Guided Study Program in System Dynamics

System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management[1]

Assignment #17

Reading Assignment:

There is no reading assignment.

Exercises:

1. Fishbanks Modeling Exercise

Fish Banks, Ltd. is a role-playing game developed by Dennis L. Meadows at the University of New Hampshire. Dr. Meadows developed the game to inform people about using natural resources effectively and prudently. Although the game originally targeted corporate managers and public officials, anyone can benefit from the insights gained by playing the game.

In the Fish Banks game, teams of players manage their own fishing companies. At the beginning of the game, each fishing company has equal amounts of money and fishing ships. Each company has the same operating costs and technology. At the beginning of every simulated year, the teams make decisions about buying or selling ships, whether to fish or not, and where to fish. The object of the game for each company is to maximize total profits.

In this assignment you will conceptualize, formulate, and simulate the system dynamics model that underlies the Fish Banks game. The fishing system model can be segmented into two subsystems: the fish sector and the ship sector. You will build the two subsystems separately and observe the behavior of each subsystem. Then, you will combine the two models to form the final fishing system model.

Part 1 Fish Population

Forest Lake is a small lake nestled in the Pocano Mountains in northern Pennsylvania. Today, approximately 120,000 fish, mainly wall-eyed pike and bass, swim in the deep and shallow waters of Forest Lake. Forest Lake is a mid-sized lake, with a surface area of 20,000 square meters and an average depth of 10 meters. Although female fish lay several thousand eggs a year, on average only three of each female's eggs will hatch successfully each year. When the density of fish is at an optimum level, as it is now, the fish live eight months on average. The beautiful bass that give proud fishermen a reason to boast are typically three to four years old, but those fish are few and far between. The average lifetime of the fish is short because most fish die young; big fish devour the little ones. The average lifetime of the fish, however, varies with the crowding in the lake because of the competition for food and other nutrients. For example, if the lake were twice as dense in fish, the average lifetime of the fish would drop down to approximately four and a half months. If the lake were half as dense in fish, the average lifetime of the fish would rise to nine months.

A. From the above description, formulate a stock and flow model of the fish population. In your assignment solutions document, please include the model diagram, documented equations, and a graph of any lookup functions that you use in the model.
Hint: the model should include a constant that represents the carrying capacity of the lake.

B. Draw a reference mode for the behavior of the fish population over a period of 10 years. Then simulate the model. In your assignment solutions document, please include a graph of the behavior of the fish population. Explain.

C. Imagine that some local ruffians decided to go fishing with dynamite last night. They kill half of the fish in the lake and skim a few off the surface of the water to take home. Draw a reference mode describing the behavior of the fish population for the next 10 years. Then simulate the model in this scenario. In your assignment solutions document, include a graph of the behavior of the fish population. Explain.

D. Imagine Woodlock Pond, a body of water almost exactly identical to Forest Lake, just a few miles away. The fish in Woodlock Pond, however, died out many years ago. A child and his father catch ten small fish in a plastic bag filled with water, drive over to Woodlock Pond, and drop the fish into the pond. Draw a reference mode describing the behavior of the fish population in Woodlock Pond. Simulate the model. In your assignment solutions document, include a graph of the behavior of the fish population. Explain how and why the behavior that you observe differs from the behavior that you observed in the previous scenario in part C. Extend the time horizon as long as necessary to observe the entire significant behavior.

Part 2 Catching fish

Four families live in the woods surrounding Forest Lake. Currently, each family has one fishing boat that they take out onto the water every day in search of fish. The families are able fishermen, and the waters are densely populated with fish, so every day each boat brings back twenty fish. The families realize, however, that if the waters were less dense in fish their daily catch would suffer. In fact, if the waters were three quarters as dense in fish, each boat would only be able to catch nineteen fish a day. If the waters were half as dense in fish, each boat would only catch ten fish a day. If the waters were only one fourth as dense in fish as they are today, the families would only catch one fish a day.

A. From the above description, add an additional flow of fish caught by fishermen to the fish population model. Formulate an equation for the flow, using auxiliary variables as necessary. In your assignment solutions document, include the modified model diagram, documented equations, and graphs of any additional lookup functions that you use in the model.

