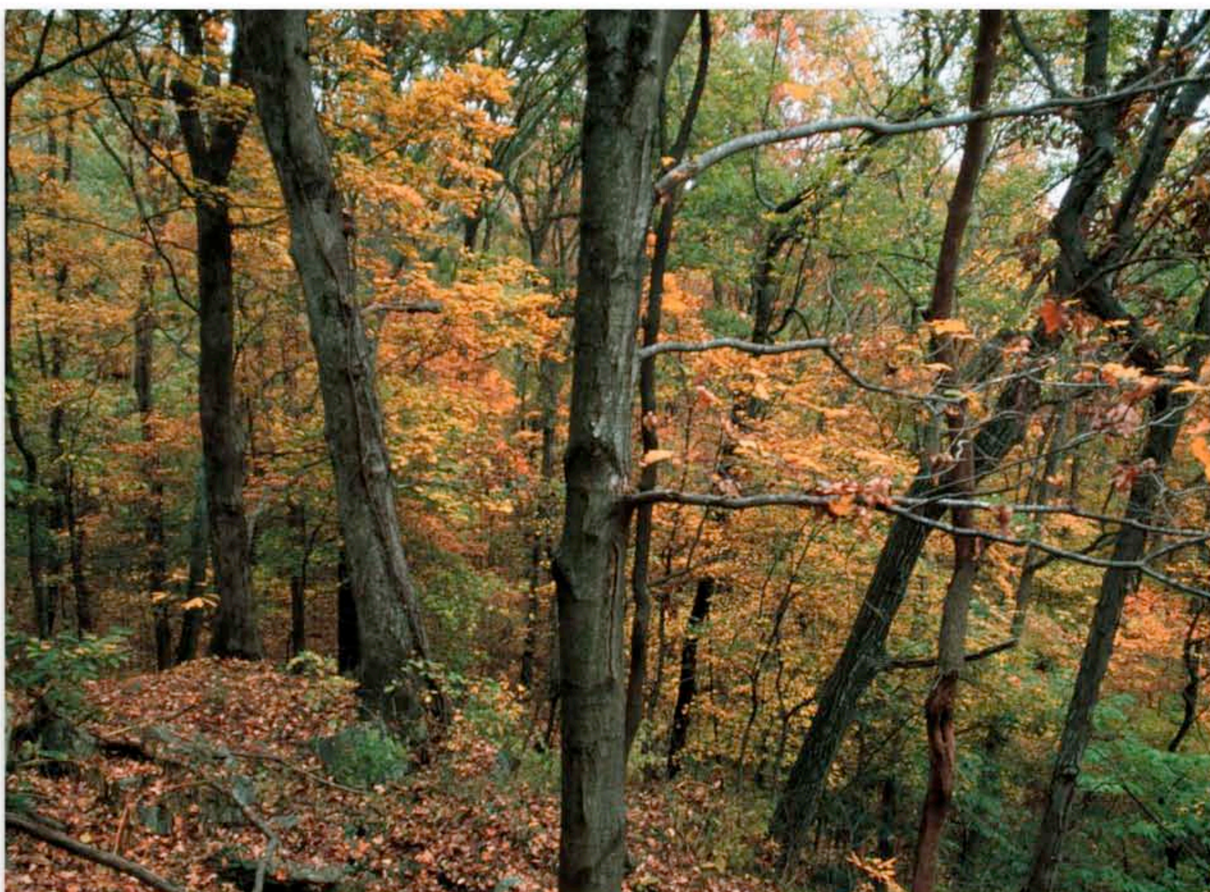
A Mathematical Model for the Forest

Overview

Students sample lichens, identify trees and saplings, and look for wounds on trees to determine overall forest health. This information is entered on data sheets for analysis with a Forest Health Index, a simple algebraic formula that allows students to assess the overall health of the forest. The exercise sharpens identification, observational, and data-acquisition skills and introduces students to a very practical use of elementary algebra.



Title

A Mathematical Model for the Forest

Investigative Question

How can the health of an Illinois forest be determined with a simple mathematical model using data collected from trees?

