EvolutionLab

Introduction

Evolution is a common theme throughout biology. The influence of evolution can be seen from the structure and function of molecules at the biochemical level through the interactions of populations of different species at the ecosystem level. However, because evolution occurs on long time scales that are difficult to observe directly, the mechanisms which drive evolution are often misunderstood by students and the general public.

EvolutionLab is a program allows you to simulate “experiments” in evolution. It was inspired by the research of Peter and Rosemary Grant and their students as described in Grant (1991) and the book The Beak of the Finch: A Story of Evolution in Our Time (Weiner 1994). In detailed long term studies of several populations of finch species in the Galapagos Islands, the Grants discovered that morphological characteristics such as beak size can evolve significantly within a few years in response to selection factors brought about by changing environmental conditions. However, you must keep in mind that EvolutionLab is not an exact simulation of this complex biological system; like most models, EvolutionLab is a caricature of nature aimed at demonstrating some simple principles of adaptation by natural selection.

The premise for the model is that there are two small islands, “Darwin Island” and “Wallace Island,” which both contain a small population of finches. These birds feed on seeds produced by plants growing on the islands. There are three categories of seeds: soft seeds produced by plants that do well under wet conditions, seeds which are intermediate in hardness produced by plants that do best under moderate precipitation, and hard seeds produced by plants that dominate in drought conditions. You can manipulate various parameters of the system and observe changes in the distributions of beak size and population numbers over time.

EvolutionLab is based on a model for the evolution of quantitative traits—characteristics of an individual that are controlled by large numbers of genes. These traits are studied by looking at the statistical distribution of the trait in populations and how the distribution changes from one generation to the next. For the finches in EvolutionLab, the depth of the beak is the quantitative trait. You will investigate how this trait changes under different biological and environmental conditions.

Accessing EvolutionLab

You need a Java-based web browser and Internet access in order to use EvolutionLab. Internet Explorer, Safari, Firefox, or Chrome should work, but Java must be installed and enabled. Mac OS X comes with a Java Virtual Machine. For other operating systems, you can download and install java for free. Once you have logged into EvolutionLab, you can click on the link of the left for Technical Requirements for more information.

EvolutionLab is one of 12 applets that make up Biology labs On-Line. To access EvolutionLab, go to the url BiologyLabsOnLine.com and click on the button for EvolutionLab. Log-in using the username and password supplied by your instructor. Once you are logged in, click on the Start Lab button. EvolutionLab will open in a new window (see Figure 1).
Figure 1. Input summary view of *EvolutionLab* showing the input values for each island.

**Changing the Input Values**

The *EvolutionLab* input views are shown in Figure 2. You can switch from one input parameter to another using the buttons on the left. The input parameters are described below.

When you switch to a different parameter, the values that you selected for all the previous parameters remain in effect; in other words, you can manipulate more than one parameter at a time. The **Reset All** button at the bottom left of the screen allows you to reset all the inputs to their default values on both islands. You click the **Done** button when you are finished selecting input values.

Before you run a simulation, you may want to vary the duration, in years, for the experiment. The drop down menu on the bottom left of the summary view (Figure 1) allows you to choose among 100 years, 200 years, or 300 years. The larger values are better for seeing subtle effects.

To execute a simulation, click the **Run Experiment** button on the bottom left side of the view. This will begin the simulations on both islands. The screen will change to output view once the simulation has completed.

There are seven input values that can be manipulated (Figure 2). Four deal with biological attributes of the finch population: initial mean beak size, heritability of beak size, variation in beak size, and clutch size. The last three values are attributes of the environment and the population: island size, initial population size, and annual precipitation. Each of these parameters are described below.

**Initial mean beak size**

The beaks of the Galapagos finches are used to gather food and to crack seeds. The dimensions of the beak critically affect what foods the bird will be able to gather and eat. One important parameter is the depth of the beak, the distance from the bottom to the top of the beak as seen from the side. Deep beaks are stronger and can be used to crack harder seeds. Unfortunately, deep beaks usually require larger birds who then need more food. Shallow beaks are more efficient for eating soft seeds.
Figure 2. The various input views for EvolutionLab. Beginning with the upper left images and proceeding across and down: initial mean beak size, heritability of beak size, variation in beak size, clutch size, island size, initial population size, and annual precipitation.
You can use the sliders to vary the mean beak size of the finch population on each island at the start of the simulation. As you move the slider, the image of the bird will change to illustrate what the average finch looks like in the population.

*Heritability*

Heritability is a measure of the genetic contribution to a characteristic (phenotype) of an organism. If the heritability of a trait is large (near one), then the progeny of a mating will be more similar to their parents than unrelated individuals. If, on the other hand, heritability is low (near zero), then the environment will be more important in determining the phenotype and the progeny will vary around the average value for the population. One method for measuring heritability is to plot the beak depth of each bird versus the average beak depth of each bird’s parents (“midparent value”). The slope of the line produced by this plot is equal to the heritability.

You can use the sliders to vary the heritability for beak size for each island population. Heritability remains constant at this value throughout the simulation. As you move the slider, the graph of offspring beak size versus the midparent value will change to illustrate the heritability value that you are selecting. The mean value for the plot is equal to the initial mean beak size that you have chosen. The amount of dispersion of the points around the plot is determined by your selection for variance in beak size.

*Variance*

Variance is a measure of how different the phenotype is from one bird to the next. If the variance of a trait is large, then there will be large differences among birds for that trait. If, on the other hand, variance is low (near zero), then all of the birds will be very similar to one another.

