

Population Simulation, AKA: Grahz, Rahbitz and Fawkzes

by

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Abstract. In an effort to give students a more visceral experience of science and instill a deeper working knowledge of concepts, activities that utilize hands-on, laboratory and simulated experiences are recommended because these activities have a greater impact on student learning, especially for Native American students. Because it is not usually feasible to take large and/or multiple classes of high school science students into the field to count numbers of organisms of a particular species, especially over a long period of time and covering a large area of an environment, the population simulation presented in this paper was created to aid students in understanding population dynamics by working with a simulated environment, which can be done in the classroom. Students create an environment and populate the environment with imaginary species. Then, using a sequence of “rules” that allow organisms to eat, reproduce, move and age, students see how the population of a species changes over time. In particular, students practice collecting data, summarizing information, plotting graphs, and interpreting graphs for such information as carrying capacity, predator prey relationships, and how specific species factors impact population and the environment. Students draw conclusions from their results and suggest further research, which may involve changes in simulation parameters, prediction of outcomes, and testing predictions. The population Simulation has demonstrated success in the above student activities using a “board game” version of the population simulation. A computer version of the population simulation needs more testing, but preliminary runs are promising. A second – and more complicated – computer simulation will simulate the same things and will add simulated population genetics.

A. Introduction

In this simulation students will see how species in an ecosystem affect each other. Students will pay particular attention to population sizes, and how population sizes are related to other organisms in the ecosystem.

Students will consider three different organisms: producers (referred to in this paper as “grahz”), primary consumers (referred to in this paper as “rahbitz”) and secondary consumers (referred to in this paper as “fawkzes”).

Each student group will set up a geographical area using hexagons (referred to in this paper as hexes). This will be like a map of an ecosystem, with the hexes dividing up the area into small sections. Hexes are used because they fit together, have the same area, and they evenly contact each adjacent hex. See Figure 1.

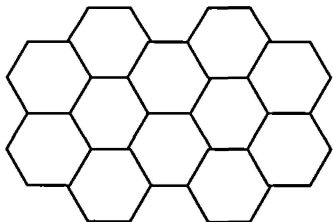


Figure 1: Section of Environment divided up using hexes

The grahz will grow on each hex like grass on a field. Different colors will represent different amounts of grahz (the grahz population) growing in each hex. The colors are as follows:

Table 1: Grahz Colors

Grahz Color	Meaning
Dark green	High population: thick, green, healthy grahz
Light Green	Medium population: thin but still green grahz
Brown	Very low population: very sparse and brown grahz
Black	No producer left in this hexagon: all grahz has been eaten

In addition to the grahz there are the rahbitz, which are represented by yellow foam-sheet cut-outs. The rahbitz eat the grahz, thus the population of grahz is affected in each hex where the rahbitz feed.

Also living in the environment are the fawkzes, which are represented by blue foam-sheet cut-outs. The fawkzes eat the rahbitz, which affects the population of the rahbitz.

If rabbits and fawkes do not get enough to eat they die of starvation. If they get enough to eat and live a long time, eventually they will die of old age.

In this simulation each student group will set up an environment and populate it with grah, rabbit and fawkes. Groups will then allow time to pass and see how the population of each species changes. Students collect data on the population of each species each time segment (or "turn"), then graph the data and draw conclusions about how each species affects, and is affected by, the population of the other species.

For this population simulation students constructed "board" simulations, where they used cardboard as the board and divided it into hexes. They then cut out different color hexes from felt to represent the different colors of grah. Rabbits and fawkes were cut out of foam sheets, and numbers (for ages) were written on the foam, and paper clips were used to keep track of individual organism ages.

Figure 2 shows the actual board with the different colors of grah (made of felt) and the foam rabbit (there were no fawkes for this particular simulation).

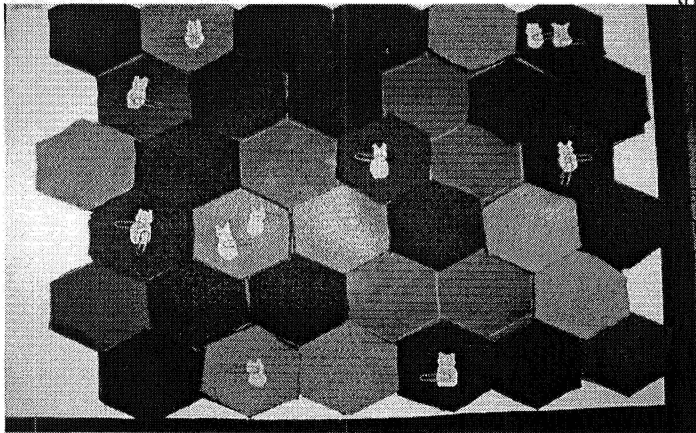


Figure 2: The Board Version

B. Running the Simulation: The Sequence

1. Step 0: Populate

Students begin by populating the environment. Because this is not an active part of the simulation this is called Step 0.