Overview

Students sample lichens, identify trees and saplings, and look for wounds on trees to determine overall forest health. This information is entered on data sheets for analysis with a Forest Health Index, a simple algebraic formula that allows students to assess the overall health of the forest. The exercise sharpens identification, observational, and data-acquisition skills and introduces students to a very practical use of elementary algebra.

Objective

Using a mathematical model and observational skills, students determine and critique the health of a forest.

Materials

Per group of five students: measuring tape in meters; meter stick or tree caliper; tree field guide; 30-m length of string or rope; marking flags; Students Pages 1, 2, and 3; lichen field guide (optional). Clipboards are handy.

Per class: Several plant presses will be needed if leaves are to be preserved, but heavy books can also be used to press and preserve leaves.

Time

Two 50-minute class periods.

Advance Preparation

1. Copy student pages and assemble the necessary materials. You may wish to contact your local forester for a list of the trees in your area.

2. Obtain permission from the owner of the forest you intend to visit. If you are going to visit a state or federal natural area, secure permission from park personnel.

Introducing the Activity

1. Students are certainly familiar with the practical applications of arithmetic, but they may be less convinced of the usefulness of algebraic formulas. Write the formula $FHIV=1X + 2Y + 3Z$ on the chalkboard to introduce this activity. Students will use this algebraic statement to determine if the forest they sample is in good health. They will develop skills in tree identification and observation. They will discover the utility of combining two disciplines, science and mathematics, to achieve a stated goal—and they will even have fun collecting and interpreting the data!

2. Introduce and explain the concept of a descriptive mathematical model. You may want to refer to the introductory paragraph on Student Page 2.

Procedure

1. Distribute Student Page 1 and discuss forest health monitoring as presented there. Explain why lichens, the identity of seedlings and saplings, and the presence or absence of wounds are indicators of forest health.

2. Divide the class into five groups before leaving the building. Be sure that each group has the required materials, including pencils and their copies of Student Pages 1 and 2.

3. At the site, each group of students sets up its own plot and collects data independently of the other groups. Sampling techniques are given on Student Page 1, but your supervision and assistance will probably be necessary. Groups record their data on Student Page 2. Trees should be identified by referring to a field guide. Leaves from troublesome examples may be brought back to the classroom for identification as may leaves from all trees sampled for verification or as the basis of a leaf collection. Lichens do not need to be identified to species, but students must be certain that what they identify as a lichen is indeed a lichen. It's probably a good idea to show students examples of lichens in the field before they set up their plots.

4. The data sheet (Student Page 2) should be completed in the field.

5. Back in the classroom, distribute copies of Student Page 3. Each group rates its forest plot using the information collected in the field and the Forest Health Index.

6. Each of the three variables in the model are not of equal importance and must be weighted based on its contribution to the final analysis. Thus, we multiply each variable by a constant to adjust its importance relative to the other variables. In our example, we suggest that the X variable is least important and is therefore multiplied by 1; the Y variable is moderately important and should be multiplied by 2; the Z variable is most important and is multiplied by 3.

7. Students are now ready to compute the Forest Health Index Value for their forest. The higher the value, the healthier the forest is likely to be. For example:

X = +1 (>100 lichens or >40% of sampling band covered =+1)

Y = +1 (>75% of seedlings and saplings same genera as witness tree)

Z = +1 (<25% trees show damage)

Forest Health Index Value = 1X+2Y+3Z
FHIV = 1(+1)+ 2(+1) + 3(+1)
FHIV = +1 + 2 + 3
FHIV=+6

8. After each group has calculated its Forest Health Index Value, calculate the average Health Index for all data obtained in the forest by the five groups. Example based on data from five groups:

+1	+1	0
+1	0	+1
-1	0	-1
0	+1	+1
-1	+1	+1
X=0/5=0	Y=+2/5=0.4	Z=+3/5=0.6

FHIV= IX + 2Y+3Z
FHIV= 1(0) +3(0.4) +2(0.6) FHIV=0+1.2+1.2
FHIV for all plots = 2.4

Assessing the Activity

Student groups are assigned to recalculate their model values. But before doing this, ask each group to change the constants used in the model and provide a short written justification for their changes. Groups then recalculate their model values based on the altered constants and compare their recalculated model with their original model. How did changing the constants change their Forest Health Index Value? Finally, average the recalculated values of the five groups and compare those values with the original values. Discuss why judgment is important in assessing ecosystem health. Who determines the value of such constants in real-life models? Foresters? Researchers?

