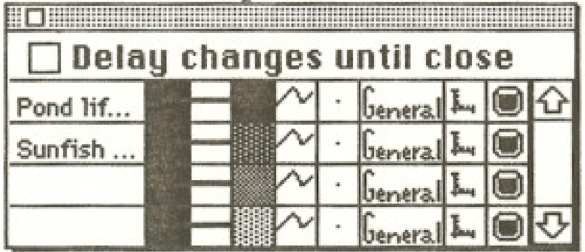
Figure 13. Picture icon ecosystem with sun, pond life, sunfish, and bass.

Food Chains and Hierarchy

The screen shown in Figure 13 is a **food chain.** The energy flows from left to right, becoming transformed to a new, more valuable form as it goes from sun to bass. This change from many small units of sunlight to less of small life, fewer of sunfish and a very few large units of bass is an example of hierarchy. Hierarchy is the organization found in all systems: many small units support fewer larger units. Another example is a business which has many workers, a few supervisors, and one president.

Calibrating the Bass Model

1. In the dialog boxes set the Pond life biomass and Sunfish biomass at the steady state quantities you found in your previous graph (like Figure 10). These were about 3000 and 470, respectively.
2. Would the bass numbers stabilize quickly if you put in a lot of bass, perhaps 50 large adults at 1 kg each? To see what happens, set the bass biomass to 50.
3. Run the simulation.
   You will find the weight of bass is so low that you cannot read it from the graph. Take a few minutes to change the graph so that the bass values are plotted with their own axis values, on the right side of the graph.
4. Click on the ⊡ tool in the plot window:



5. In the first column, third row from the top, click the empty label box and type "Bass kg/ha".
6. Next, click the ⌊ tool in the eighth column, third row. It changes to the ⌋ tool, indicating that the third input on the plotter will be plotted on the right-hand axis. Figure 14 shows the new window.

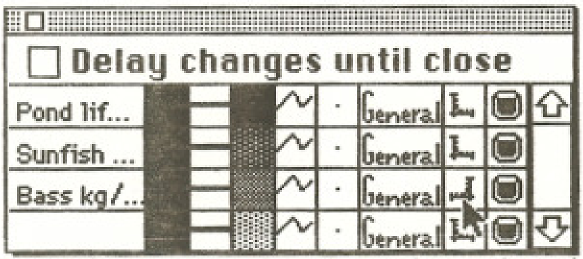


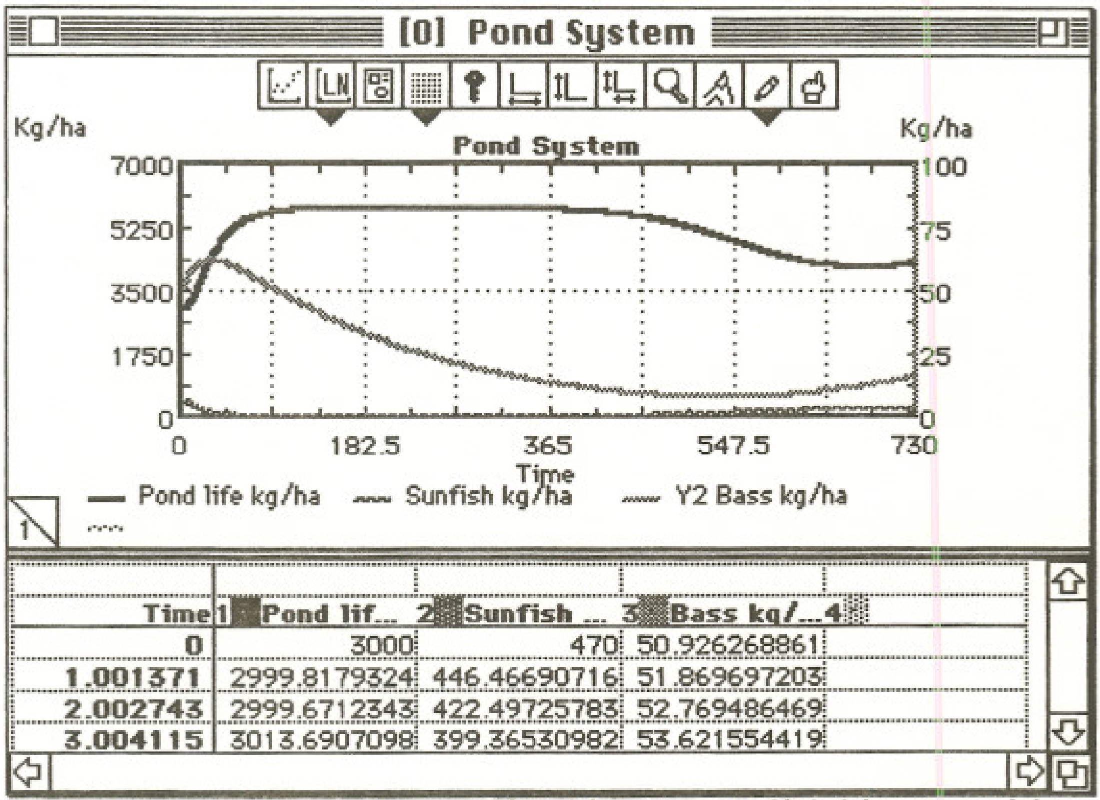
Figure 14. Changing the third row to be plotted on the right-hand axis.

7. In the plot window, click the label "Y2" that is above the right-hand vertical axis. Type "Kg/ha".
8. Just below this, click the number "1" on the axis and type "100".
9. At the bottom of the right-hand axis, click the number "-1" and type "0". The right hand axis values should now be 0 to 100.

Bass Model Simulations and Questions

Run the simulation again. A graph like Figure 15 should be the result.

1. Describe the changes in the quantity of bass. Explain.
2. How long would it take for the bass to come to a steady population? (To run the simulation out to 4 years, change Simulation Setup to 1460 days.)



Time	1 Pond lif...	2 Sunfish ...	3 Bass kg/...	4
0	3000	470	50.926268861	
1.001371	2999.8179324	446.46690716	51.869697203	
2.002743	2999.6712343	422.49725783	52.769486469	
3.004115	3013.6907098	399.36530982	53.621554419	

Figure 15. Graph of growth of pond life biomass, sunfish biomass and bass biomass when the initial quantity of bass biomass was 50 kg.

Now try starting the quantity of bass low and run another simulation.

3. Put in a lower quantity of bass to start, such as 4 kg/ha. Figure 16 shows the result with 4 kg/ha of bass.
4. How long did it take to reach the steady state level?

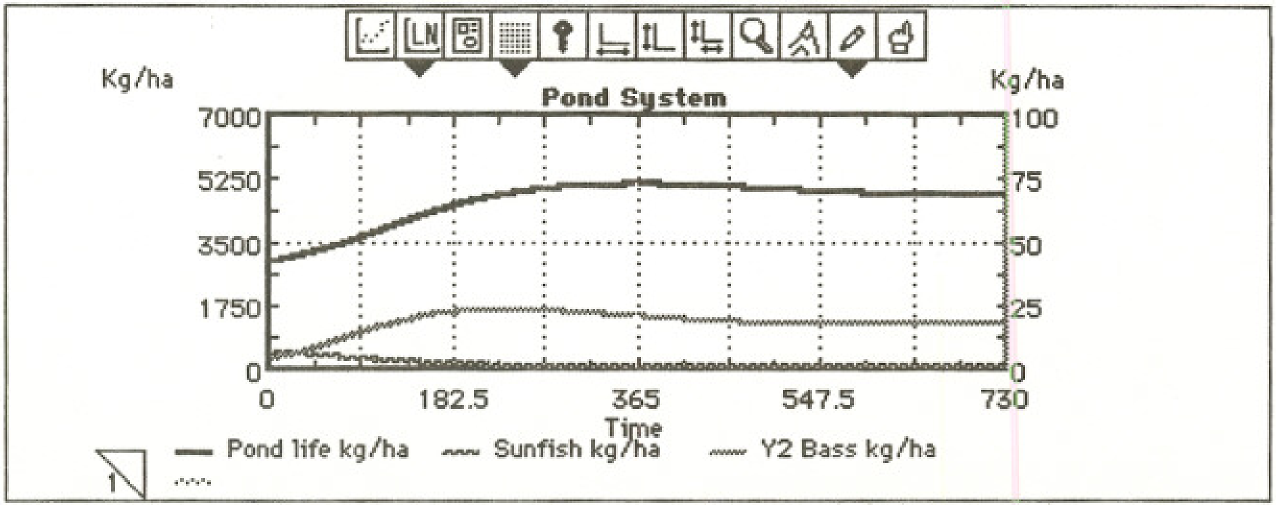


Figure 16. Graph of growth of pond system when the initial quantity of bass biomass was 4 kg.

5. After studying the graphs, how many adult bass would you put in the pond to get to the steady state as fast as possible?
6. At that quantity how long will it take to produce a steady population of bass?
7. Record the weights of bass, sunfish and pond life at steady state.
8. How many bass will this pond support?

Carrying Capacity

The amount of bass the pond will support is called its **carrying capacity** for bass. The steady levels of the other components are the pond's carrying capacity for their populations.

Maximum Sustainable Yield

The goal of **maximum sustainable yield** is to catch as many fish as possible while maintaining enough stock so that reproduction and growth will replace the fish caught year after year.

Adding Fishing to the Model

You now want to know how many fish you and your friends can remove without fishing out the pond. How many will give the maximum sustainable yield?

1. Pull down the **Fishing** block from the library and attach it to the Bass.

2. Attach the output connector of the Fishing block to the last input connector on the plotter. Your screen should look like the one in Figure 18.

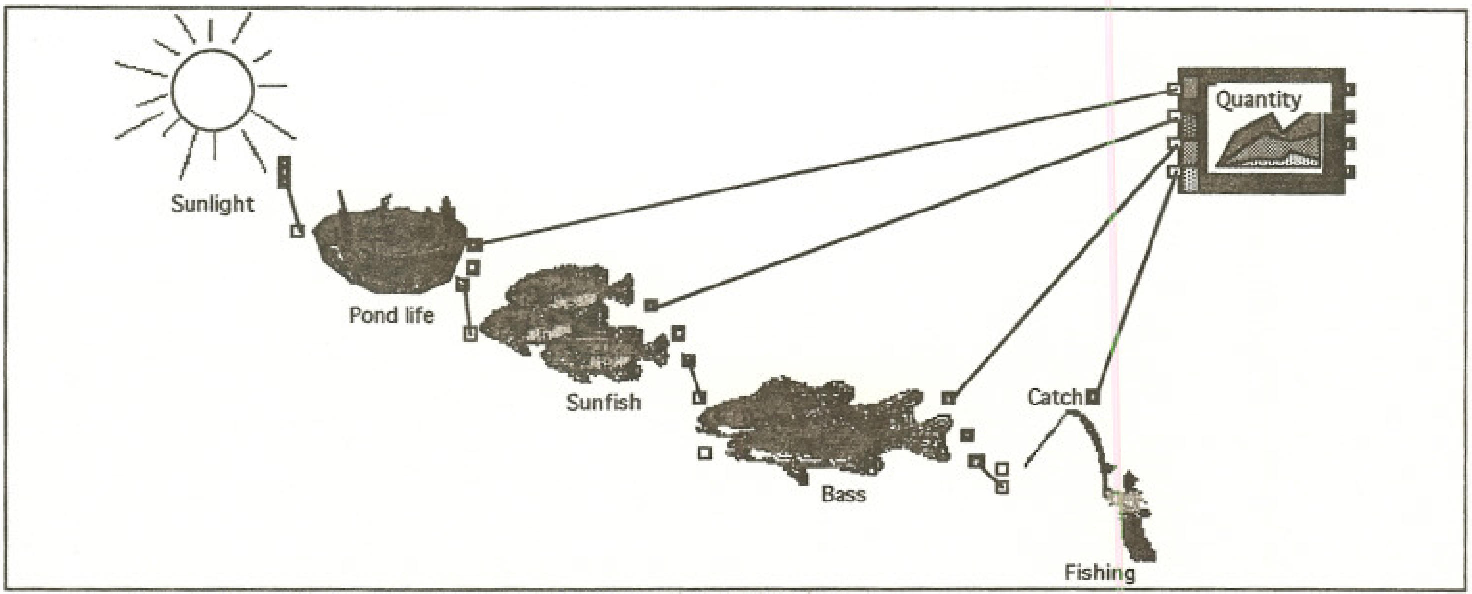
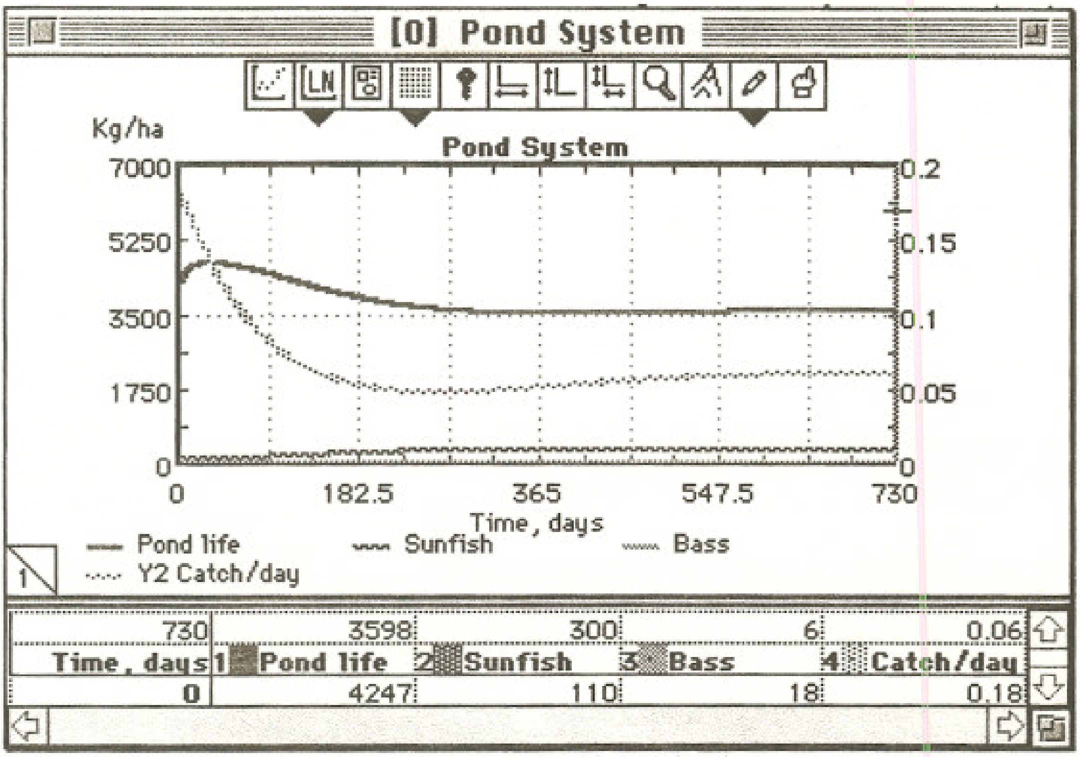


Figure 18. Picture icon ecosystem with fishing.

