Curaçao Simulation

General Instructions

1. Click the white Open Simulation button to the left of your screen. The simulation settings open in a window.

2. Scroll through the options, drop-down menus, and HELP functions, noting the purpose of each parameter. Each parameter can be set individually, and the default values can be restored by clicking on the "Default Reset" button. The default parameters represent the assumptions of the example published by Knipling in 1979.

Exercise 1. Knipling's example

1. Execute the model (without changing any parameters) by clicking on the Run Simulation button at the bottom of the window.

A diagrammatic representation of the island of Curacao, divided up into "cells," will appear. The blue cells represent sea, the green cells land, and the yellow cells areas infested with the target insect. The intensity of the yellow color is a function of the population density of fertile females.

In this simulation, we divide the island into three concentric zones, Zone 1 being the innermost zone. The default places native insects only in the center zone.

2. Click the Next Generation button below the diagram of the island to advance the simulation one generation at a time.

How many generations is eradication achieved?

How many sterile males had to be released in total?

3. Click the Start Again button below the diagram to clear the simulation.

Exercise 2. Minimal initial release ratio

1. In the Sterile Males options box, be sure that Uniform Release (by zone) and Release by: Ratio (known population) are selected.

To simplify the simulation at the start, we will deal only with the central zone, called Zone 1.

2. Find the ratio column for Zone 1 (which represents sterile males to fertile males). Reduce this number and repeat the simulation until you find the lowest ratio (to the nearest tenth) that will result in eradication.

Under the assumptions that Knipling used, eradication could have been achieved with a lower ratio of released sterile males to native, fertile males. (Remember the "normal trend," that is, the population increase with each generation, and think about what proportion of the matings must be sterile to offset this increase.)

What is the minimum initial ratio required for eradication?

In how many generations is eradication achieved at this ratio, and how many sterile males in total must be released?

How does this compare with the results of the original Knipling example? (Explain.)

Exercise 3. Sterile male competitiveness

1. Under Sterile Males, change the Competitiveness from 1.0 (sterile males equally competitive with native males) to 0.5 (sterile males half as competitive as the native males).

Now what is the minimum initial release ratio (to the nearest tenth) required for extinction?

How do your results compare with the original Knipling model (equally competitive sterile males)? (Explain.)

Exercise 4. Fecundity of females

1. In the Native Insects options box, increase the Eggs per female from 200 to 300. Run the simulation.

Now what is the minimum initial release ratio required for extinction in this situation, and how does it relate to the normal trend? How does underestimating female fecundity affect the success of SIR?
Exercise 5. Survival to adult

1. In the Native Insects options box, increase the rate of Survival to Adult from 0.05 to 0.08. (This parameter sets the proportion of eggs that survive to the adult stage, with 1.0 being 100%.)

What is the normal trend in this case, and what is the minimum initial release ratio required for extinction?

What are the possible consequences of underestimating insect survival in the population we are trying to eradicate?

Exercise 6. Initial release ratio based on population estimate

In the real world, you would not know the exact population density in your treatment zone. You would have to sample the population, calculate a mean population density, and include some measure of the error in your estimate.

1. To simulate how population estimates would affect SIR, in the Sterile Males options box, select Release by: ratio (estimated population). This time your estimates of the native population (and therefore your actual release ratios) will be different each time you run the model, varying about the mean according to a normal distribution.

2. Run the simulation as before, noting the number of generations and the total sterile males required for extinction.

3. Run the model 10 times using the original initial release ratio of 9.0 and another 10 times using the minimum initial release that you determined in Step 3.

How many times out of ten were you successful in eradicating the population in each case?

Why do you suppose Knipling used 9:1 as the initial release ratio in his example?

Exercise 7. Spatial aggregation

Knipling’s example assumed a uniform distribution of the native insects over the target area. In nature, however, insects are likely to be dispersed in “clumps” or aggregates.

1. To observe the effects of aggregation on SIR, in the Native Insects options box, set the Aggregation Index (coefficient of variation) to 0.4. (Note that a value of 0.0 will be a uniform distribution, while a value of 1.0 will be severely clumped. You’ll also realize that we are back to using a ratio based on a known population, but this time the spatial aggregation of the insects will be different for each run.)

2. Run the model 10 times (the initial release ratio should be 9.0.) Jot down the number of generations and the total number of sterile males released each time.

How many times were you successful in eradicating the native population? (Explain the reason for any failures.)

3. Set the Aggregation Index to 0.5 and repeat run the model 5 times.

What effect does the tighter aggregation have on the success of the sterile insect release method? (Remember that you are releasing the same initial population in Zone 1 in each case.)

Exercise 8. Emigration

1. Now add the element of pest mobility to the spatial aspects just considered. Again set the Aggregation Index (coefficient of variation) to 0.4, and now set the Probability of Emigration to 0.01 (1 insect in a 100 will leave each cell for one of the adjacent ones in each generation).

2. Run the same model 5 times, and note the movement of the population each time. (Once the population trend turns upward in Zone 2, there is no point in continuing with further generations.)

3. Check the populations in a few selected cells in Zone 2 in each generation by moving the cursor to the desired cell and double clicking. A dialog box will tell you the populations of native and sterile males in that cell.

Why is extinction of the population not possible?

Exercise 9. Border zone

1. To see the importance of establishing a border zone in attempting to eradicate a mobile pest, rerun the problem in the previous step (Total Population, Zone 1: 1000000; Aggregation Index: 0.4; and Probability of Emigration: 0.01), but this time also add 4500000 sterile males to Zone 2.