For simplicity, especially in first runs of the simulation, students initially populate the entire environment with healthy grah: all hexes dark

green. Then students populate the environment with rabbit and fawkes. Again, for simplicity, it is often good to do an initial run with just grah and rabbit. This allows students to see how just two organisms affect each other. This also allows students to find the carrying capacity of rabbit in an environment with no natural predators. This initial set up is recorded on the data collection sheet on time zero.

Before actually running the simulation student groups should make predictions on what will happen to the population of grah and rabbit (and fawkes if used) over a period of time. These predictions should be recorded as hypotheses.

2. Step 1: Eat

This step begins the active part of the simulation. Each individual organism will eat. It is assumed that grah gets energy from the sun, water from their roots and CO₂ from the air, so we do not need to simulate eating for the grah. Later in the simulation, growth of the grah is simulated.

The rabbit eat the grah. To simulate this, in each hex that there is a rabbit the grah color is changed to simulate that it has been affected by the eating of the rabbit. The greater the number of rabbit in a hex the greater the change in that hex's grah color. Black is the lowest color a hex can be and represents the grah being severely overeaten.

If there is not enough nourishment in a hex for a rabbit to consume (represented by the color of the hex) then that individual rabbit (or rabbits) goes into famine mode. This means that this individual rabbit is on the verge of starvation. Any rabbit in famine mode will not be able to reproduce while in this mode. To show famine mode a red marker is put on the rabbit (red paper clips work well, as can be seen in figure 2).

If a rabbit is *already* in famine mode and there is not sufficient nourishment in the hex, then that rabbit dies of starvation and is removed from the environment board. Conversely, if a rabbit in famine mode is in a hex with sufficient nourishment it is able to consume the needed nourishment and is no longer in famine mode, and the red marker is removed.

Fawkes operate similar to rabbit during the eating step. One difference is that fawkes do not eat each turn. When they do eat they eat

rahbitz. If they can not eat a rahbit when needed they go into famine mode, and famine mode operates the same for fawkzes as it does for rahbitz.

3. Step 2: Reproduce

At certain ages both rahbitz and fawkzes reproduce (although the ages are different for rahbitz and fawkzes). To keep things simple, when a rahbit or fawkz reproduces, a new organism of the same type is placed on the same hex as the "parent" organism. This particular simulation does not simulate male and female pairings – rahbitz and fawkzes just reproduce asexually. This is to keep the simulation manageably simple.

Any organism that reaches reproduction age but is in famine mode is *not* allowed to reproduce.

4. Step 3: Update and Record Data:

This step has a number of parts. First, each rahbit's and fawkz's age is incremented by one. This simulates aging of each organism. Any rahbit or fawkz that has a new age that is *beyond* the age limit for that type of organism dies of old age and is taken off the board. The rahbitz and fawkzes on the environment board have ages pre-written on them and a marker (a paper clip) is changed to indicate the current age of each individual on the environment board.

Second, the population of each type of organism is recorded on the data sheet: number of each color of hex, number of living rahbitz, and number of living fawkzes.

Third, the grahz grows, so in each hex the grahz color changes to simulate growth.

5. Step 4: Move

Rahbitz and fawkzes do not stay in the same place, so they must be moved to new hexes. Rahbitz move randomly one hex. Since each hex has six neighbors, a six-sided die is the easiest way to move rahbitz.

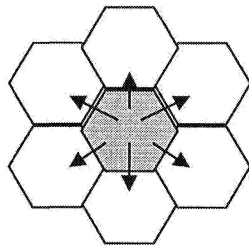


Figure 3: Rahbitz move randomly one hex

The fawkzes only move when they are hungry and can move multiple hexes. They move to the same hex as a rahbit so they can eat. In other words, rahbitz wander but fawkzes hunt.

This finishes one turn of the simulation sequence, and the sequence continues by going back to Step One: Eat. For best results, the sequence is gone through many times.

