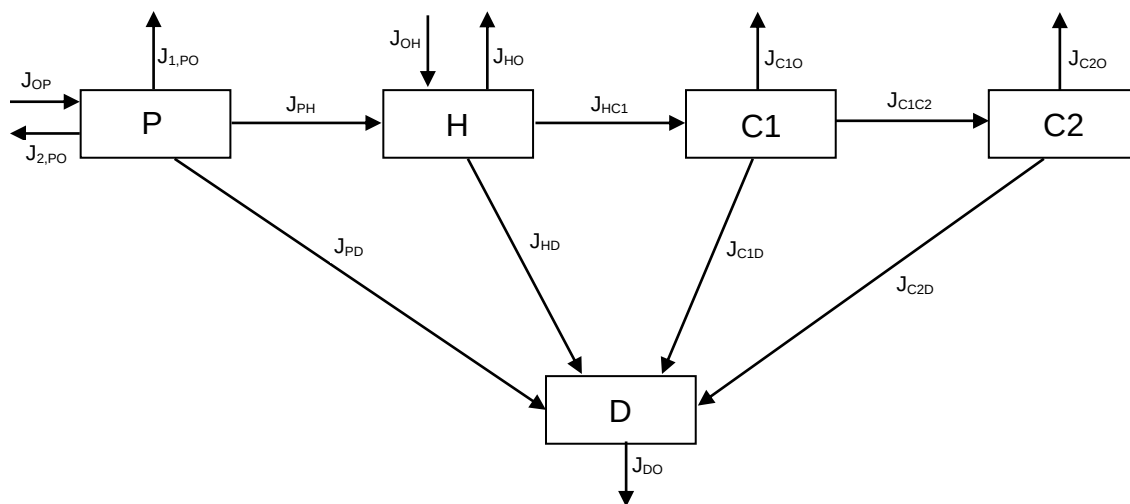


BIO 480/680 Lab Exercise 5
Silver Springs Compartment Model
Due date: 14 March 2025

For this exercise, we will apply the program for developing compartment flow models (Berkeley-Madonna) to a classic model of an aquatic system.

The goal of the exercise is to develop the five-compartment model described as the Silver Springs model of energy flow through an aquatic ecosystem (handout from Keen & Spain text, Chapter 13, pp 203-9). We will be using the modifications or enhancements described as part of Exercise 13-3 in that text, where the feeding functions are like predator-prey functions (donor-recipient product). You will not be writing your own program to solve this model but using the Berkeley-Madonna program to develop and solve the model. For your results, draw graphs of compartment quantities versus time.



Remember, a model is developed in Berkeley-Madonna by using the mouse to select the compartment (reservoir) tool and drawing the actual boxes for each compartment and giving the box a name for the structure it represents or the material it contains. Next, arrows are drawn to connect the boxes, representing flow between compartments. The five compartments also have external flows (sources or sinks): if you draw an arrow with only one end in a compartment, the infinity symbol will be added, indicating the external source or sink.

Influences (arcs) are drawn to the flow arrows from the compartments that influence those flows. See the transfer equations below to see what the influences should be for each flow. One can enter (or modify) the equation that describes the flow between compartments by double-clicking on that particular flow. All of the labels for each compartment or flow can be selected and dragged around to make them more visible. Note that the description of the Silver Springs model uses several parameter names

with Greek letters – for Berkeley-Madonna, you will have to rename these using standard alphabet characters. All of these parameters will have to be entered as Globals before you can enter the flow equations.

The units for time will be “weeks” and your simulations should be run for 3 years or 156 weeks. This value has to be entered in Berkeley-Madonna as the STOPTIME.

Experiment 1: Use all the standard values shown in the list of parameters below.

Experiment 2: Use the standards values as in Experiment 1, but reduce the average light intensity from 400 to 300.

For your Results from Experiment 1, draw graphs of the compartment quantities as varying with time. You can make a graph with all five compartments present. But you will see that some of the compartments have much smaller quantities than others, so you should draw a graph with just those compartments so that you can really see how they are varying. Be careful to notice that the compartment quantity lines may use different axis scales – you can set the vertical axes to the same scales if you want (see the tutorial we used earlier for the Berkeley-Madonna program). If you want to select a variable to appear in a graph, use the little buttons at the bottom left below the graph. If a variable you want to see is not present in those buttons, double-click on the graph to see the choices for variables to plot. If you select a variable and an empty graph appears, run the model again (select “Run”).