This input determines two values for the simulation. First, it determines the initial population variance—variance in beak size for the entire population. The population variance may change during the course of the simulation. The variance parameter also determines the sibling variance—variance in beak size among individuals with the same parents. The sibling variance is a measure of how much variability is inherent in a trait. If you look at the plots of offspring beak size versus the midparent value for the heritability parameter, the sibling variance represents the amount dispersion of the points around the regression line. In *EvolutionLab*, the sibling variance remains constant throughout the simulation.

You can use the sliders to change the variance for each island population. As you move the slider, the width of the bell-shaped probability distribution will change to reflect the value that you have chosen.

*Clutch Size*

Clutch size is the number of eggs that a female bird lays in her nest. In the *EvolutionLab* simulation model, birds mate for life, live for one year, and each female produces only one clutch of eggs per year. For a mating pair to replace themselves, they must produce at least two offspring; this is why clutch size is set to a minimum of two eggs. The maximum clutch size of thirty eggs is unrealistic; however, most bird species produce more than one clutch in their lifetime, so a total of thirty or more offspring per mating pair is possible.
You can use the sliders to change the mean clutch size for each island population. As you move the slider, the number of eggs in the nest will change to reflect the value that you have chosen.

Population

You can use this input to set the initial number of adult birds on each island. The population size of each island will vary with time as birds reproduce. As you move the slider, the number of highlighted birds will change to reflect the values you have chosen.

Island Size

The island size determines how large a finch population the island can support. The maximum number of finches that an environment can support is known as the “carrying capacity” of that environment. For the purposes of this simulation, the islands are assumed to be roughly circular and island size is represented as the radius of the island in kilometers. The size of each island remains constant throughout the simulation.

You can use the sliders to change the size of each island. As you move the slider, the island images will change to reflect the values you have chosen.

Precipitation

Precipitation has a major influence on the numbers and types of seeds the finches feed upon. High precipitation favors the production of annual herbs which produce an abundance of soft seeds. As annual precipitation decreases, the number of annual herbs decreases, thereby causing an increase in the proportion of hard seeds, which are produced by long lived trees and vines.

There are three seed types in EvolutionLab: soft, medium, and hard. The proportion of these three seed types will change continuously as you vary the level of precipitation. The rainfall level and distribution of seed types remain constant throughout the simulation.

You can use the sliders to change the level or precipitation for each island population. As you move the slider, the pie chart will change to reflect the distribution of small, medium, and hard seeds.

EvolutionLab Output Data

The EvolutionLab output views are is shown in Figure 3. You can switch from one representation of the output data to another using the buttons on the left. The output views are described below.

Once you have viewed the output results, you can repeat the simulation or return to the input view to set up another simulation. To repeat or modify the current inputs, click the Revise Expt button on the bottom left side of the view. This will return you to the summary view with all the input values from the last experiment. You can then either modify the input values or rerun the experiment with the same input values. One reason for re-running an experiment is that the simulation is based on a “stochastic model,” which means that random factors are included for survival, mating and reproduction. Even with the same input parameters values, the simulation will never return exactly the same results. It is always wise to repeat a simulation experiment several times to be sure the results are consistent. In some cases, random forces may play an important role in determining the results. If you wish to run a completely different experiment, click on the middle button at the bottom of the view marked New Expt. This will return you to the input view with all the parameters set to their default values.
Figure 3. The various output views for EvolutionLab. Beginning with the upper left images and proceeding across and down: mean beak size over time, population size over time, histograms of beak size for each year, yearly listing of the mean beak and population sizes, and a summary of the input selections.

There are five data representations that can be examined. You can look at a plot of the mean beak size over time, a plot of the population size over time, histograms of beak size for each year, a listing of the mean beak and population sizes over time, and a summary of your input selections. Each of these data representations are described below.

**Mean beak size**

In this data representation the mean beak size for the two islands are plotted over time. This view can reveal trends in evolution of the beak depth trait. Darwin Island is plotted in red and Wallace Island is plotted in blue.
Population size

In this data representation the number of birds in the two island populations are plotted over time. This view can reveal trends in population numbers. It is also possible for one or both populations to become extinct. Darwin Island is plotted in red and Wallace Island is plotted in blue.

Histograms

The histograms show the distribution of beak size for every year of the simulation. The blue portion of the histogram represents the population of young birds before mating (fledglings) and the red portion of the histogram represents the population of adult birds that have survived and reproduced. The slider can be used to change the year.

Field notes

The field notes are a textual log of the mean beak depth (± standard deviation) and population size for every year. You can scroll through the list to look at the yearly values for the two populations.

Input summary

This view is a reminder of the input parameter values that were chosen for each island. The values for Darwin Island are shown in red and the values for Wallace Island are shown in blue.

Exporting Results from EvolutionLab

Due to a security constraint in Java, you cannot print or write to the hard disk from the Java applet. To work around this problem, EvolutionLab has an “export” feature that sends the data to regular HTML web page. This web page can be saved or printed, or you can copy and paste from the web page. The export feature is used for the output views. If you are planning on writing a report, you should export graphs and/or data after each experiment that you want to save. To use this feature you must disable any pop-up blockers for this web site.

Exporting Graphs

The plots of mean beak size over time and population size over time can be exported as images in a regular web page. Click on the Export Graph button. A new web page will open with the exported graph. You should either save the web page on your hard drive or save the image with a name that reminds you which experiment you have run. Usually a right-click or ctrl-click or a held click while holding the mouse pointer over the image will bring up a menu that will let you save the image.

Exporting Data

When you click on the Export Data button, a java window will appear with a summary of your input values and a year-by-year listing of the mean beak size and population numbers for each island. You can click on the Export Notes button that the bottom of the notebook to get a html web page with these data. Alternatively, you can select data in the notebook and copy/paste into another application such as a text editor. This can be a useful way of keeping track of your input values for each experiment.

References