B. Draw a reference mode for the behavior of the fish population over a period of 10 years. Simulate the model. In your assignment solutions document, include a graph of the behavior of the fish population. What is the new equilibrium level of the fish population? Why?

C. Imagine that the families hear about a new net that can double the daily catch of any boat. The families immediately buy these new nets. Draw a reference mode for the behavior of the fish population over a period of 10 years. Simulate the model. In your assignment solutions document, include a graph of the behavior of the fish population. What is the new equilibrium level of the fish population? Why?

D. For some unexplainable reason, fish steaks become the latest craze in Harrisburg, PA. The price of fish rises. The families begin to make quite a profit selling their fish at the local market. They invest their profits in the acquisition of extra fishing boats. Now each family has new nets and two boats. Draw a reference mode for the behavior of the fish population over a period of 10 years. Simulate the model. In your assignment solutions document, include a graph of the behavior of the fish population. What is the new equilibrium level of the fish population? Why?

Part 3 Building boats

What determines how many fishing boats each family has? Each family starts out with one boat. The boats still use the old nets. Each family has decided to invest 50% of their yearly profits from fishing into building new boats. The family determines its yearly profits by subtracting operating costs from revenues. Each boat costs $10,000 a year to operate. A fish sells on the local markets for about $5. A new boat costs $20,000.

A. From the above description, formulate a stock and flow model of the total number of boats around Forest Lake. In your assignment solutions document, include the model diagram and documented equations.
*Hint: Assume that the total catch per year is a constant 20 fish/boat/day * 4 boats * 365 days/year = 29,200 fish/year. We recommend that you build this model in a separate Vensim PLE document from the previous sector.*

B. Draw a reference mode for the behavior of the total number of boats on Forest Lake over a period of 10 years. Simulate the model. In your assignment solutions document, include a graph of the behavior of the total number of boats. At the given conditions, how many boats will fish in Forest Lake in ten years?

C. With the special nets, the total catch per year doubles. Draw a reference mode for the behavior of the total number of boats on Forest Lake after each family purchases the new nets. Simulate the model. In your assignment solutions document, include a graph of the behavior of the total number of boats. At the given conditions, how many boats will fish in Forest Lake in ten years?

Part 4 Bringing it all together

Now we are ready to bring together both sectors of the model.

A. Copy the model from part 3 and paste it into the model from part 2. Use connectors to link the variables that represent the total number of boats on the lake and the total catch per year of fish between the two models. In addition, create a stock that keeps track of the total profits of the families by summing up their yearly profits. In your assignment solutions document, include the complete model diagram and documented equations. Identify all feedback loops in the model.

B. Draw reference modes for the total number of boats on the lake, the fish population, the yearly profits, and the total profits. Simulate the model, assuming that the boats still use the old nets. In your assignment solutions document, include graphs of the behavior of the four above variables.

C. Explain the dynamics driving the behavior of the four variables graphed above. What feedback loops dominate at different points in time?

D. Refer back to the appendix of *Systems 1* by Draper Kauffman[3]. What system note(s) does this model illustrate?

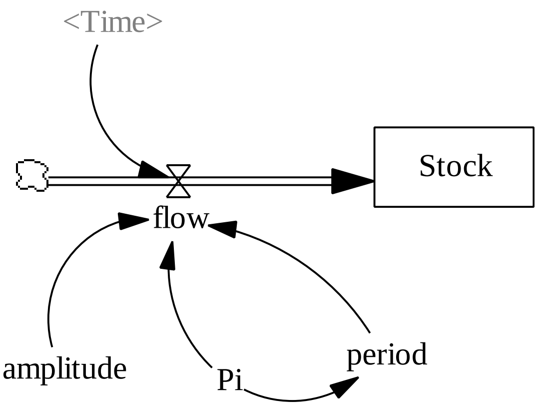
E. Consider the scenario in which each family uses new nets that double the daily catch of fish. Draw reference modes for the total number of boats on the lake, the fish population, the yearly profits, and the total profits. Simulate the model. In your assignment solutions document, include graphs of the behavior of the four above variables. Use your understanding of the dynamics of the fishing system to explain how and why the behavior generated under this scenario differs from the behavior in part B.

