Natural Selection and Camouflage

Introduction

In this lab, we will look at change in coloration over time on different backgrounds, with different population sizes, with different individual sizes, and with drastic environmental changes using the Bug Hunt Camouflage model in Netlogo.

References and Further Reading:

Brebbia, C. A., Greated, C., & Collins, M. W. (2011). *Colour in Art, Design & Nature*. WIT Press.

Farkas, T. E., Mononen, T., Comeault, A. A., Hanski, I., & Nosil, P. (2013). Evolution of Camouflage Drives Rapid Ecological Change in an Insect Community. *Current Biology*, *23*(19), 1835–1843. doi: 10.1016/j.cub.2013.07.067

Merilaita, S. (2003). Visual Background Complexity Facilitates the Evolution of Camouflage. *Evolution*, *57*(6), 1248–1254. doi: 10.1111/j.0014-3820.2003.tb00333.x

Niu, Y., Sun, H., & Stevens, M. (2018). Plant Camouflage: Ecology, Evolution, and Implications. *Trends in Ecology & Evolution*, *33*(8), 608–618. doi: 10.1016/j.tree.2018.05.010

Schaefer, H. M., & Stobbe, N. (2006). Disruptive coloration provides camouflage independent of background matching. *Proceedings of the Royal Society B: Biological Sciences*, *273*(1600), 2427–2432. doi: 10.1098/rspb.2006.3615

Stevens, M., & Merilaita, S. (2009). Animal camouflage: current issues and new perspectives. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1516), 423–427. doi: 10.1098/rstb.2008.0217

Bug Hunt Camouflage Model Information
(Duplicated from the info tab of the model in the model library)

This is a model of natural/artificial selection that shows how a population hunted by a predator can develop camouflaging. For example, in a forest with green leaves, green bugs may emerge as the predominant bug color.

When a predator uses color and shape to identify the location of prey in an environment, then the colors and patterns in the environment provide additional selective pressure on the prey. If some of the prey tend to blend into the background better, they tend to survive longer and reproduce more often. If this continues over many generations, the distribution of colors in a population may shift to become better camouflaged in the surrounding environment.

How it works:

You assume the role of a predator bird. After you press GO, click on bugs as fast as you can using your mouse. You may also keep the mouse button depressed, and move the cursor around the world.

You can watch your consumption by watching the "Bugs Caught vs. Time" plot. As its slope decreases, your efficiency (or, in other words, your rate of bug consumption) decreases. Also, the time to catch a batch of bugs is plotted in the "Time to Catch 10 Bugs" plot.

Try to consume bugs as fast as possible to remove any "deliberation" on your part as a predator. The camouflaging effect will emerge more clearly if you aren't taking your time trying to find bugs that typically would be more difficult to find.

Bugs have 3 genes that determine their phenotype for color. One gene is RED-PIGMENT-GENE-FREQUENCY, another is GREEN-PIGMENT-GENE-FREQUENCY, and the last is BLUE-PIGMENT-GENE-FREQUENCY. The more frequently the gene for a pigment is coded for, the stronger that presence of color is in the overall blend of pigments that results in a single phenotype for coloration (determined by an RGB [Red-Green-Blue] calculation).

With each bug you eat, a new bug is randomly chosen to reproduce one offspring. The offspring's gene-frequency for each of the three pigment genes may be different than the parent (as determined by the MUTATION-STEP slider).

How to use the model:

CARRYING-CAPACITY determines the size of the population on SETUP, and how many bugs are in the world at one time when GO is pressed and bugs are being eaten.

MAX-MUTATION-STEP determines how much the pigment genes can drift from their current values in each new generation. For example, a MUTATION-STEP of 1 means that the gene frequency for any of the three pigments could go up 1, down 1, or not change at all in the offspring.

OFFSPRING-DISTANCE determines how far away (in patches) an offspring could show up from a parent. For example, a distance of 5 means the offspring could be 0, 1, 2, 3, 4, or 5 patches away from the parent.

BUG-SIZE can be changed at any time during GO or before SETUP to modify the size of the shapes for the bugs.

SHOW-GENOTYPE? reveals the RGB (Red-Green-Blue) gene frequency values for each bug. The values for Red can range from 0 to 100, and this also true for Green and Blue. These numbers represent how fully expressed each pigment is (e.g. 40-100-24 would represent genetic information that expresses the red pigment at 40% its maximum value, the green pigment at 100%, and the blue pigment at 24%.

ENVIRONMENT specifies the file name to load as a background image on SETUP or on CHANGE-ENVIRONMENT. The image file must be located in the same directory as the model.

MAKE-SINGLE-GENERATION creates one offspring from the existing bugs, without being limited by the CARRYING-CAPACITY. This can only be used, when the model is paused and GO is not running.

TOTAL-CAUGHT keeps track of how many bugs you have caught.

BUGS IN WORLD keeps track of how many bugs are in the world & view.

The plot "BUGS CAUGHT VS TIME" gives a measure of your progress and performance as a predator.

The plot of "AVERAGE HSB VALUES" shows how the average values for the hue, saturation, and brightness of the bugs changes over time.