Calibrating the Fishing Model

1. Enter the values from the steady levels (like Figure 17) in the dialog boxes of Pond life, Sunfish, and Bass. The dialog box of the Fishing block is set for one hour of fishing per day.

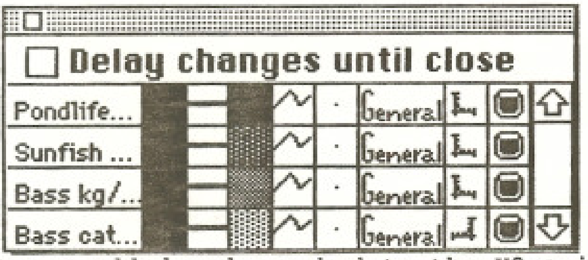


730	3598	300	6	0.06
Time, days	1 Pond life	2 Sunfish	3 Bass	4 Catch/day
0	4247	110	18	0.18

Figure 19. Simulation graph of ecosystem with fishing.

To see the fishing catch numbers in your graph as shown in Figure 19, you need to change the calibration of the graph to graph the catch on the right axis.

1. If the Plotter isn't already open, showing the graph, double-click on the Plotter block to open it.
2. Click on the right-hand vertical axis label and type "Kg/ha/day". Click on the upper axis value of "100" and change it to "0.2".
3. Click on the ▣ tool. In the eighth column, third row, click on the ┘ tool to switch it back to a └. This will cause the bass to be graphed on the left or Y1 axis.
4. In the first column, fourth row, click in the empty label box and type "Bass catch/day". Also in the fourth row, click on the └ tool to change it to a ┘. This will cause the catch per day to be graphed on the right or Y2 axis as shown in Figure 20.



☐ Delay changes until close

Pondlife...	General	└
Sunfish ...	General	└
Bass kg/...	General	└
Bass cat...	General	┘

Figure 20. Fourth row added and graphed to the Y2 axis.

Now, you can see the weight of bass caught from the pond per day. At an average of 1 kilogram per bass, how many is this per year?

The **Fishing system** model included with this module shows the entire system described above.

"What if" Experiments

1. What would happen to the fish population if you and your friends doubled your fishing time? If you cut it in half?
2. How much fishing time would give you the maximum sustainable yield?
3. Move around the country (change sunlight by checking the map in Figure 5) - where would a pond like this yield the most fish?
4. How many could you catch in a pond where you live?

Nonsense Models

In the library you are given many blocks which can be connected. For example, you can connect fire to pond life and get a graph. The BioQUEST library does not recognize that this connection does not make sense in the real world, and that the graph is meaningless. You must always use your knowledge to check whether any model is realistic. (In the full version of Extend, you can program blocks to give error messages if they are incorrectly connected).

Advanced Questions

1. How would the situation change if you fished sunfish as well as bass? Connect a new Fishing block to the sunfish and try various fishing rates.
2. Add a gar. It is a fish that eats sunfish but it isn't fun to fish and we are not accustomed to eating it. How many hours can you fish now? Why? Note that to graph the output of the gar you will need to remove one of the connections to the plotter because it has reached its limit of 4 inputs. You can disconnect the Pond life from the plotter and connect the Gar; its output will be shown in the pond life part of the table.
3. Consider all the factors you can control in your model. How might the control of these be translated into real policy? For example, fishing catch can be controlled in many ways.

Which of these controls is easiest to regulate? Which are most effective in reducing over-fishing?

Decision Making: Over-fishing

Recently, among people working in both freshwater systems and marine systems, there has been much discussion about keeping the fish populations up to a sustainable yield. When species are over-fished, the quantities are removed faster than reproduction can replace them. In some cases fishermen lose their jobs for lack of fish. This has happened to several marine species, such as sardines, Pacific salmon and redfish. In these situations, processors have switched to less desirable fish, such as menhaden. However, worldwide fish catches have been going down. Large refrigerator ships which use high technology sonar to find fish and large power-driven nets to catch everything in their way have been so efficient they have reduced quantities of many species. Various regulations, such as the 200-mile fishing limit around the U.S., have cut down on such exploitation. Several international groups are trying to negotiate agreements on limiting fishing, such as the one recently concluded on protection of whales.

An interesting example is a recent controversy in concerning Native American fish spearing. Sports fishermen and resort owners fear that by exercising their treaty rights, Indians are depleting fish populations.

Taking fish of one type may cause other species that are not fished to displace the preferred species. To sustain a species may require humans doing something to help the preferred species remain competitive. This factor is not in this model.

You can see how modeling a system can help you see what affects any particular fish. It is essential to understand the system the fish is a part of to make any useful suggestions for control. As in making any kind of model, the results will not apply if any important factors have been left out.

Flows of Energy and Materials

All systems operate with energy. Many ecosystems depend primarily on the sun's energy. This energy flows through the system being used by the processes of production and consumption. In all these processes the used energy is released as waste heat. Some ponds and rivers receive most of their energy from that flows in from outside. You can include such a source with the "force source" symbol from the General System Symbols library , discussed below.

Materials like carbon, phosphorus and oxygen flow through the system, from plants to animals and back to plants, pushed by the flow of energy. Energy comes into a system, is used, and is then released as waste heat. Materials cycle around and around.

Making the Pond Model with General System Symbols

Included in the BioQUEST library is a collection of General System Symbol blocks. A General System Symbol can replace each of the picture blocks you have been using. There is a Producer symbol which can represent any organism which produces biomass by photosynthesis: pond life, grass, rainforest trees or coral algae. The Consumer symbol can be used for organisms which consume producers or other consumers: fish, squirrels, foxes, snakes, or alligators. Using these general symbols you can make ecosystem food webs for any system.
The General System Symbols are pre-programmed blocks, just like the blocks you used in the Pond Life models above. However, these symbols correspond to the research and examples discussed in several publications produced by the authors, as listed in the References section of this manual. The symbols are shown in Figure 21. Table 1 is a list of them with their definitions.

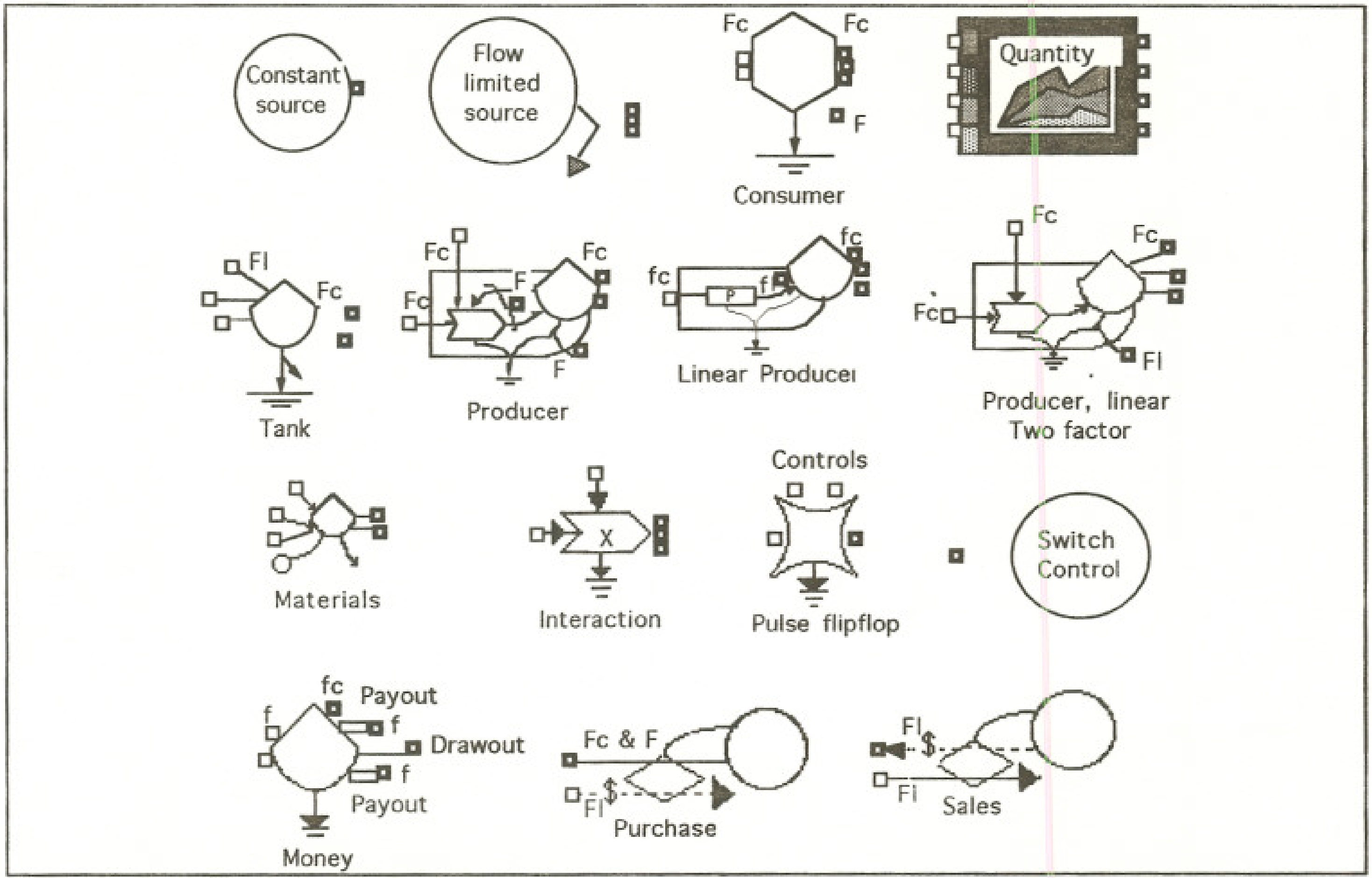


Figure 21. General system symbols.

Table 1
List of General System Symbols and their Definitions

Constant source - energy source which delivers a constant input, flow or source depending on which box is checked on the dialog screen. Constant force is a source that maintains a constant

concentration or pressure regardless of how much is used. Constant flow sends a set amount into the system per unit time.

Flow limited source - energy source which delivers a steady, source-limited flow, such as sun, rain, and rivers.

Consumer - unit such as fish, microorganisms, humans, and cities with storage and autocatalytic conversion that uses the products from other units for its growth..

Plotter - plotter which produces four graphs.

Tank - storage of a quantity, such as water or materials

Producer - unit such as plants with production process and storage which makes products from energy and raw materials.This producer is an auto-catalytic process with feedback from the biomass produced to photosynthesis.

Linear Producer - plant photosynthesis dependent only on light or other production dependent on one source.

Producer, linear Two factor - unit such as plants with photosynthesis dependent on light and raw materials, with no internal feedback.

Materials- a flow of materials from an outside source and recycled materials from other parts of the system, as nutrients in the soil coming in the rain, being used by producers, and being recycled back from consumers.

Interaction - production process which combines different types of energy or material flows to produce a yield.

Pulse flipflop - switch, such as fire controlled by threshold of grass and something to start the fire.

Switch control - source of pulses that control switching on and off.

Money - storage of money with outflows to pay people.

Purchases - work of humans in proportion to the money received.

Sales - flow of money to pay for goods.

To use the General System Symbols, pull down those symbols you want from the library to build the pond system. Since fishing is an outside influence, its action is represented by two symbols: the Constant source symbol (anglers) and the Interaction symbol (fishing action) that connects the anglers to the fish. The general symbols are put together in the same way as the picture blocks in the previous models, starting with the sun at the left and going up the food chain connecting output connectors to input connectors.

