Changes in Genes and Size of a Population

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ABSTRACT

The first part of this model simulates how the size of an animal population changes as a result of the amount of available food. The second part of this model simulates genetic inheritance and variety in a population. It shows how the gene pool of a population will change over time due to environmental pressures (natural selection).

I. INTRODUCTION

Population dynamics and natural selection can be complex topics, but they are critical to understanding how the natural world interacts with itself and with humans. A population is a group of organisms of the same species living in the same area. The size of a population depends on many factors, but this model focuses on one of the most important: food supply. Most members of any population naturally tend to reproduce and thus increase the population size, but a higher population size means less available food. Limited food supply is an external pressure that requires organisms to adapt and become more efficient, or die. This sometimes leads to a general change in common genetic traits of the population (the total of all genetic information in a population is called the gene pool).

This is the idea of natural selection: that when a genetic trait helps an organism produce more offspring, that trait is passed down and becomes ever more popular in newer generations. An obvious way an organism can reproduce more is if it lives for a longer period of time. Thus, genes that increase the survival rate are likely to appear more often in each new generation, and genes that inhibit survival are not as likely to be passed on.

II. METHODS:

The first part of this code takes several factors and simulates the changes in a population and food supply over time. The inputs include: starting population size, starting food supply, and monthly food growth rate. The output is a dual-plot of population size vs. time and food supply vs. time (Fig. 1). There is an option to plot data from multiple simulations on the same plot, so the user can see a basic trend within the somewhat randomized data.

The code creates a list of the members of the population, and age and mating cycles are associated with each individual. Each time interval (in this case, month), a loop is run: the amount of food is increased, each of the organisms eats, and some reproduce if they meet the requirements. For simplicity, reproduction is asexual in this model. Offspring are simply added to the end of the population list. If the organisms' ages get too high, there is a chance they will die. Also, if the amount of available food goes to zero in the middle of the loop cycle, the rest of the organisms left in the cycle will die. Organisms that die are removed from the population list.

The second part of this code branches off from the first by modeling the system of genetic inheritance. The inputs are the starting amount of food, growth rate of food, number of months over which to run the simulation, and number of months in between data plots. The output is a plot showing all of the individuals (as colored shapes) in the population at given times (Fig. 2 and Fig. 3).

This code takes a list of individuals, as in Part 1, but it adds information for plot shape (indicates male or female), size and color. The mechanism of food growing and being eaten and possible starvation is similar to Part 1, but there is a rule that larger-sized animals require more food to survive. Reproduction is sexual, which means genes are passed from two parents to the offspring. The code simulates multiple allele inheritance of color and size, which is how the more complex traits of animals (such as skin color and size) are inherited. It means there are multiple genes for a single trait, and an offspring can receive all of the father's, all of the mother's, or a mixture of their genes, which can result in a mixed version of the father's and mother's traits.[1] The code uses basic random number functions to generate such probabilities. It also has a function for random gene mutations, which sometimes occur in nature.