C. Caveats

I must put in a few caveats here. First, and very importantly, this is a simulation. It is obviously very much simplified from any "real world" situation. As mentioned, this simulation does not simulate male and female differences. In fact it does not simulate any real individual differences, such as size of the individual, "fitness" of the individual, or other individual characteristics. In fact, each individual of the same type reproduces and eats at a predetermined age which is the same for all organisms of the same type. Of course, this limits the power of the simulation and any close correlation to the real world, but it does preserve simplicity. These two considerations (realism and simplicity) had to be balanced to fit the situation at hand: using a simulation in a high school Environmental Science class that meets 50 minutes a day and may have up to 30 students of all ability levels. Actual experience indicates that the balance chosen works well.

A second important caveat is that although "grahz" sounds similar to "grass," "rahbitz" sounds similar to "rabbits" and "fawkzes" sounds similar to "foxes," there is very little relation between the simulated creature and any real world counterpart. The names for simulated creatures were used because the "grahz" is vegetation that grows similar to grass, "rahbitz" eat vegetation as do rabbits, and "fawkzes" eat other animals as do foxes. The simulated names were chosen to help students put a visual in their mind that made sense, more so than the more scientifically correct terms producer, primary consumer and secondary consumer (which are correct terms, but cumbersome to use and give students little connection to the real world). It has been emphasized to students who have done this simulation that the spelling of the simulated names is purposely different to make it clear that the "grahz" does *not* simulate actual grass, other than grahz simulates a type of vegetation.

D. Participants

This simulation was used in three Environmental Science classes at Alchesay High School in Whiteriver, Arizona, located on the White Mountain Apache Tribe reservation. Each class had approximately twenty students, which were divided into groups of four. One hundred percent of the students that did this population simulation were of Native American descent.

E. Results

1. Student Engagement and Attitude

Using this simulation with high school classes has been very successful. In general it took awhile for students to “get the hang of it,” but once they did the simulation proceeded smoothly. Students liked the “hands-on” aspect of the simulation: changing grahzc colors, rolling the die, moving rabbitz and fawkz, counting populations, et cetera... The simulation kept students engaged; they had to be active in “running” the simulation, they had to pay attention while counting and checking ages for reproduction and old age, they had to move individuals to the correct locations, they had to cooperate in collecting data and keeping track of information, and they assigned each group member roles (often tacitly).

Students showed they were interested in the simulation: when given a choice many students chose to do the simulation over traditional learning activities; the timbre in students’ voices indicated pleasure when talking about the simulation; students compared with other groups how their environments were doing; and one group even named each rabbit on the environment. In an end-of-the-year survey many students indicated the simulation as their favorite activity during the year. The survey also indicated their attitudes about science improved; hopefully the simulation was a big part of these improved attitudes.

2. Student Graphs

Students used the data they collected to make graphs. Figure 4 shows a graph students made after 18 turns. This graph shows that even after a few turns some trends and interactions can be identified.

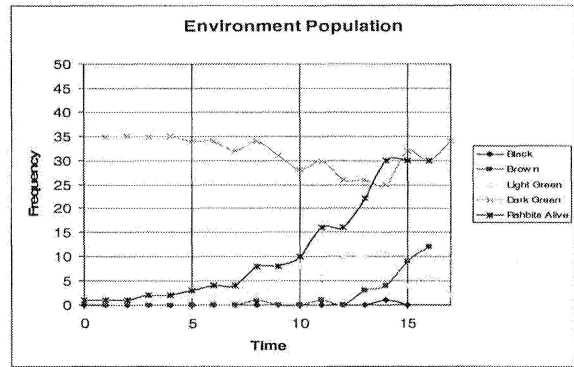


Figure 4: Student Data Graphed, 18 turns

For instance, it can be seen that as the rabbit population grows (the line that starts in the lower right and increases the quickest), the number of dark green hexes falls (the line that starts in the upper left and decreases). Also, as the rabbit population continues to grow higher some black hexes begin to show up in the environment at turn thirteen.

Students that were able to run through more turns in the simulation obtained even better results in terms of observable trends and relationships. Figure 5 shows a student made graph with data from 36 turns.