We have calibrated a pond model for you to experiment with. Open the **Pond, general symbols** model using **File, Open.** As shown in Figure 22, it shows the same system as shown in Figure 18 but with general system symbols.

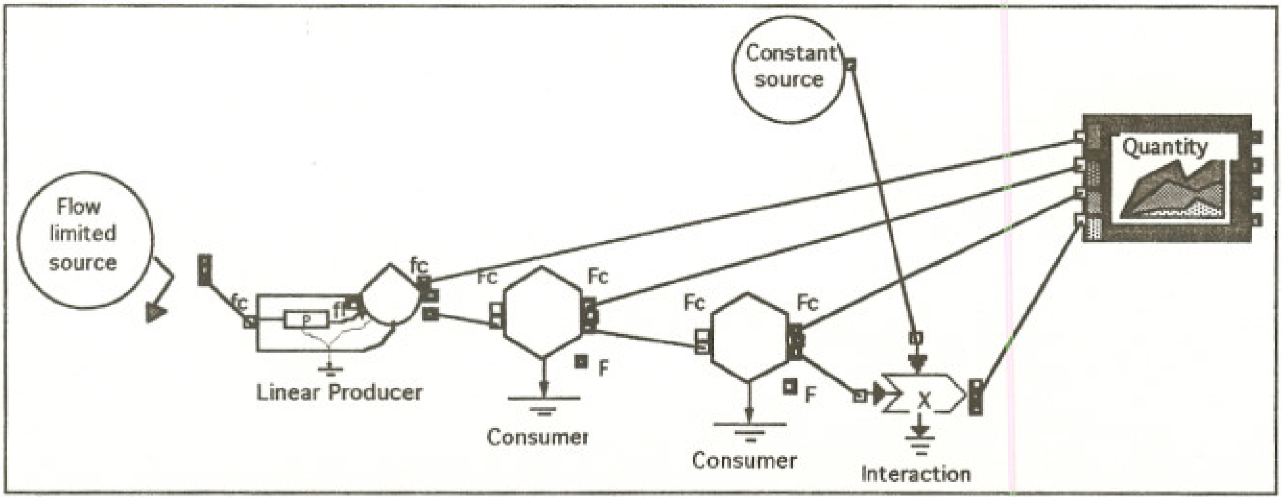


Figure 22. Model of pond ecosystem using general system symbols.

These general system symbols have dialog boxes with more items to be typed in than do the blocks you used previously (which have built-in values for such variables as rates of production and consumption). Because there are more variables (values) when you use the general symbols, you will not get exactly the same answer as you did with the picture icon models. However, appropriate values have already been entered in the dialog boxes in the Pond, general symbols model so you can run the model. After you have run the model, experiment by changing the values.

"What if" Experiments

1. What other systems have similar components which interact in the same way? If your system were a forest, what would you label the symbols? Write forest labels on a printout of your pond diagram drawn with general symbols.

PART II: A GRASSLAND FIRE SYSTEM

Controversial questions are being raised about fires and the part they play in maintaining natural ecosystems. Fires recycle nutrients and start new cycles of growth. By modeling a grassland, we can see how it grows without fire, and then put in fire and see what it does to the grassland. What is the effect of more frequent fires? Modeling experiments like these are done to help householders and park managers make such decisions as whether or not to let natural fires burn, and if they should control-burn their grasslands.

Let's study a grassland in Nebraska. It is a system of grasses and their consumers (animals and microbes). The sun, of course, is the energy source for grass photosynthesis. Nutrients (fertilizer elements such as nitrogen, phosphorus and potassium) are also necessary for photosynthesis. Respiration of the grasses and consumers produces nutrients which recycle back to the soil to be used by the grasses again. Fire, which is a natural occurrence in grasslands, is also a consumer which recycles nutrients. A picture of a grassland with fire is shown in Figure 23.

Figure 23. A grassland includes grasses, periodic fires, consumers such as mice, rabbits, birds and insects, and decomposers such as insects and microbes.

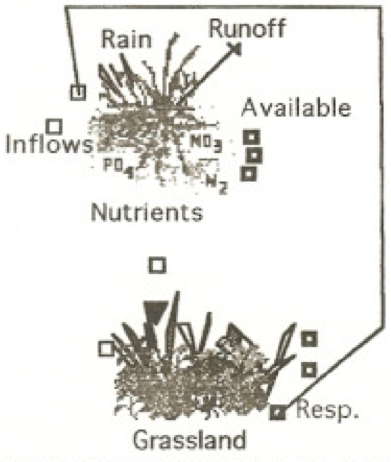
Building the Grasslands Model

1. Open the **Grassland worksheet;** it shows just a **Plotter** which is already calibrated. The three blocks you need are: Sunlight, Grassland and Nutrients.
2. Pull down the **Sunlight** icon from the library and place in on the worksheet.
3. Pull down the **Grassland** icon. The Grassland block simulates herbs and grasses; small consumers like mice, rabbits and insects; and decomposers like microbes, insects and worms.

   The Grassland block has two input connectors: for sunlight at the left and nutrients at the top. It has three output connectors: Resp. is an outflow of nutrients from the respiration of the grassland; the other two outputs can be connected to the Plotter or any consumer of the grassland.
4. Pull down the Nutrients block. The Nutrients block simulates inorganic soil nutrients like phosphorus, nitrogen and potassium.

   The Nutrients block has two input connectors for nutrients from various consumers or fire. It has three output connectors (marked Available), one to go to the plotter and two which can be connected to producers which use nutrients.
5. Arrange and connect the blocks according to the convention that shows energy flowing from left to right, and the recycle of nutrients from the respiration of the grassland back to the nutrients in the soil to be used by photosynthesis of the grasses.

   Bent lines can be made to connect two components. To put in a bend: stop moving the mouse where you want the bend. Let up on the mouse, then mouse-down again and move in a new direction.



A bent connecting line made by mouse-up/mouse-down while drawing the line.

6. Connect the quantities you want to be graphed - amount of nutrients and grassland biomass - to the plotter. (Figure 24).

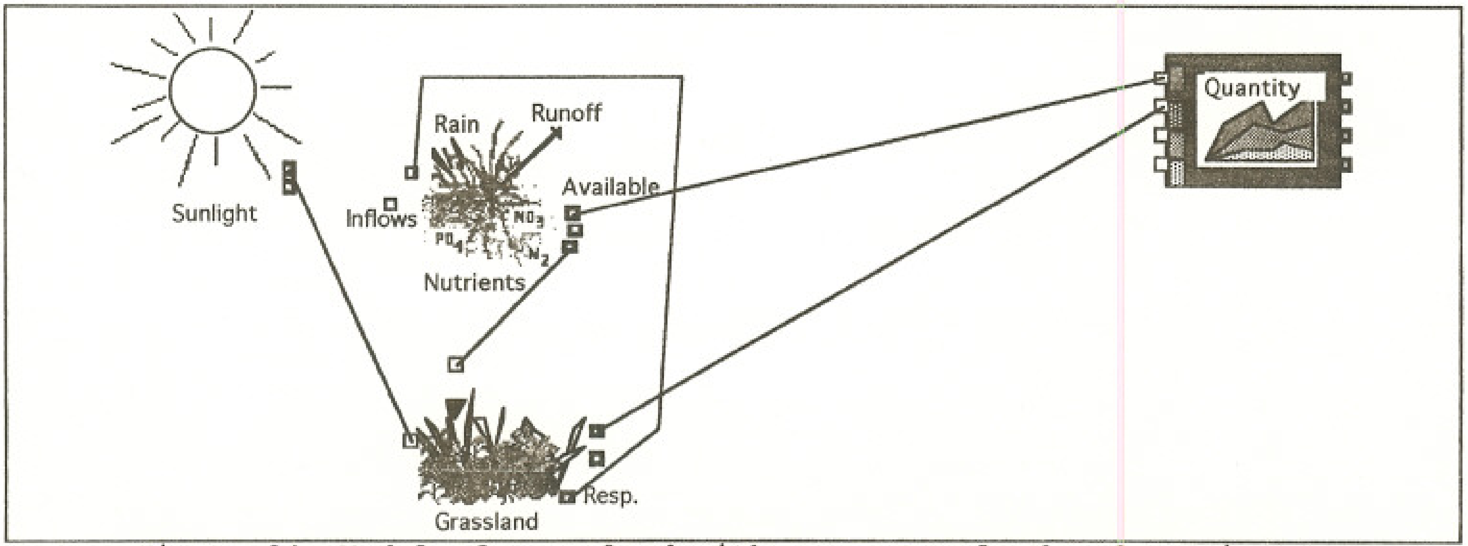


Figure 24. Model of grassland with sun, grassland and nutrients.

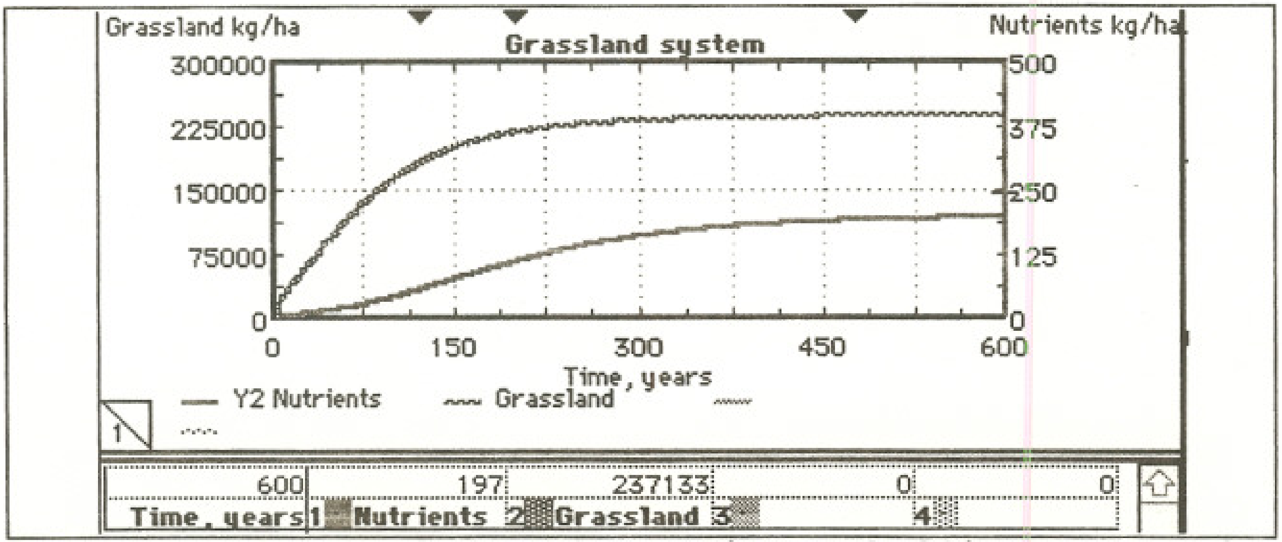
Calibrating the Grassland Model

Let's start the grassland growing in an area which has not previously been grassland - and let's keep out fire.

1. To gather the data for this model, go to Figure 5 to record the sunlight in Nebraska (about 3800).
2. If you set the dialog box of Grassland at a low number, for example 10 kg/ha, the simulation graph will show growth of the system in a new area. The Nutrients dialog box gives you two settings: set the rain nutrients at 2 kg/ha/yr and the soil nutrients at 20.
3. Run the simulation. You should get a graph that looks like the one in Figure 25.
4. Record the quantities at steady state.

Questions

Why does the quantity of grassland biomass level off?



600	197	237133	0	0
Time, years	1 Nutrients	2 Grassland	3	4

Figure 25. Graph of grassland growth, recording grassland biomass and quantity of soil nutrients.

Succession

The gradual buildup of biomass and increasing **diversity** (number of different kinds) of species and then leveling of quantities in an ecosystem is called succession. Over time different plants and animals replace the early ones. Each set of plants and animals prepares the area for the next, until an ecosystem is produced which tends to stay the same. This mature state is called the **climax** ecosystem which remains until caused to restart by catastrophic events.

In a grassland area succession is a process that starts with seeds which blow onto an open field, producing plants that grow up and reproduce. These first grasses catch the sun and rain and build up organic matter in the soil. The next season other seeds can take root here, building up more biomass and more diversity. This growth of biomass and diversity comes to a steady level when the herbs and different kinds of grasses are using the available resources of sun, rain and nutrients.

When the graph of biomass in Figure 25 levels off, there is a balance of growth and decomposition, of production and consumption. This is the **carrying capacity** of the grassland. Remember the discussion of carrying capacity in the pond? It is similar in most ecosystems: succession increases biomass and diversity until the carrying capacity is reached.

This climax state persists until fire, an epidemic of insects, or some other catastrophic event consumes the storages, causing the succession to start over.

Adding Fire to the Model

Fire caused by lightning is a natural part of most grassland ecosystems. Fire is just a very fast consumer. It burns both living and dead biomass and it recycles the nutrients which stimulate renewed grass production. About half of the nutrients blow away after a fire. Another role of fire is to maintain the grassland by burning other vegetation, such as shrubs, which might grow up and take over.