III. FIGURES:

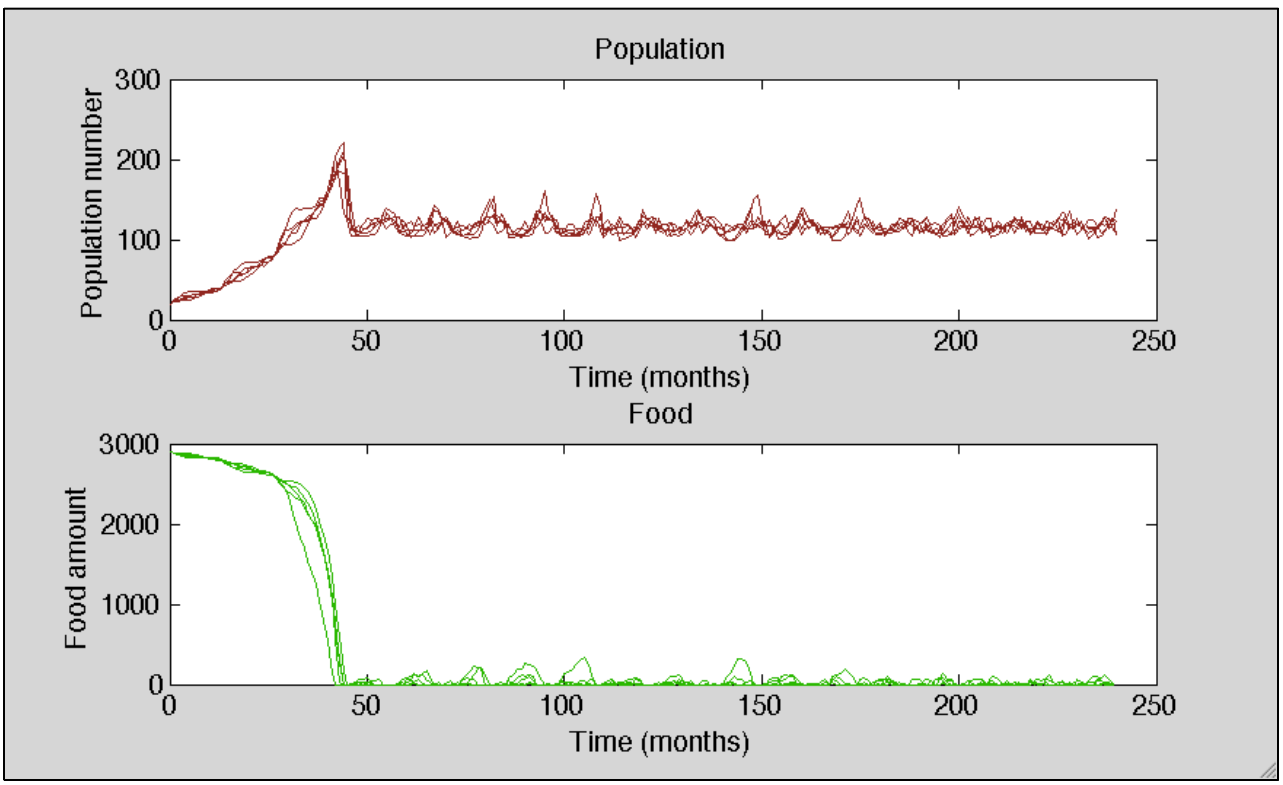

Fig. 1. A graph of population vs. time and food supply vs. time.

[1] Tissot, Robert, *Multifactorial Inheritance*, http://www.uic.edu/classes/bms/bms655/lesson11.html (October 2012).

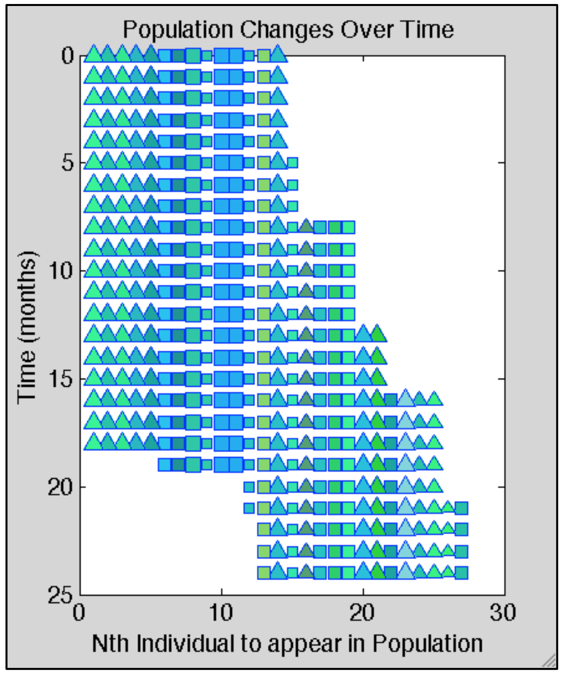

Fig. 2. A plot of all the individuals in the population over time. Individuals are displayed across the x-axis. Time increases down the y-axis because of the tendency to think of offspring as "descending" from their parents. A column starts when a new organism is born and ends when it dies.