F. Propose a method to optimize the total profits of the families. How would you change the model to incorporate this policy design? (You do not need to change the model, just explain in terms of changes in parameters and additional structures how you would approach the problem. Of course, if you would like to model your policy suggestions and send us documented equations along with the output of your model and an explanation of the behavior that you observed, please take up the challenge.)

2. Understanding Oscillatory Systems

This is the first in a series of exercises designed to help your understanding of oscillatory systems. Build the following model in Vensim PLE and then complete the exercises. Make sure that the time step is smaller than 0.0625 (or small enough that the value of DT no longer has a substantial effect on the result of the simulation). The time horizon over which you simulate the model should be at least 16 units of time.

[3] Kauffman, Draper L. J., 1980. *Systems 1: An Introduction to Systems Thinking*.



amplitude = 1

flow = amplitude * SIN(2*Pi*Time/period)

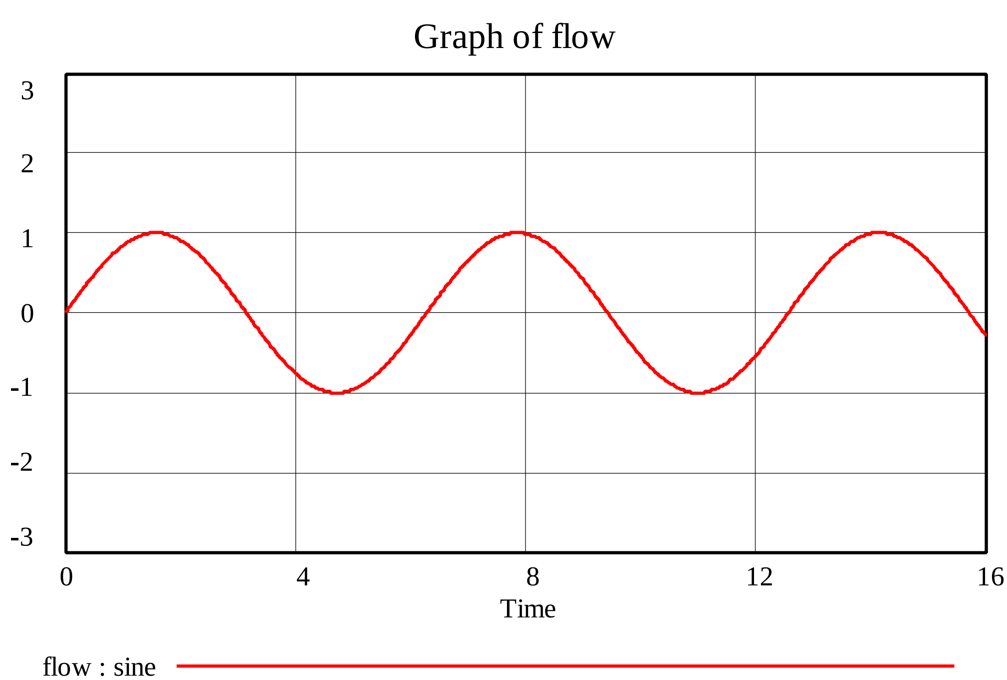
period = 2*Pi

Pi = 3.14159

Stock = INTEG (flow, –1)

TIME STEP = 0.0078125

A. Graphically integrate the following flow. You do not have to submit your graph, but make sure it is correct.



B. Simulate the model to confirm your graphical integration. In your assignment solutions document, include graphs of the behavior of the “flow” and of the “Stock.” Describe the relationship between the two graphs.

C. Create a new dataset and simulate the model with “amplitude” equal to 2. In your assignment solutions document, include graphs of the behavior of the “flow” and of the “Stock” in this simulation. You may wish to change the initial value of the “Stock.” Describe the relationship between the two graphs and compare the simulation to that from part B.

D. Repeat part C with “amplitude” equal to 0.5.

E. What conclusions can you make about the relationship between an oscillating “flow” and its “Stock” as the amplitude of the “flow” changes?