To add fire to your grassland system:

1. Pull the **Fire** block down from the library.
2. Place it at the right of the model.
3. Connect an output flow from the **Grassland** block to the Fuel input of the Fire block.
4. Connect the Nutrients output from the Fire block to one of the input connectors on the left of the Nutrients block.
5. Something to start the fire is needed: pull down the **Fire sources** block (with the lightning/match icon) from the library and connect it to the top right input of the Fire block. Your model should look like Figure 26.

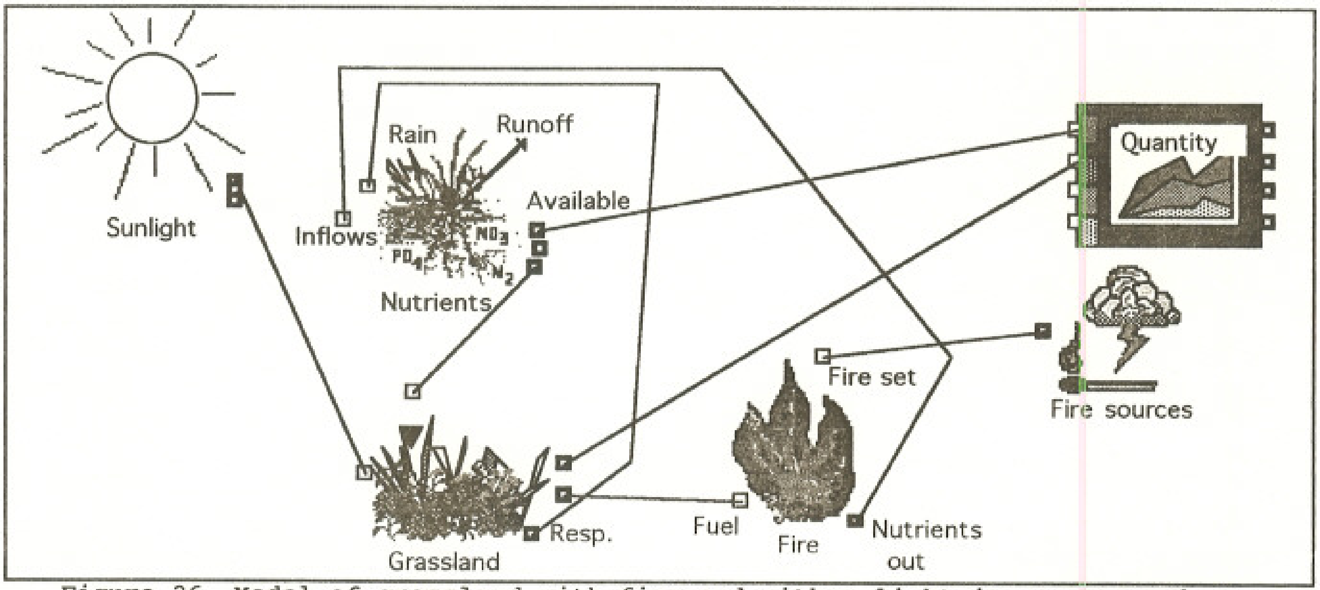


Figure 26. Model of grassland with fire and either lightning or a match to start it.

After this grassland has reached its climax, we'll change the management to allow fire.

Fire Caused by Lightning

Fire can be started either naturally by lightning, or by humans. You will see how it works with lightning first. When grasses have built up enough dead leaves and litter (burnable threshold) they will catch fire and burn when lightning strikes. In most grasslands this happens every three or four years.

1. To look at the Fire dialog box, double-click on the Fire icon; a reasonable biomass quantity (30000 kg/ha) is set for fire to start.
2. Look at the Fire sources dialog box. There are two possible sources to start a fire: lightning and human management. The checkboxes allow you to choose one, or the other, or both at the same time.

In the dialog box, the lightning box is already checked. The fire will burn when two situations are true: the biomass of grass has reached its burnable threshold and lightning strikes. When the lightning checkbox is selected, the Lightning source block has been programmed to produce lightning at random times (various uneven times).

Calibrating the Fire Model

1. To run the simulation for 30 years, change the time to 30 on the **Run Simulation** screen. Also change the **Time per step (dt)** to 0.1.
2. Set the Grassland dialog box at the steady state level from Figure 25.
3. In the Nutrients dialog box, leave the Nutrients flowing in the rain at 2 kg/ha and change the soil nutrients to the steady state from Figure 25.
4. Run the simulation.

Your graph will resemble Figure 27, but will not be exactly like it. Be sure you know which line is biomass and which is nutrients and what happens to each when fire comes. Why do they go in opposite directions between fires? Why are they about level at the beginning of the graph?

1. Run it again. The new graph will look different from either of the others.
2. A computer question: What causes the graphs to be different?
3. An ecosystem question: What circumstances in the real world cause this variation?

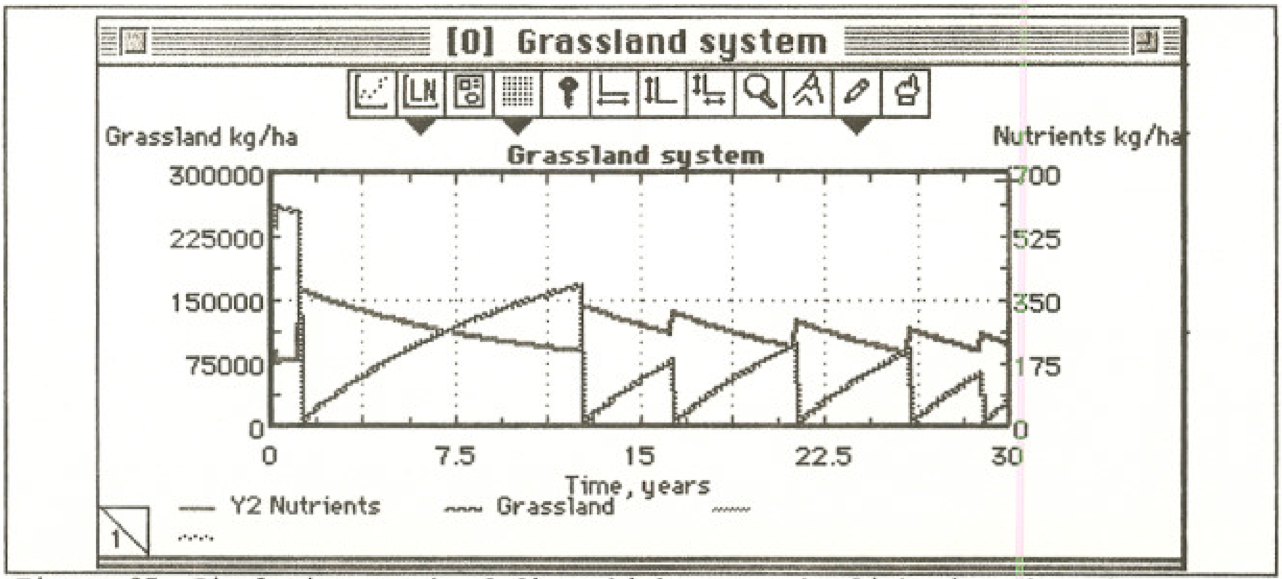


Figure 27. Simulation graph of fire which starts by lightning when the grassland biomass enough to sustain fire (reached its burnable theshold).

Controlled Burning

Deliberate controlled burning is another way fires burn grasslands. Park managers may want to keep the burnable biomass down to avoid a serious fire, or they may want to control the vegetation to keep the area in grasses. If grasslands grow without fire, shrubs will get started, and then tree seedlings come in, and often in several years a forest has taken the place of the grassland. This is succession several years past the grassland stage. Can you think of what, besides fire, has kept our Middle Western states grassland?

1. Decide how often to start the fires and set up a program to burn the grassland that often. In the Fire sources dialog box, put in the number of years you decided. Be sure to unselect the "Lightning..." choice and select the "Fire started by Managers" choice.
2. Run the simulation. If you used 5 years in the Fire sources dialog, your simulation should look like Figure 28.

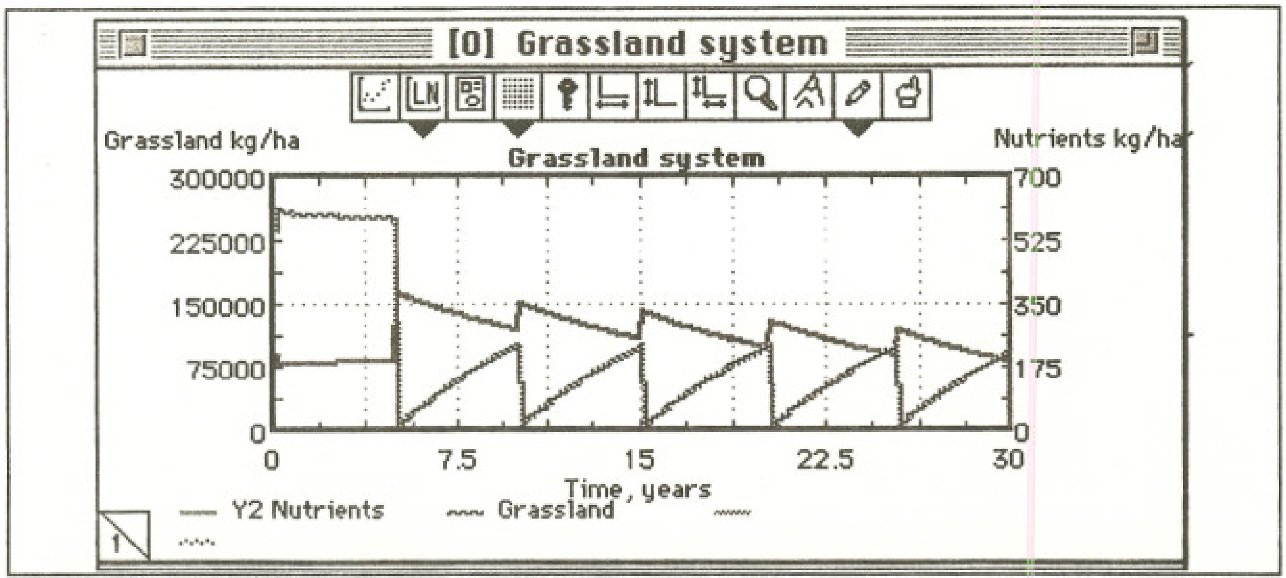


Figure 28. Simulation graph of fire every five years.

"What if" Experiments

1. What will happen to the grassland if fire is always put out when it starts? What will you do in the fire sources dialog box to be sure there is no fire? Run the simulation. Compare the changes in grassland biomass and nutrients to those in Figure 27 (with lightning fires). What do you suppose this heavy buildup litter causes when a fire finally gets going?

2. What would the pattern of lightning fires be if the herbs, grasses and animals were different kinds which produced less dead burnable material? To try this: in the Fire dialog box double the quantity of biomass needed to support a fire. Run the simulation. Explain your results.

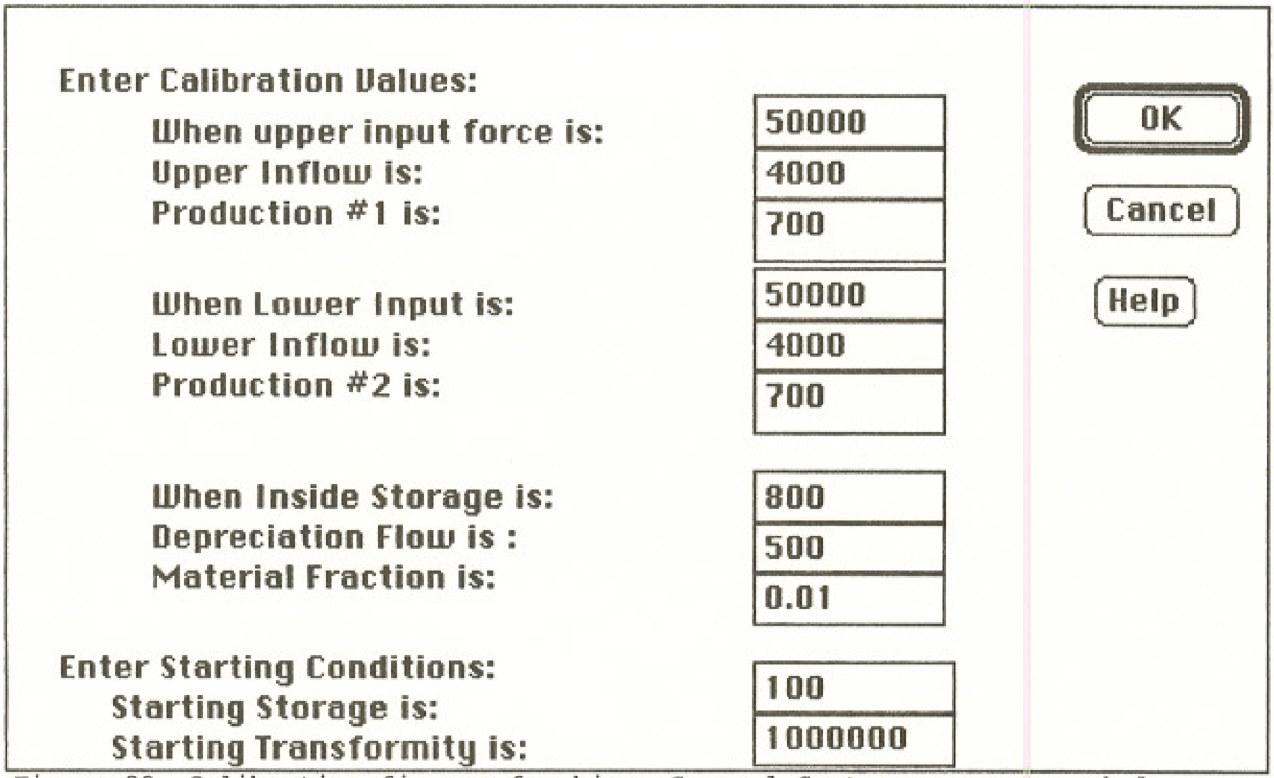
3. Change the Sunlight dialog to put this grassland in your part of the country. (First, change the threshold in the Fire dialog box back to the original so you can compare this graph to that in Figure 27.) How does this change the pattern of lightning fires? Explain.