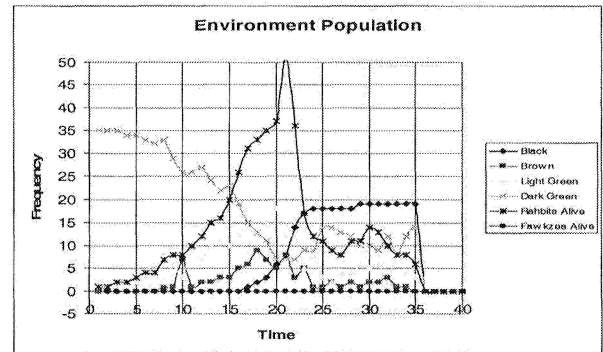


Figure 5: Student Graphed Data, 36 turns

From this graph the same initial information from figure 3 is seen, but it can also be seen that with more time the rabbit population “tops out” and begins to fall. The rabbit population does *not* crash, however, and begins to recover. It can also be seen that as the rabbit population initially falls, the number of dark green hexes rebounds. This relationship – increase in rabbit population results in a decrease in dark green grass population, and visa versa – is exactly the type of relationship that students should get out of this type of simulation. It should be noted that some student groups did simulations where grahzc eaten to black did *not* grow back, while

other groups did simulation where grahze eaten to black was allowed to grow back. Figure 4 shows the latter situation.

One interesting teacher observation was that when students were asked why the rabbit population fell, students quickly and confidently answered, "They starved." This is because the students experienced the events of the environment – they saw what happened because they were running the simulation – thus students could interpret the graphs with experiential knowledge. This is the type of deeper understanding teachers hope for in student learning, which this simulation activity generated.

In addition to learning about the concepts the simulation demonstrates, students also develop skills and knowledge of collecting data, using spreadsheets and computers, interpreting graphs, making hypotheses, and drawing conclusions – in essence the scientific method and the tools that can help with the process.

F. Lessons Learned and Adjustments

From doing this simulation with real high school classes, a few things were learned which resulted in adjustments for the simulation. Originally the rabbit had an age limit of 10, and reproduced at ages 3, 6, 9. It was believed that reproduction ages that were evenly spaced would result in a smooth population increase. But in practice it was realized that because the reproduction age being a multiple (in this case of 3) resulted in booms of reproduction every third turn. This was not a smooth increase at all! The reproduction ages were adjusted to ages that were *not* multiples of each other. The 3, 6, 9 was changed to 3, 5, 8, which resulted in a much smoother population increase. A similar situation occurred with fawkes, which was adjusted also.

Originally, when vegetation reached the color black it was considered dead and was not allowed to grow back. Upon reflection it was realized that one of two situations would occur. One, eventually *all* the vegetation would die out, then rabbit would all starve, followed by starvation of fawkes. Or, two, enough of the vegetation would die (the majority of hexes black) so there wouldn't be enough for rabbit to survive, followed by the starvation of fawkes.

It was found, however, that either situation takes quite a long time to happen, and most students did not reach either stage. The simulation has

been run with black vegetation being dead and not growing back, and with the situation where black vegetation does grow back. Doing both is instructive to students, especially having students predict results *before* the simulations are run.

Data gathering and graphing are positive skills for students to practice and use. However, graphing each individual color of grahze made the graphs "busy." One method used to make the graphs less busy was to average the grahze population by giving each grahze color a number. This was easy to do with the spreadsheets so students would not be occupied with tedious calculations. Detailed information is lost, but trends can be seen in a less busy graph. Depending on the type of analysis desired, either presentation of data is easy with spreadsheets.

G. Versatility – The Essence of Simulation

The nice thing about this simulation is its versatility. For instance, in the above description of the simulation there are four colors to represent vegetation health. But there is no rule that says the vegetation colors couldn't be only two... or twelve. The same goes for just about any parameter in the simulation. Why not change the reproduction ages, or age limit that rabbit and or fawkes can live? Instead of moving one hex, rabbit could move two. Fawkes could eat once every five turns, or once each turn. The variations are endless, which gives students (and teachers) a vast set of hypotheses to explore. Students could find the carrying capacity of rabbit with an age limit of ten. They could then hypothesize what would happen if the age limit was changed to twelve or eight. The students could then easily do the simulation again with changed parameters and see how the graphs compare and differ, drawing conclusions about how particular parameters affect populations and the environment.

H. Computer Simulation

In addition to creating the board version of the Population Simulation, this author also wrote this simulation as a computer application. The computer simulation follows the same sequence as outlined above. Currently it uses very rudimentary graphics, but still shows how many rabbit and fawkes are in each hex and the

color of the grah in each hex. The user clicks for each turn and the computer goes through one sequence turn almost immediately and the user sees how the rahbitz and fawkzes have moved and how the grah color has changed from being eaten. The program can also be configured so that many turns run without pauses, allowing 10, 50, 100 or more turns to be done in a matter of seconds. The data can then be exported to an EXCEL spreadsheet, which can be graphed. The computer version tracks many variables such as how many rahbitz or fawkzes die of starvation, by being eaten or from old age. This gives the user information as to which is a greater factor, old age, starvation, et cetera...