The histograms of "CURRENT HUES" and "INITIAL HUES" shows a distribution of hues in the current and starting populations.

The histograms of "CURRENT SATURATIONS" and "INITIAL SATURATIONS" shows a distribution of saturations (of colors) in the current and starting populations. Low values represent "grayish" colorations and high values represent "vivid" colorations.

The histograms of "CURRENT BRIGHTNESSES" and "INITIAL BRIGHTNESSES" shows a distribution of brightnesses (of colors) in the current and starting populations. Low values represent "dark" colorations and high values represent "light" colorations.

The plot of "VECTOR DIFFERENCE IN AVERAGE GENOTYPE" shows how the average values of the genotype of the population change overtime. The plot shows the vector difference between the average value of red gene frequency, green gene frequency, and blue gene frequency for the current population as compared to the initial population.

Credits and References

Inspired by this: BugHunt! Macintosh freeware:
https://web.archive.org/web/20101213084130/http://bcrc.bio.umass.edu/BugHunt/.
Novak, M. and Wilensky, U. (2005). NetLogo Bug Hunt Camouflage model.
http://ccl.northwestern.edu/netlogo/models/BugHuntCamouflage. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.
Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Instructions

1) Keep model presets as they are:
   a) Carrying-capacity = 15
   b) Bug-size = 1
   c) Environment = poppyfield.jpg
   d) Max-mutation-step = 26
   e) Offspring-distance = 8
2) Press 'setup' then press 'go'
3) Set a time for 1 minute. Click on as many bugs as fast as you can in that 1 minute.
4) When the timer goes off, press the 'go' button again to pause the model
5) Copy down:
   a) Time Number at Pause 1 (the number of 'time' at the top of the model)
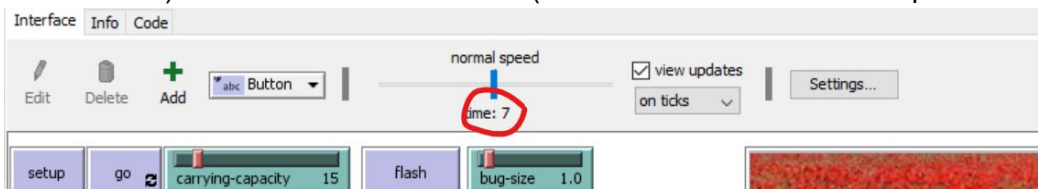
   b) Total bugs caught
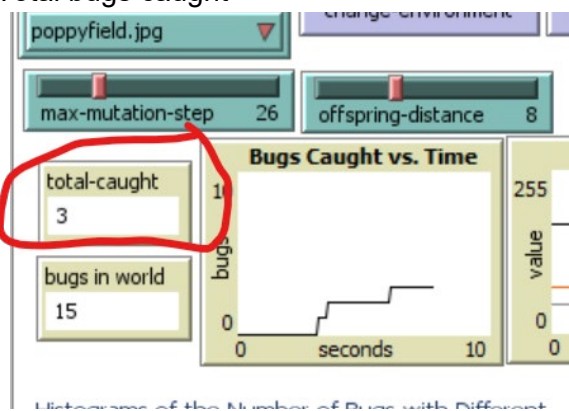
   c) Average hue
   d) Average brightness
   e) Average saturations
      i) All three of these values can be found from the plot HSB values. Hover over the line corresponding the the value of interest and copy down to the data sheet (the red is the value of interest, the black is where you should place your cursor if you are interested in the 'average hue' value)
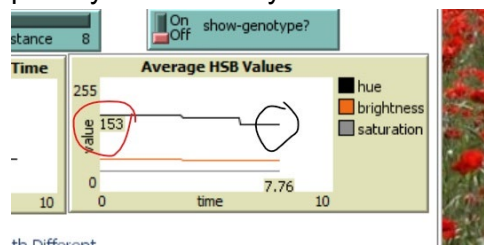
6) Reset timer for 1 minute, press 'go' (DO NOT PRESS SETUP BEFORE YOU PRESS GO) and catch as many bugs as possible until the timer goes off again. Record the values in the data sheet.
7) Repeat this process a third time and copy down final values in the data table.

Graph the change in bugs caught, hue, brightness, and saturation over time.

Repeat the whole procedure for the three different backgrounds.

What do you think will happen in each background? Write down 2-3 hypotheses.

Paste your graphs below.

What do you notice? How do the values change over time?

Repeat the whole procedure with the poppy background and the carrying-capacity set to 100

What do you think will happen with a large population? Write down 2-3 hypotheses.

Paste your graphs below.

How does a large carrying capacity/population affect the final values?

Reset the carrying-capacity to 15 and set bug-size to 5.0
and repeat the whole procedure.

What do you think will happen with a large bug size? Write down 2-3 hypotheses.

Paste your graphs below.

How does the size of the bugs affect the final values?

Reset the bug size to 1.0, and repeat the procedure with the poppy background. At the second pause (Step 6) change the background to the glacier.

What do you think will happen after the environmental change? Write down 2-3 hypotheses.

Paste your graphs below.

What if the environment changes drastically?