Advanced Questions

1. If you put an animal consumer, like bison, into the system, what will be the pattern of grassland biomass growth? To do this, disconnect the Fire blocks. Pull down a Consumer symbol block from the library and put it to the right of the Grassland block. Connect its input to the Grassland, its respiration to the nutrients, and an output box to the Plotter. In the Consumer dialog box, type in the calibration numbers shown in Figure 29. Run the simulation. Explain how

the bison consumer changes the growth of the system. Bison weigh about 800 kilograms. How many hectares of this grassland would it take to support a bison?

2. Propose a management system for the grassland in Figure 26 as if it were a park where people came to see the grassland and to camp. Consider the survival of the grassland ecosystem and also the needs of the people who use the park.



Enter Calibration Values:

When upper input force is:	50000
Upper Inflow is:	4000
Production #1 is:	700
When Lower Input is:	50000
Lower Inflow is:	4000
Production #2 is:	700
When Inside Storage is:	800
Depreciation Flow is :	500
Material Fraction is:	0.01

Enter Starting Conditions:

Starting Storage is:	100
Starting Transformity is:	1000000

Figure 29. Calibration figures for bison General System consumer symbol.

Decision Making: Management for Fire

We can relate our fire model to the recent fires in Yellowstone National Park. In Yellowstone fire had been kept out for a hundred years until 1972 when the fire suppression policy was lifted. In 1989, after several very dry seasons, fires got out of control, burning thousands of acres of forest and some human development. Reaction to this destruction caused much controversy and a modification of the policy. However, in the 1990 season, much of the land became green again, the start of a new succession. More frequent fires are more natural and prevent catastrophic fire.

Questions arise as to which kinds of ecosystems have fires naturally and where fire-dominated ecosystems are normal. Which ecosystem in your area is, or was, controlled by fire? How do the effects of many small fires compare to a few large ones?

Making the Grassland Fire Model with General System Symbols

For each model discussed in this manual, it is suggested that you also use the general symbols. This will give you practice so that you can make models of any system, not only those in this module.

1. To make the grassland model with the General Symbols (Figure 21), you open the **Grassland, general symbols** model using **File, Open.** In this new model, each picture block in the grassland model (Figure 24) has been replaced with a general symbol (producer, consumer etc.) (Figure 30).
2. If you open each dialog box, you will see that appropriate numbers have been entered; the fire is set to burn at random.
3. Run the simulation and compare it with Figure 27. Remember the random numbers make each run different.
4. When you have the grassland model running, try changing some values.
5. As in the Grassland fire system model, delta time in the Simulation Setup dialog is less than 1. See Part IV for more information about choosing the correct delta time for a model.

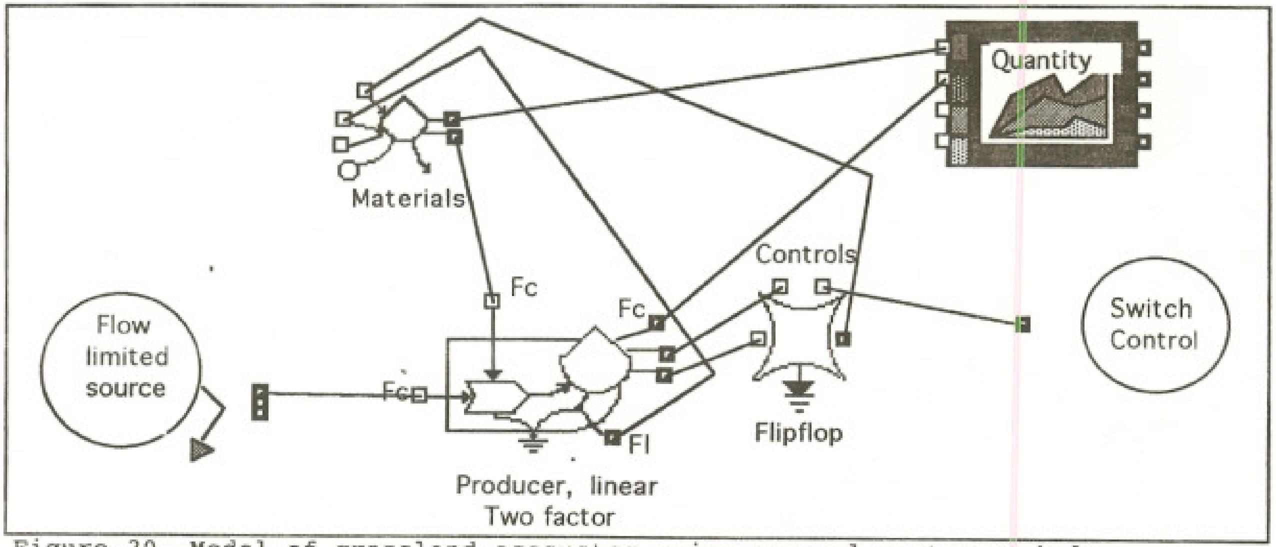


Figure 30. Model of grassland ecosystem using general system symbols.

PART III: LOGGING A FOREST

Part of the study of environmental decision-making involves economic use of ecosystems. Decisions are often based on financial considerations along with ecological ones. Examples are the sale and draining of wetlands to make new land for agriculture, paving over good agricultural land for shopping malls, and logging. Our third model will explore logging. When data from a specific forest is put into the model, decision makers can answer questions such as how much natural forest production is necessary to maintain the economic system.

The forest ecosystem depends on the energy flow of the sun. Forest production includes smaller plants, litter (dead biomass), and small consumers, as well as the trees to be logged. The logging process takes people and machines. The flow of money goes from the companies who buy the logs to the bank and from there to pay for the people and machines necessary to do the logging. A picture of a logging system is shown in Figure 31.

Figure 31. Picture of a logging system.

Modeling the Forest

Start by building and running a model of the forest without logging.

1. Open the **Forest worksheet.** It shows a Plotter which is already calibrated.
2. Pull down the **Sunlight** and **Forest** blocks from the library.
3. Connect them with the Sunlight on the left. Connect the biomass of the Forest to the plotter. Your screen should look like that in Figure 32.

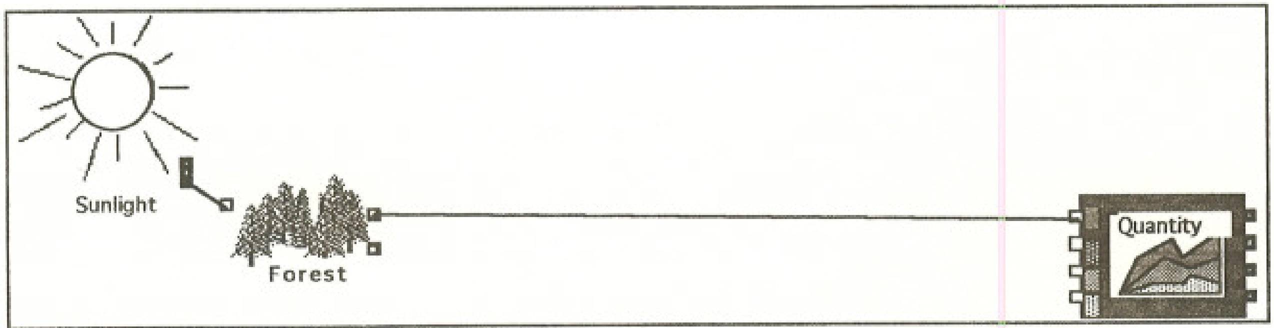
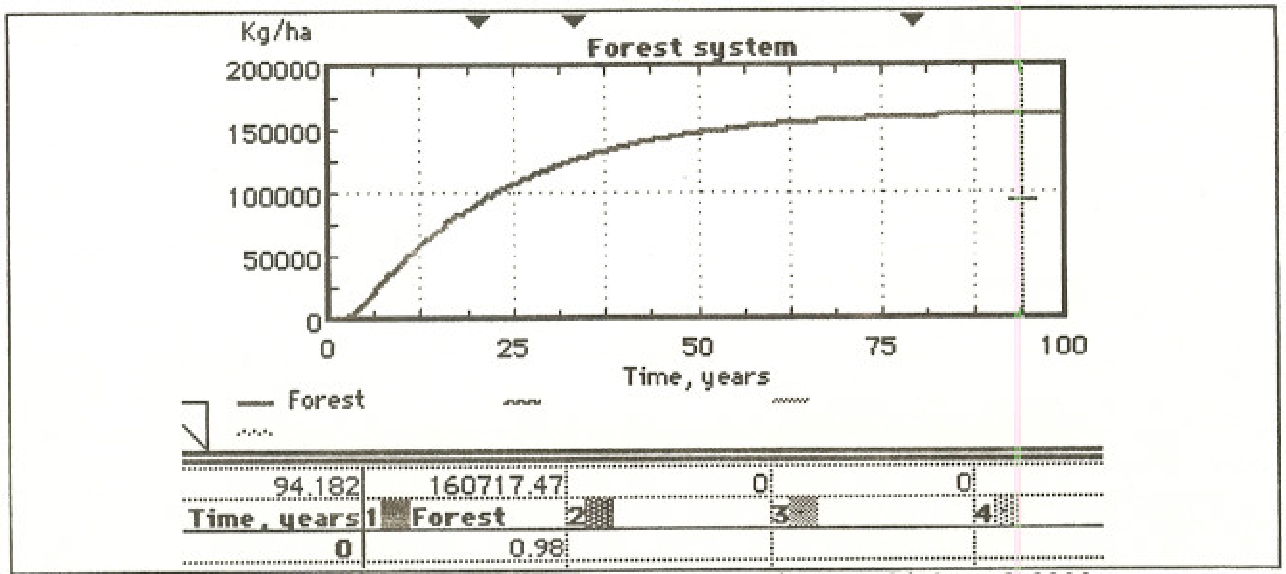


Figure 32. Model of sun and forest.

4. Go to Figure 5 to get the data for the sun in the Northwest where much logging is done and put that into the sun dialog box.

You will start the Forest with seedlings and run the simulation to see how many years its takes for a forest to grow to maturity (climax), where production equals consumption so there is no net change in biomass. This is the process of succession as discussed in Part II.

5. Put "1 kg/ha" in the Forest dialog box to represent seedlings.
6. Run the simulation. Your graph should match the one in Figure 33.
7. Record the steady state quantity of forest biomass.



94.182	160717.47	0	0	
Time, years	1 Forest	2	3	4
0	0.98			

Figure 33. Simulation graph of forest growth, with sunlight of 3000 kilocalories/m2/day.

Adding Economic Activity to the Forest - Logging

Next you will add the economic blocks to show what happens when the forest is harvested and the logs are sold to pay for labor and machines to run the process.

1. Pull down four more blocks: **Logging**, **Product sales**, **Goods & services**, and **Cash.**
2. Arrange and connect them, starting with the **Logging** block to the right of the **Forest** block. Your screen should look like Figure 34.

The economic (money) blocks are a bit different from the ecological ones. Sales and purchases are exchanges. The **Product sales** block represents the sale and receipt of payment for the logs from the harvest. The **Logging services** block represents the purchase and payment for materials and labor necessary for the logging process, including saws, trucks, workers in the forest, and secretaries and administrators in offices somewhere.

The **Cash** block is the transfer of money from the logging company's receipts to the payout for goods and services. Money comes in from sales (to the Receipts input) and goes out for purchases (from the Payout output).