The computer simulation also allows for ease in altering parameters. The user can choose the age at which rahbitz or fawkzes reproduce, the maximum age that they can live, how far fawkzes can move when they hunt, and more. Then the user can place rahbitz and fawkzes on the environment and determine how many turns the simulation is to be run. After exporting data to a spreadsheet, graphs can be read showing how the parameters chosen have affected the environment. This gives students great freedom in making hypotheses and quickly testing them.

This particular computer program has not yet been field tested with students, but plans are to test it this coming school year with high school Environmental Science classes. Preliminary tests by this author have been promising, however. There are bugs to be worked out, as with all computer applications, especially new ones. Figure 6 shows a graph from a run of the computer simulation with parameters the same as the students used for the board version of the simulation.

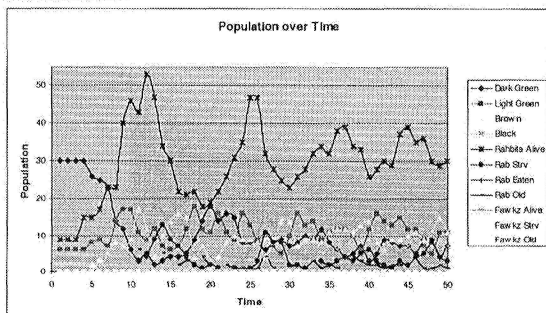


Figure 6: Computer Generated Data

It is very similar to the data and graphs that the students generated.

Figure 7 shows another computer generated graph, but this time with the situation where black hexes (grahz all eaten) does *not* grow back, which is the same situation as in figure 5.

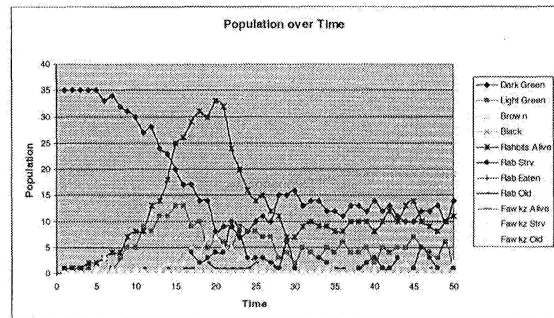


Figure 7: Black Grahz Does Not Grow Back

Notice that the topping out point of rabbit populations are different in figure 5 and figure 7 (which can be attributed to the random feature in the simulation – rabbit movement), but the number of black hexes in both simulations seems to plateau at just under 20 hexes. This suggests that the simulations are in fact simulating essential environmental processes and bringing them out in the graphs. Also, as expected, the overall population of rabbitz is lower than for the situation where the grah is allowed to grow back.

I. The Next Step

Currently this author is writing another computer simulation with the same basic idea as the Population Simulation. The new computer simulation has a few major differences. First, it simulates male and female differences in the organisms. This greatly complicates the reproduction step of the sequence, but with added realism and the computer takes care of all the added complication.

Second, with the ability to simulate male and female differences, the passing on of genes can be simulated and is. This new computer program simulates the passing on of genes. Each individual organism has two sets of genes, the active gene (the phenotype) and the recessive gene (the genotype). When reproduction occurs, the offspring gets genes from each parent.

Because each organism has genes that determine the organism's characteristics, the user does not have to set parameters such as how long an organism will live – this is determined by the individual's genes. What the

user does set is the *range* for each parameter that the genes code for.

With genes coding for individual characteristics, more characteristics of an organism can be simulated. Also, with the structure of the programming, it is fairly easy to add new genes.

The program tracks a lot of data which can be exported to EXCEL and graphed. Not only can populations be graphed (and types of deaths and so on) but gene information can also be graphed for time. This will allow the user to determine if environmental factors affect genes and how they are affected, and *visa versa*.

Although not currently in the new program, there is room to add additional environmental factors such as water content, pollution levels, altitude and more. The ability to add more species is also very real.

J. Conclusion

Overall, the Population Simulation – the board version – has been very successful with high school students. The simulation itself has proved to be engaging for students and allows students to experience concepts in science at a deep level. Students have indicated that they have enjoyed working the simulation and test results have indicated that they have learned science concepts deeply and attitudes toward science have improved.

The computer version allows for results to be generated more rapidly, which allows the simulation of more situations. This will be field tested with high school students within the next year.

A new computer version is being developed which should allow for much greater realism – including genetics – and greater versatility.

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