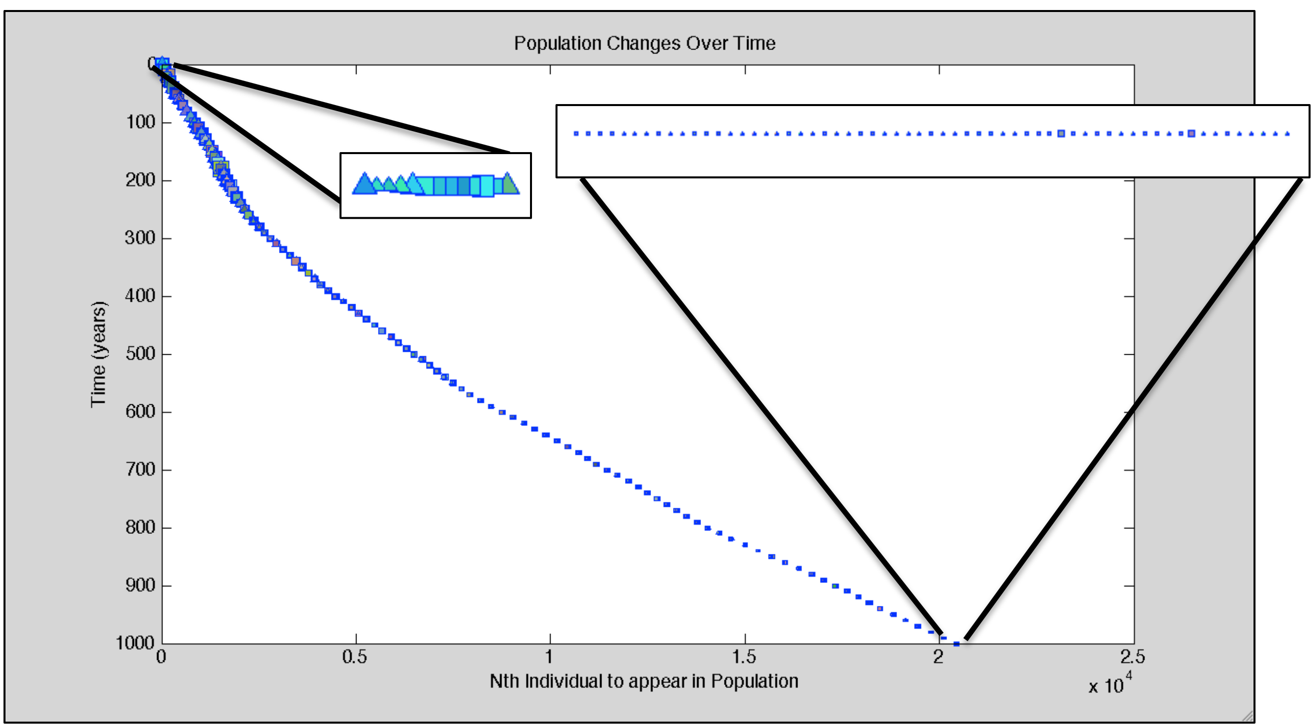

Fig. 3. A plot similar to Figure 2, but over a much longer period of time. Individuals are plotted every 10 years instead of every month. The first and last groups to be plotted are enhanced for visibility.

IV. CONCLUSIONS:

In Figure 1, population initially increases exponentially and thus food supply decreases exponentially. When the food supply is depleted, the population drops sharply, indicating widespread starvation. The population then levels off to a number at which the amount of food grown every month is just enough to sustain all of the organisms. This indicates that food supply is potentially a very important factor in the grown or decline of a population.

In Figure 3, it is apparent that the population has changed over 1000 years, and not just in number. All of the individuals are significantly smaller in size than their original ancestors. The mechanism for passing down the "size" gene is not partial to smallness or largeness. It is simply a random combination of the father's and mother's genetic data. However, the food mechanism does select against largeness by ruling that large animals need more food to survive. Therefore, the reason for this change in genes is that the smaller organisms lived longer (because of a smaller chance of starvation) and thus reproduced more. Each new generation was increasingly likely to receive genes from a small-sized parent. This is an example of the process of natural selection, and it serves to explain how a population's gene pool can adapt to deal with environmental pressures.

V. CHALLENGES:

The main challenge of this simulation was assigning the right amount of "strength" to the food/size mechanism in genetics model. If the rule was too drastic (large animals *very* likely to starve), the population went extinct before the simulation ended. If it was too subtle, large and small animals survived almost equally, and the shift in the gene pool was random.

VI. FUTURE EXTENSIONS:

There are many potential additions that could make this code more realistic and helpful. Competition for mates and food could be implemented (probably favoring larger-sized animals). A “predator” rule could be enabled which favors a certain coloring in organisms (like camouflage). Other needs that were assumed to be met (like shelter, water, space, etc.) could be introduced as limited resources. Finally, a useful upgrade to this code would be to create two different environments with different environmental pressures, and introduce an identical population into each of them. Ideally, the simulation would show the two populations becoming increasingly different from each other as a result of their different environments.

VII. ACKNOWLEDGEMENTS

I would like to thank Dr. Heather Whitney for showing me how MATLAB can be used to solve problems and model a wide variety of natural systems.

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