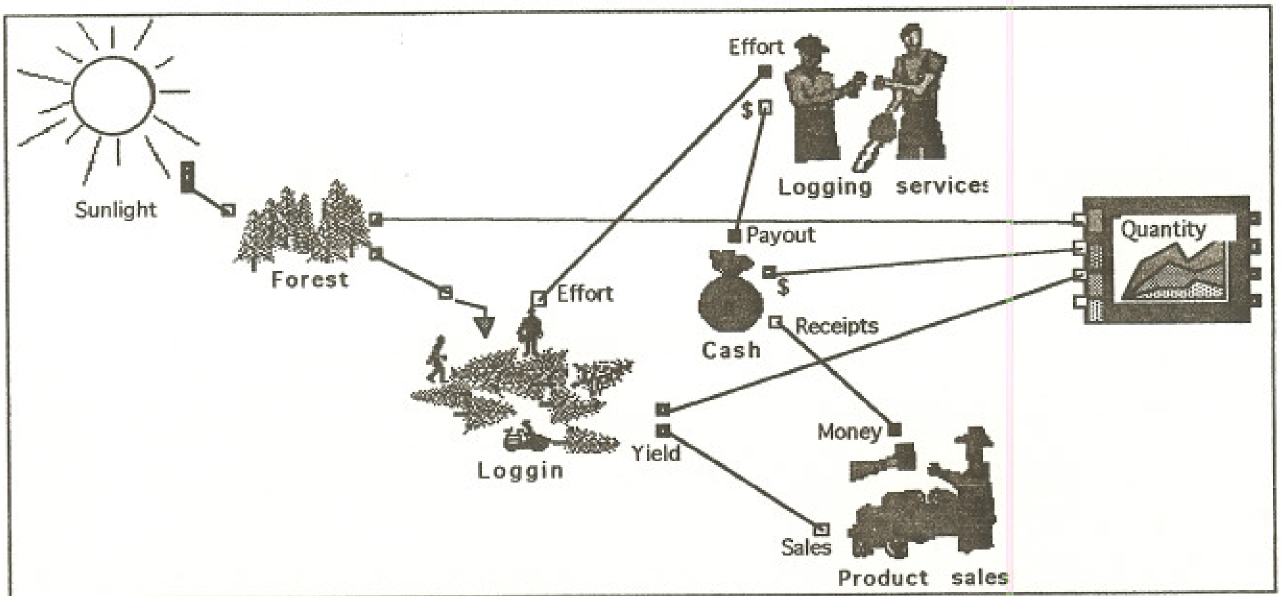


Figure 34. Model of logging system, with sunlight, forest, logging, product sales, cash, and logging services.

Connect the economic blocks as shown in Figure 34. The Yield output of the Logging block connects to the input connector of Sales and to the second input of the Plotter. The output of Sales (the money flow) connects to the Receipts input of the Cash block and to the third input of the Plotter. The Payout output of the Cash block is connected to the input connector of Logging services, and the output connector of Logging services is connected to the Effort input of the Logging block.

Calibrating the Logging Model

1. Go to Table 2, below, to collect the data for the economic part of this system.
2. Record figures for the sales price of logs (to go in the Product sales dialog box), and the cost of all the materials and labor the company has to buy (to go in the Logging services dialog box).

Table 2
Economic Data for Logging Model

Sales price of logs	$20.00 per cubic meter
Cost of goods and services	$ 4.00 per hour

3. Leave the Sunlight dialog box set at the number for the northwest.
4. Go to Figure 33 or your records to read the steady state forest biomass from the graph to put in the Forest dialog box.

Simulation of the Logging Model

1. When you have finished entering data in the dialog boxes, run the simulation.
2. Click the ☑ tool at the top of the Plotter window and fill in the labels for the first three rows as "Forest", "Income", and "Logs". In the second row, eighth column, click the ⊡ tool to plot the second input (income) on the right (Y2) axis.
3. Click at the top of the Y2 axis and label it "$/ha/yr". Change the top number on the Y2 axis to "1000" as shown below.
4. To print labels on the graph, you need a drawing program like MacPaint or Canvas.

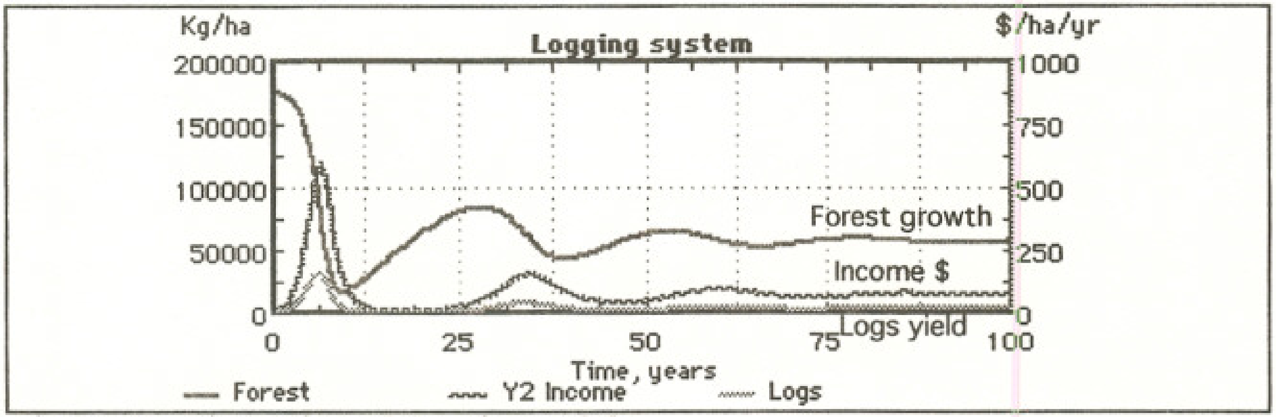


Figure 35. Simulation of logging model.

"What if" Experiments

1. Using Figure 35, answer these questions.
   a. From the point of view of someone interested in the forest, describe what happens to it over the next 100 years.
   b. If you are the company manager, what does the model tell you about income over the 100 years.

2. What would happen to the company if the prices it received for logs doubled? Double the number in the Product sales dialog box and run the simulation. According to the model, what does the company do with its money? Check the graph of logging harvest to see that the company puts more into the logging process to make more yield.

3. If this company moved to South Carolina, how would the system be different? Would it make more or less money if the log price and cost of goods and services stay the same? (Check the map in Figure 5 to change the Sunlight input.)

Advanced Questions

1. What difference would an inflation rate of 4% make? (Put sunlight back to the northwest.) Increase both the timber sales price and the price of goods & services by 4%, a one-

time inflation. Run the simulation. How does it affect the amount of money received? Will the company be able to buy more with its profit? Why?

2. Let's ask some questions about trade and exchange if these logs are being exported to Japan. In Japan the average quantity of goods which people can buy for the dollar is less than in the US. If we sell our logs to Japan and spend the money to buy Japanese goods, this trade is equal in money. When you look at the exchange of goods, is this trade equal, to Japan's advantage, or to our advantage?

3. Create a "what if" question of your own using your knowledge about the real world and what factors can change in a real-world scenario.

Sustainable Yield

Because the flows of sun, rain, and weathering of rocks to make soil are set by earth processes beyond human control, the amount of forest growth is limited and the yield that can be harvested is limited. In the simulation of logging which you ran first, a steady state was reached in which sustained yield was maintained year after year.

If, however, prices of wood are increased, the economic system tends to cut more than the sustainable yield, and the forest is used up, no longer growing what it would before it was overcut. Not included in this model is the work by humans necessary to keep the forest soils fertile and able to compete with weed species during regrowth.

Decision Making: How Much Logging

Questions about what logging should be done are arising all over the country.

In national forests logging permits are sold to private companies that usually cut more biomass than is being replanted. To maintain the forests, quantity of biomass cut must be replaced; it is not enough to plant the same number of seedlings as mature trees that were cut.

In the Northwest the spotted owl, an endangered species, can only live in "old growth" 100+ year-old stands of trees. However, to maintain sustainable yield at the greatest profit for the logging industry, the industry cuts younger stands which are just past their maximum growth rate.

Find an example of a forest controversy in your area and learn enough about it to form an educated opinion. Perhaps this will lead to your taking some action, such as letter writing, inviting speakers with different points of view to class, or attending a political hearing on the subject.

Making the Logging Model with General System Symbols

Figure 36 shows the same forest system as above, except represented with the General System symbols shown in Figure 21. Open the model file **Logging, general symbols**, run it, and compare the simulation graph to Figure 35. This graph will be somewhat different because it starts with the growth of a new forest. Experiment with some "what ifs."

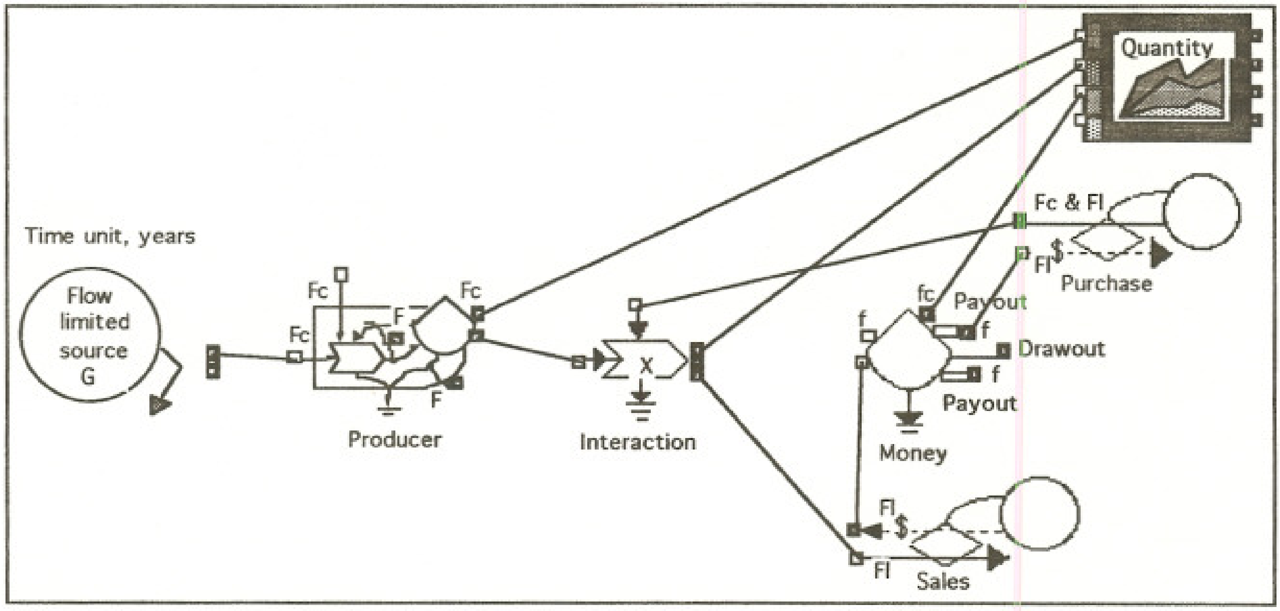


Figure 36. Logging model with general symbols.

Create Your Own Models

Figure 37 shows all the picture icon symbols. Go back to the fishing model and add product sales, or add fire to the forest. Be creative - make your own system!

The general system symbols in Figure 21 can be used for any system you want to construct, if you enter appropriate values for rates of production, consumption, etc. Try one of your special interest. Consult an expert in the field for reasonable values to put in the dialog boxes.

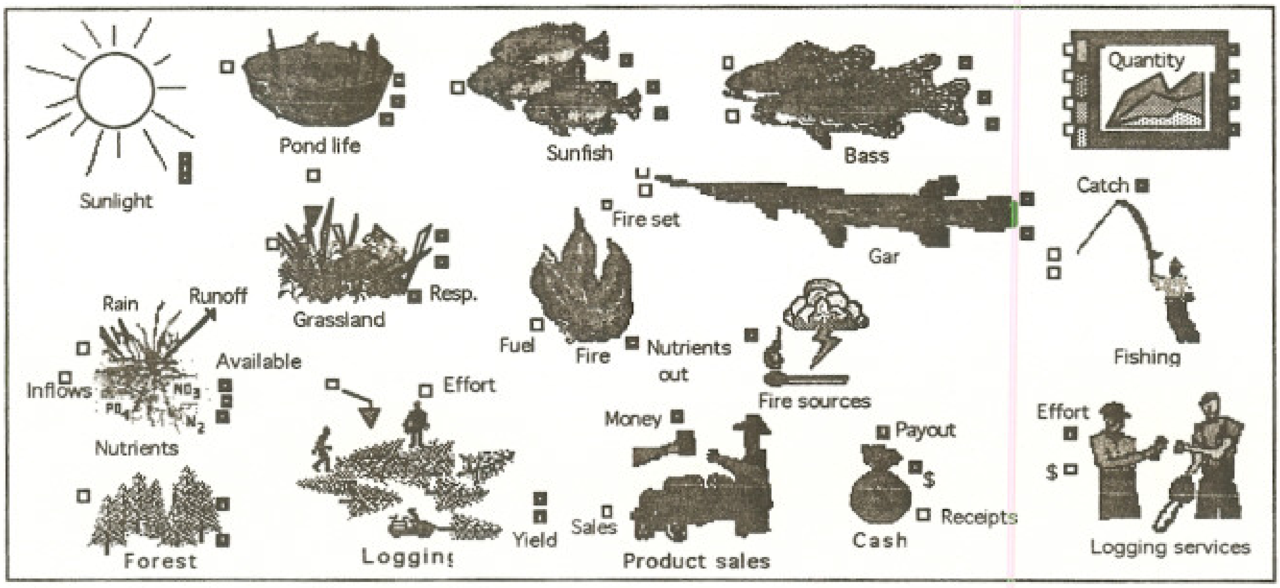


Figure 37. Picture icon symbols.

PART IV: SETTING DELTA TIME

Simulation programs such as Extend calculate model data iteratively; that is, at each step in a series of time steps. At the first step (beginning time), the program plots what the status of the model is initially. Then it calculates the changes that take place over the next time step and plots a new set of data points. Each repeated caculation is called a step or iteration. The graphs are generated as a string of successive points corresponding to the steps in time.