Since there are not yet any native insects in Zone 2, the release ratio in that zone would be undefined, so the release will have to be by numbers of insects. (Remember that initially the native insects are found only in Zone 1.)
2. Run this model 10 times.

Did you have any unsuccessful eradication attempts? If so, what was the spatial nature of the population development?

**Exercise 10. Nonuniform release—“hot spots”**

The simulations that we have done so far have assumed uniform distribution of the released sterile males (as they might be dispersed by a release from an aircraft). Let us now look at what might happen with a cell-by-cell release (as if we had to place caged insects in specific sites).

To increase our chances of success, we will use an insect that has a dispersal phase before mating. We’ll time our release to occur just before this dispersal phase. We’ll also have to distribute our cages as uniformly as possible.

1. In the Simulation Options box, choose the Release-Disperse-Mate order of events (second in the drop-down menu).

2. In the Native Insects menu, set the Aggregation Index to 0.5 and the Probability of Emigration to 0.1 and put 2,000,000 (without the commas) insects in each of the 3 zones. This is a total population of 6,000,000 insects or 3,000,000 fertile males. Therefore, for an initial 9:1 sterile:fertile ratio, you must release a total of 27,000,000 sterile males over the entire island.

3. In the Sterile Males menu, select Point release (by cell). The default settings will release 729,730 sterile males in each of 37 cells for a total of 27,000,000 sterile males released.

4. Click on the “Mark Cells” button and note the distribution of checked cells (the cells in which you will release sterile insects). Click the Save Marks button, and then run the simulation.

5. Repeat the simulation five separate times using the same parameters.

6. Increase the initial sterile:fertile release ratio to 10:1 by putting 810,811 sterile males in each marked cell, and run the simulation again five times.

7. See if you can find a distribution pattern of 30 cells (instead of 37) that will successfully eradicate the population with the same 10:1 ratio (1,000,000 sterile males per marked cell).

**Now let us see what would happen if the insects mated before they dispersed.**

8. Start a new problem with all the same conditions for your last successful eradication except the order of events. In the Simulation Options box, select Release-Mate-Disperse.

9. Use the default pattern of 37 cells, and place 810,811 sterile males in each marked cell. Run the simulation as before.

10. Set the Probability of Emigration to 0.01 (instead of 0.1), but keep everything else the same as you had it for the successful eradications (including the Release-Disperse-Mate timing of events).

**Exercise 11. Nonuniform release ____-[name of this, to differentiate it from #10?]**

With the exception of the “hot spot” releases just completed, the simulations that we have done so far have assumed uniform distribution of the released sterile males (as they might be dispersed by a release from an aircraft). Let us now look at what might happen with a cell-by-cell release (as if we had to place caged insects in specific sites). To increase our chances of success, we will do this with an insect that has a dispersal phase before mating, and we will time our release to occur just before this dispersal phase.

1. Set these parameters:
   - Simulation Options box: Release-Disperse-Mate order of events.
   - Native Insects: Aggregation Index of 0.4; Probability of Emigration of 0.1; Total population: 2000000 insects in each of the 3 zones
   - Sterile Males: Point Release (by cell); For “Release ____sterile males” insert 4500000.

4. Click on File, Run. [PHIL, HERE’S WHERE I GOT LOST. I CAN’T FIND <FILE, RUN ANYWHERE, AND CAN’T GET CROSS HAIRS, AS MENTIONED BELOW, TO APPEAR. THUS, THIS SECTION ISN’T EDITED. Note the message that reminds us that we have to mark the release points.

5. Click on Insects, Mark Cells, and note that the cursor has now changed to cross-hairs. To better see the cells, click on View, Show Grid. Press the mouse button down to see the coordinates of the cell under the cross-hairs.
6. Starting in the upper left corner of the island (Cell No. 1,3) and progressing diagonally downward to the left, double click on each cell to make a line of four marked cells.

7. Go back up to row 1 and move to the right, skipping a cell to mark Cell No. 1,5. Again progress diagonally downward to the left to mark a line of 6 cells parallel to the first, but displaced 2 cells to the right.

8. Now mark the last cell in the second row (Cell No. 2,7) and progress downward as before, marking a line of 6 cells parallel to the other two.

9. Finally, mark the line of 4 cells along the lower right margin of the island, beginning with Cell No. 4,8.

10. When the desired cells have been marked, click on Insects, Quit Marking.

11. Now progress through the simulation by clicking on Generation.

12. Repeat this same problem 5 times to see how many times you successfully eradicate the native population. (Note you will have to mark the cells again for each new simulation.) Record the number of generations and the total number of sterile males required for each successful eradication. Note the pattern of extinctions with each successive generation.

Now let us see what would happen if the insects mated before they dispersed.

13. Start a new problem with all the same conditions except the order of events.

14. Click on File, Options... and select Release-Mate-Disperse.

15. Run it 5 times just as before, marking the same cells.

   How many successful eradications did you have?

   What characteristics of the life cycle are important to consider when you release insects from cages, and how does this affect the timing of the release?

Let’s try it again, this time with a reduced mobility of the insects. To facilitate setting up your original starting conditions,

16. open the file that you saved earlier by clicking on File, Open..., and double click on nonuniform.sirInsects, Native... and set the Probability of Emigration to 0.01.

17. Run this problem 5 times also, marking the same cells as before.

   Were you successful in eradicating the native population?

   Where did the population develop?

   If you have to release from cages, what is the importance of having highly mobile insects?