For your Results from Experiment 2, you don’t have to include the same type of graphs in your report, just describe in words how the results changed for the five compartment quantities.

For your Conclusions, make sure that you describe the changes in the 5 state variables with time. Here are some questions to consider. What is the order of average group quantities? How does this make sense from the basic ideas regarding trophic pyramids as discussed in lecture? Which populations oscillate the greatest and are there time lags in the peaks for the 5 groups? What effect did reducing the average sunlight have on the compartments? Was the effect the same for all compartments?

Common mistakes with this exercise:

- All names (compartments, flows, parameters) can use upper or lower case letters, but have to be consistent in their use (case-sensitive).
- When entering equations, do not forget that multiplication must be explicitly indicated by the “*” symbol: something like $y = ax$ may mean a times x in print, but must be specified as $a * x$ in the computer.
- After entering all the parameters shown below, check their values carefully: entering 0.171 instead of 0.0171 can make a huge difference!
- Make sure (as suggested in the text and in class) that you run the model first with $R = 0$. Under that scenario, all compartment quantities should stay steady at their initial values. If this result does not appear, you have one or more errors in the

model and these should be fixed before moving on to the main model run with $R = 175$.

Transfer equations for the Silver Springs Model

Energy inputs

$$J_{OP} = M + R \sin\left(\frac{2\pi(t-11)}{52}\right) \quad (\text{photosynthesis})$$

Note: The above equation can be entered by writing $\sin(\dots)$ for the sine function and the π is entered using the internally defined variable "pi". The variable to be used for t is "TIME" (all upper-case). Don't forget the * for multiplication and / for division. Parentheses must be included as shown in the equation.

$$J_{OH} = k \quad (\text{bread feeding})$$

Feeding flows

$$\begin{aligned} J_{PH} &= a_{PH} P H \\ J_{HC1} &= a_{HC1} H C1 \\ J_{C1C2} &= a_{C1C2} C1 C2 \end{aligned}$$

Death (decomposition) flows

$$\begin{aligned} J_{PD} &= b_{PD} P \\ J_{HD} &= b_{HD} H \\ J_{C1D} &= b_{C1D} C1 \\ J_{C2D} &= b_{C2D} C2 \end{aligned}$$

Respiration flows

$$\begin{aligned} J_{1,PO} &= c_{PO} P \\ J_{HO} &= c_{HO} H \\ J_{C1O} &= c_{C1O} C1 \\ J_{C2O} &= c_{C2O} C2 \\ J_{DO} &= c_{DO} D \end{aligned}$$

Loss due to export flow

$$J_{2,PO} = e_{PO} P$$

Parameter values for the Silver Springs Model

Parameter	Flow	Value
M	Average light	400
R	Light amplitude	175
k	bread feeding	9.346
aPH	feeding, P to H	9.865e-5
aHC1	feeding, H to C1	5.577e-4
aC1C2	feeding, C1 to C2	7.231e-4
bPD	decay, P to D	0.0252
bHD	decay, H to D	0.0989
bC1D	decay, C1 to D	0.0143
bC2D	decay, C2 to D	0.0171
cPO	respiration of P	0.0874
cHO	respiration of H	0.1706
cC1O	respiration of C1	0.0980
cC2O	respiration of C2	0.0278
cDO	respiration of D	3.538
ePO	Loss due to water flow	0.0181
P ₀	Initial P	2635
H ₀	Initial H	213
C1 ₀	Initial C1	62
C2 ₀	Initial C2	9
D ₀	Initial D	25

Note: The last five values above are not entered as new parameters, but as part of the compartment description.

If your model has errors or does not generate the flat lines in the graph of compartment quantities, as indicated from running the model with R=0, try to figure them out. But if you need help, you can either send me the model file (.mmd file) or all the text appearing in the equation descriptions on the left of the program's main window.