In the Simulation Setup dialog of the Run menu, you can enter values which determine the stepsizeor time per step of the model. This is also known as delta time. For the simulation results to be correct, the "Time per step (dt)" needs to be small enough to accurately reflect changes that occur in different parts of the model.

Often, a delta time of 1 is adequate. However, in some cases you may need to have the delta time be less than 1. This keeps the time interval of each iteration small, but also results in more steps, making the simulation run slower. For example, the Grassland fire model is set for 30 years with the Time per step (dt) set at .03. This means that the model will run for about 1000 steps or iterations. If you change the "End simulation at time" value to 100 years, you do not have to change delta time from .03. However, the simulation will automatically run for about 3300 steps. For model accuracy, it is sometimes necessary to have the delta time be small, even though this means the model will run slower.

There are many reasons why delta time would need to be less than 1. Feedback loops and stiff equations in the blocks can require a smaller delta time to ensure that all calculations are reflected in the graph. Simulations that are run with too large of a delta time often show values jumping from very high to very low. This is known as instability or artificial chaos.

To determine what delta time setting is reasonable, first run the simulation with a delta time of 1 (the default setting). Then run the simulation with a delta time of .5 (one half of the original setting). If there is no significant difference between the two graphs, then delta time of 1 is appropriate. If there is a significant difference, reduce the delta time to .2 and run the simulation again. Continue halving delta time until you determine a delta time which results in no significant differences compared to the smaller delta time. The main idea is to use the largest delta time that will give accurate results, without slowing down the simulation unnecessarily.

PART V: APPENDIX

Use of General Systems Symbols and Calibration of Models

General systems symbols for EXTEND shown in Figure A1 may be connected to model systems in the same way that the picture-symbols were used. Whereas the picture symbols have most of the numerical relationships within the program, General symbols have more blanks in the dialog boxes for setting the numbers, a process called calibration.

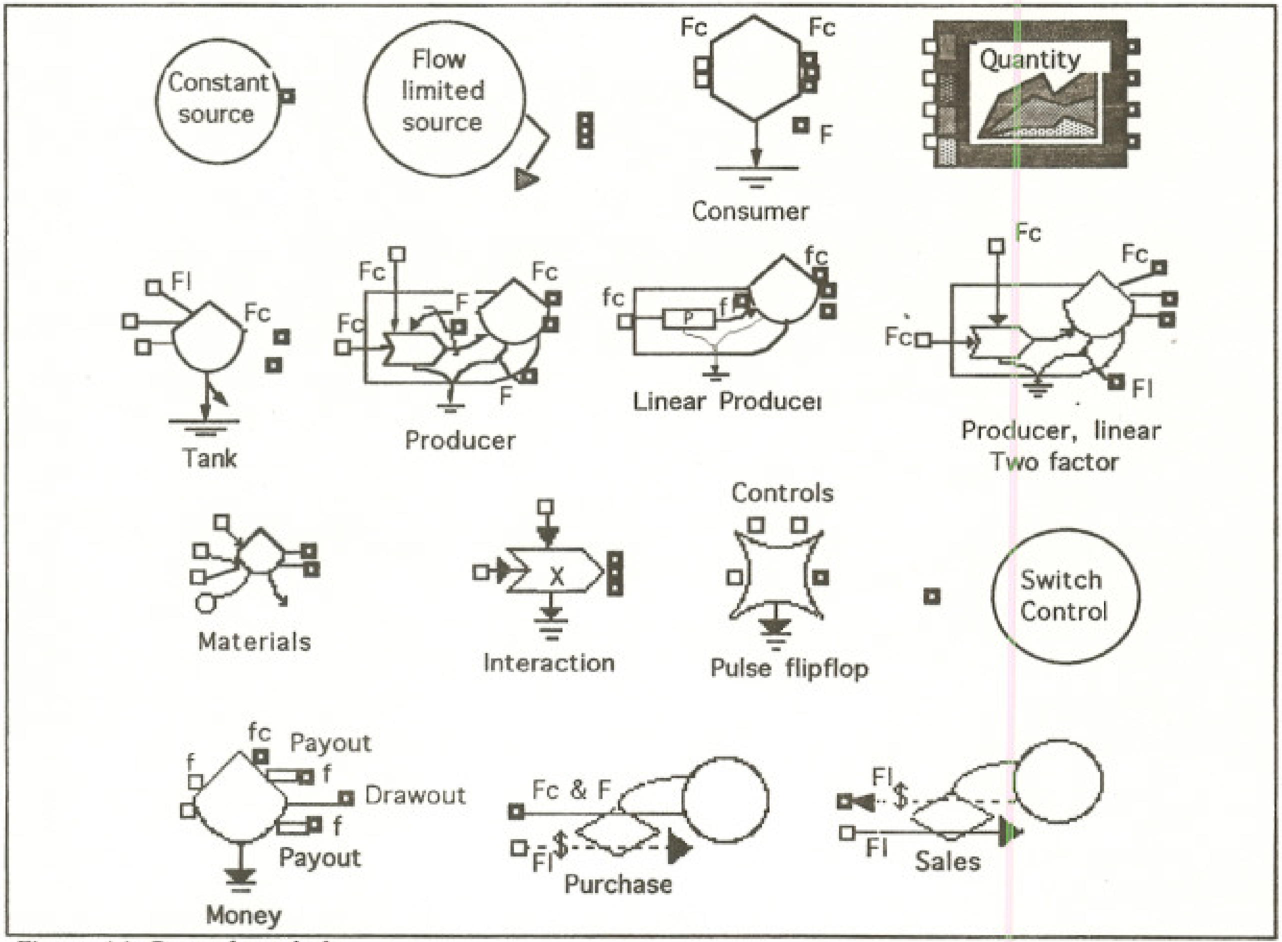


Figure A1. General symbols.

Calibration procedure:

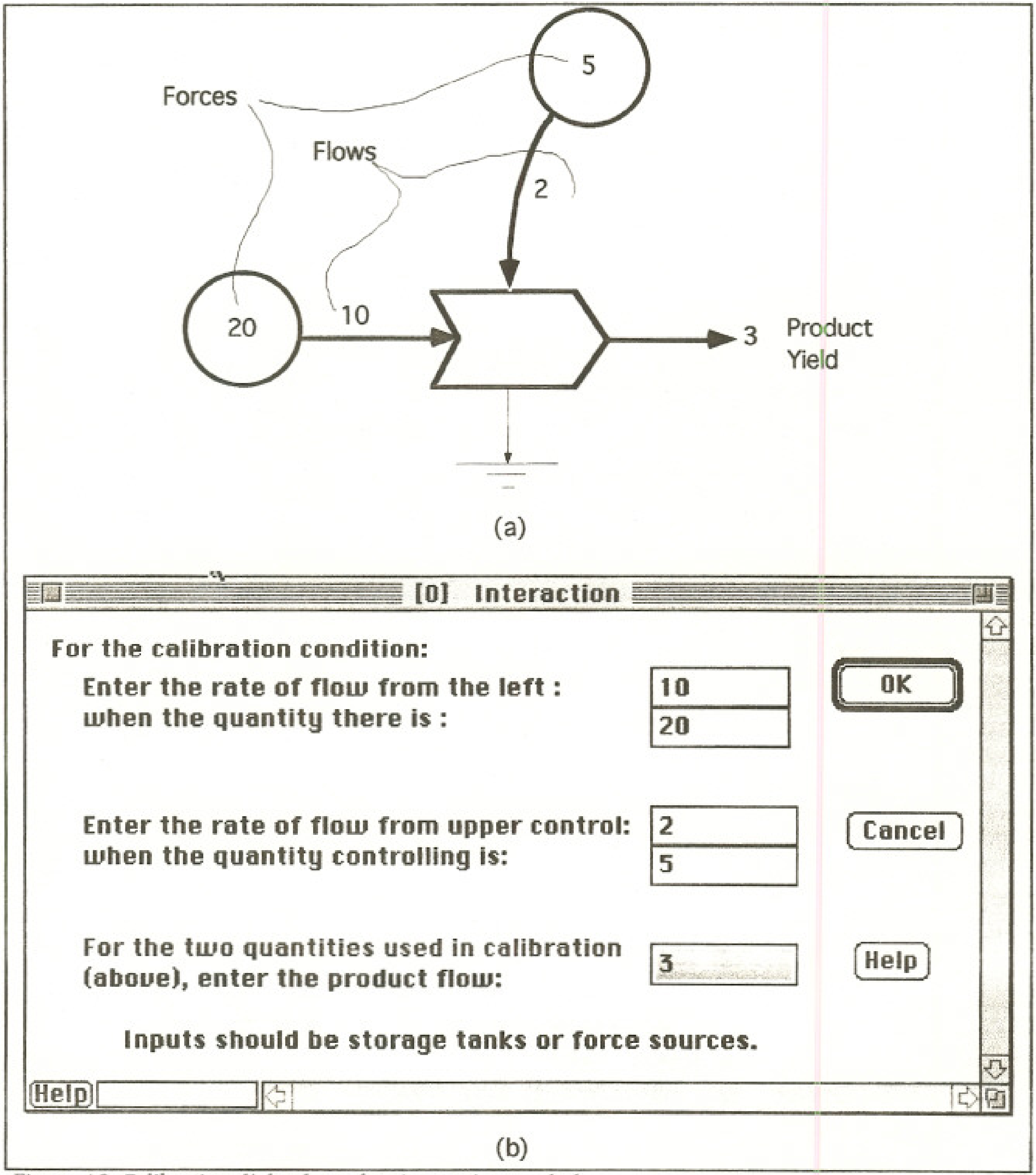
First draw the model with the general symbols on paper connected with the pathways for the flow of food, materials, energy, money, or whatever. Where composite symbols were used, show the subsystem details inside(tanks, interactions, and connecting pathways). Then write typical numbers for the flows on the pathways and for the quantities in storage in the tanks. Often it is convenient to use averages. Use numbers which balance flows in and out of tanks (steady state numbers).

Next, copy these numbers into the calibration part of the dialog boxes. Examples are given In Figure A2 and Figure A3 where the numbers to calibrate a symbol are first shown on the diagram on paper and then as represented on the dialog box.

Starting Conditions: The starting values for the storages for the simulation are entered at the bottom. They may or may not be the same as the storage in the calibration section. In the dialog box of the storage tank in Figure A3, we have entered 10 as a starting value.

Transformity: The dialog box has a place for entering "transformity" which is useful when the general symbols are used to consider energy flows in the system. Solar transformity is the joules of sun's energy required in energy transforming processes to make a joule of another kind. For example, the more steps in a food chain the higher is the transformity. The general systems symbols automatically calculate transformities during a run. Whatever is in a storage at the start can have its transformity entered approximately. This table may be helpful:

Sun	1
Plants	1000
Fuels	10,000
Smaller Animals	100.000
Larger Animals	1,000,000
Human Service	10.000.000



For the calibration condition:

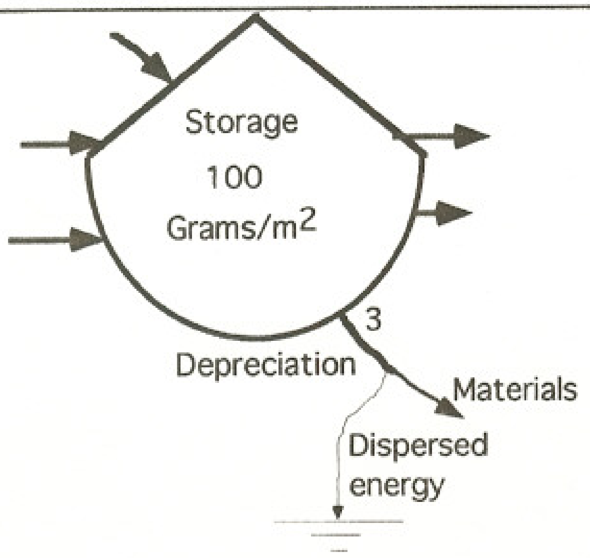
Enter the rate of flow from the left : 10
when the quantity there is : 20

Enter the rate of flow from upper control: 2
when the quantity controlling is: 5

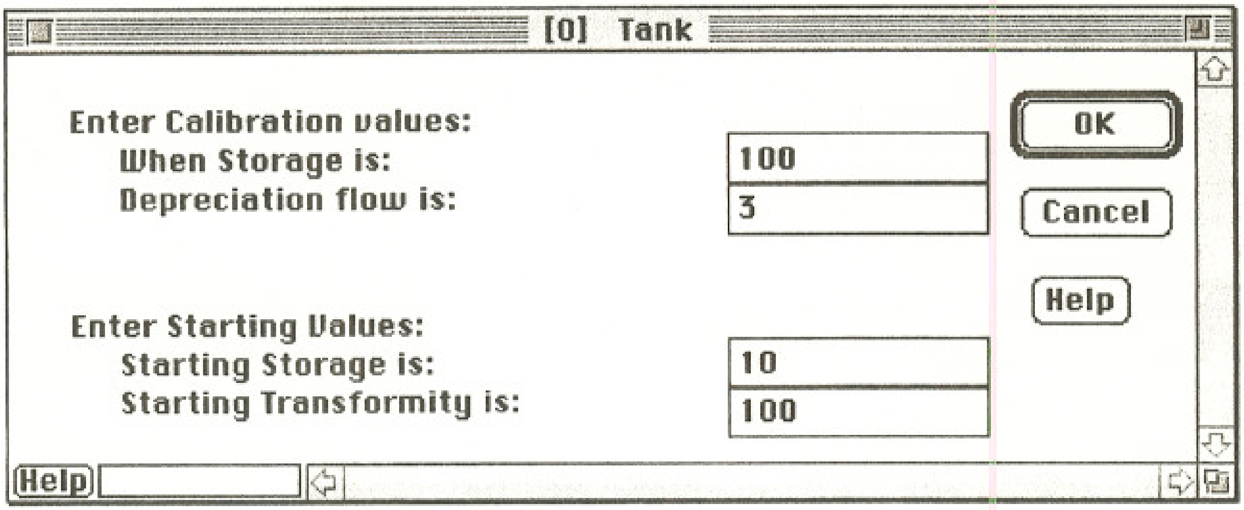
For the two quantities used in calibration (above), enter the product flow: 3

Inputs should be storage tanks or force sources.

Figure A2. Calibrating dialog box of an interaction symbol.
(a) Forces, flows, and product on an energy systems diagram;
(b) Dialog box with numbers entered from (a).



(a) Tank



Enter Calibration values:
When Storage is: 100
Depreciation flow is: 3

Enter Starting Values:
Starting Storage is: 10
Starting Transformity is: 100

(b)

Figure A3. Calibrating dialog box of a storage tank symbol.
(a) Forces and flows on an energy systems diagram;
(b) Dialog box with numbers entered from (a).

Fishing System Using General Systems Symbols

A systems diagram with numbers for calibration of the Fishing System is given in Figure A4. These are the numbers already entered on the dialog boxes of the model: "Fishing, general symbols". When this model is run, results are similar to the same model simulated with the pictorial symbols, because the numbers for calibration were similar for both.

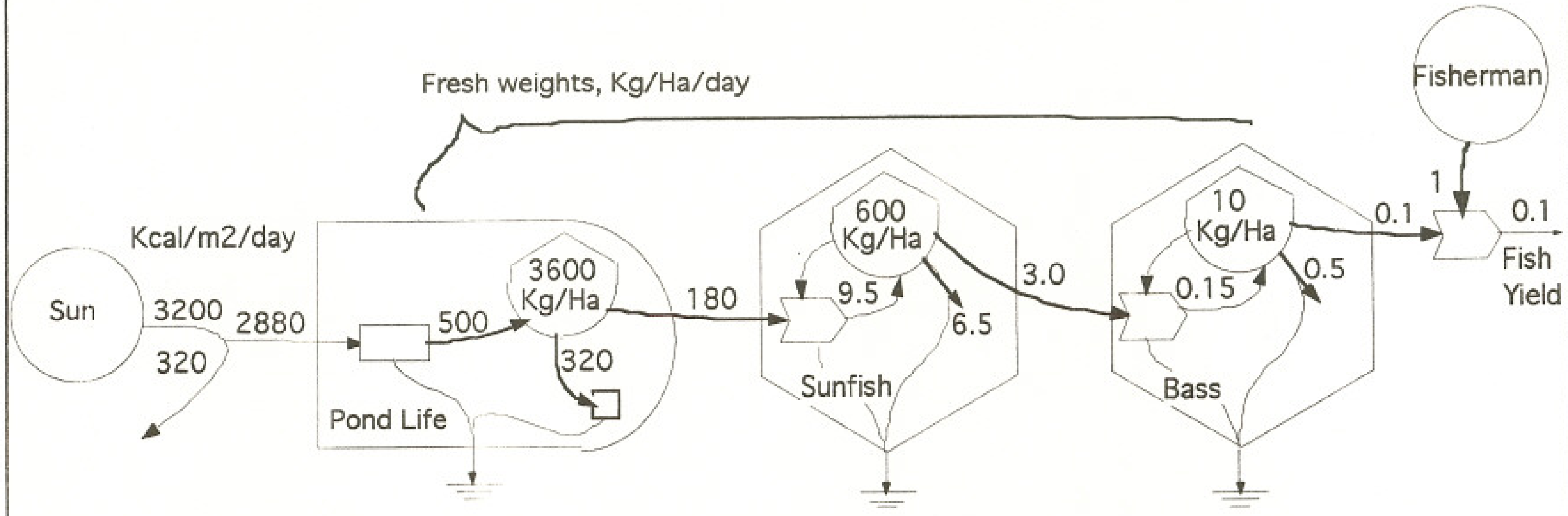


Figure A4. Fishing system with Flows and Storages Used for Calibration

Grassland-Fire System Using General Systems Symbols

A systems diagram with numbers for calibration of the Grass-fire System is given in Figure A5. These are the numbers already entered on the dialog boxes of the model: "Grassland-fire, general symbols". When this model is run, results are similar to the same model simulated with the pictorial symbols, because the numbers for calibration were similar for both.

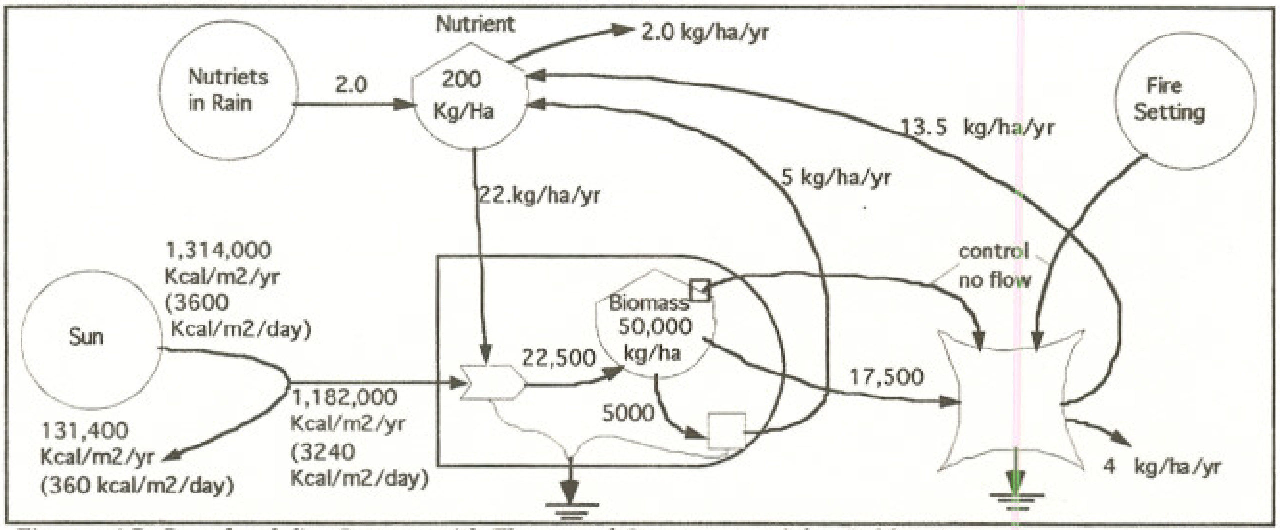


Figure A5. Grassland-fire System with Flows and Storages used for Calibration.

Logging System Using General Systems Symbols

A systems diagram with numbers for calibration of the Logging System is given in Figure A6. These are the numbers already entered on the dialog boxes of the model: "Logging, general symbols". When this model is run, results are similar to the same model simulated with the pictorial symbols, because the numbers for calibration were similar for both.

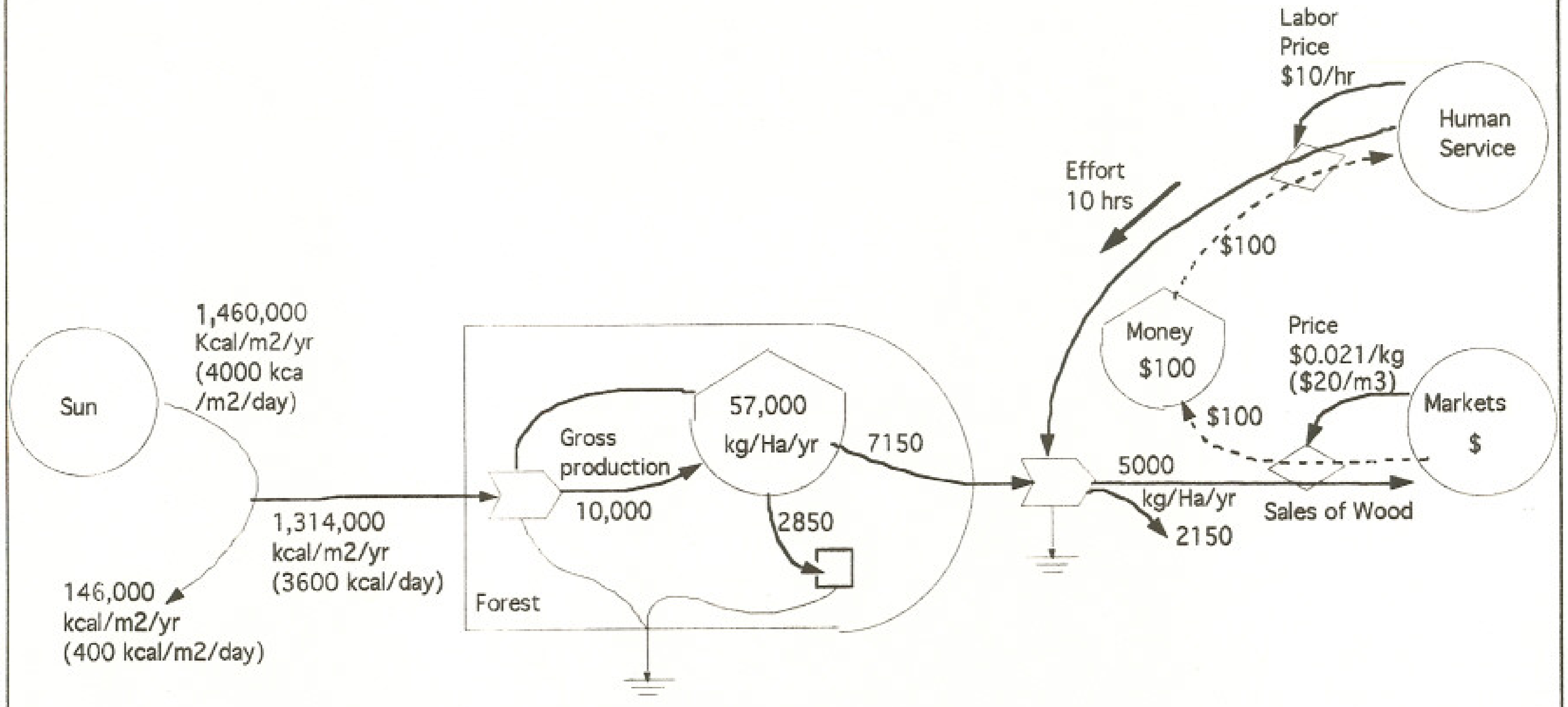


Figure A6. Logging system with flows and storages used for calibration.

REFERENCES

Items available for purchase from the Center for Environmental Policy, Black Hall, University of Florida, Gainesville, FL, 32611.

· Introductory Text:

Odum, H. T., E. C. Odum, M. T. Brown. Florida Environmental Systems and Public Policy. Center for Environmental Policy. University of Florida, Gainesville, FL 36211.

· Plastic template for drawing general symbols.

· Introductory text for international use, examples from other countries:

Odum, H. T., E. C. Odum, M. T. Brown, D. Lahart, C. Bersok, J. Sendzimir, G. B. Scott, D. Scienceman, and N. Meith. 1988. H. T. Odum: Energy, Environment and Public Policy, A Guide to the Analysis of Systems. United Nations Environmental Program, Nairobi, Kenya. UNEP Regional Seas Reports and Studies No. 95, 109 pp.

· More examples using BASIC with program listings for Apple II, PC & Macintosh:

Odum, H. T. and E. C. Odum. 1989. Computer Minimodels and Simulation Exercises. Center for Wetlands, Phelps Laboratory, University of Florida, Gainesville, FL, 319 pp.

· Microcomputer disks with 46 simulation programs in BASIC including those in the text and the previously listed "Computer Minimodels and Simulation Exercises." Available for Apple II, PC, or Macintosh. The Macintosh disk also includes system symbols for use with the program Extend.

Extend Program:

The complete Extend program is available from Imagine That, Inc., 6830 Via Del Oro, #230, San Jose, CA 95119. Telephone: 408-365-0305, FAX: 408-629-1251. The package includes the full Extend application, manual, several libraries of blocks, and many example models in the business, science, engineering, and manuafacturing fields.

BioQUEST CD-ROM:

A compendium of simulation, tools and resources for life science education, emphasing problem-posing, problem-solving and peer persuasion is available in a CD-ROM (including EDM). The ePress Project, Academic Software Development Group, Computer Science Center, University of Maryland, College Park, MD. 20742. Phone: 301-405-7600.

Articles that describe the approach:

Odum, E. C. and H. T. Odum. 1980. Energy systems and environmental education. pp. 213-229 in Environmental Education, ed. T. S. Bakshi and Z. Naveh, Plenum, N. Y.

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