Extending the Activity

1. If your students are working with computers, they may create a program or use an available spreadsheet that will accommodate the data and model. Students can then run the program and generate the results with the data they have collected.

2. Students may press the leaves they collected in a plant press or large book and prepare herbarium specimens. Information that should be included with each specimen includes species, collection site, collector, and date.

3. A good reference for lichen identification is listed below. Help students to identify the lichens they find. Identification must be done in the field; do not have students collect the lichens.

Reference

Hale, Mason E. 1979. How to Know the Lichens. The Pictured Key Nature Series. Wm. C. Brown, Dubuque, IA. 246p.

State Goals

6, 11,12 (11.4.01-04, 11.7.01-03, 11.7.06, 12.7.01)

Concept

The health of a forest can be evaluated by gathering data and using a mathematical model to analyze it.

Safety and Waste Disposal

1. Obtain permission before entering private land.

2. Watch out for poison ivy in Illinois forests!

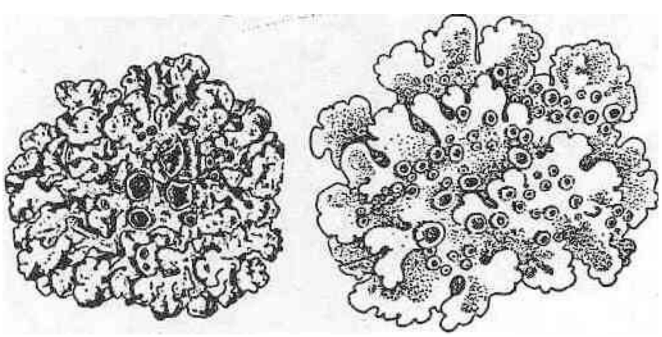
Student Page 1: Background Information

The health of forest ecosystems has gained popular attention in recent years because of environmental concerns about air pollution, acid rain, global climate change, and long-term resource management. Several federal and state agencies are working together to develop a program for monitoring and reporting on the status and trends of forest ecosystems. In this activity, you will acquire skills related to assessing the health of an Illinois forest. These skills will prepare you as citizen scientists for ForestWatch.

Monitoring Lichens

Lichens are fungi that live in close association with algae. Lichens are highly responsive to environmental stresses in forests, including changes in forest structure, air quality, and climate. You will collect data on epiphytic lichens (those that grow on trees and shrubs) to determine the degree of nitrogen- and suitor-based air pollution in a forest. The sensitivity of lichens is a result of their total reliance on the atmosphere for nutrition. Because lichens are so sensitive to air-bome pollutants, they are useful as an early indicator of improving or deteriorating air quality.

Sampling technique: Walk into the forest, perpendicular to the edge, for 40 m. Stop and use this point as the center of a circle 30 m in diameter. You may place marking flags around the edge of your plot. Walk in a spiral pattern, outward from the center, and count all lichens seen on trees and shrubs in a 100-cm band. To do this, choose a point on the trunk (or trunks in the case of shrubs) that is 1.3 m above ground level. Measure 50 cm above and below that point to create a 100-cm sampling area around the tree or shrub trunk. Note that some colonies may overlap; count these as individual colonies. Some lichen species may form blankets on the trees or you may be unable to count discrete colonies. If this happens, determine the percent of the tree sample area that is covered with lichens. Use the same sampling area as before. If you find that less than 10% of the trunk within this area is



covered with lichens, count that tree as having 0 lichens. If 10-40% is covered, count that tree as having 10 lichens. If more that 40% is covered, count that tree as having 20 lichens. You may stop when you reach the outer edge of the plot or when the total lichen count reaches 100. Record the data on Student Page 2. Save this plot for use later in monitoring tree damage.

Monitoring Tree Regeneration

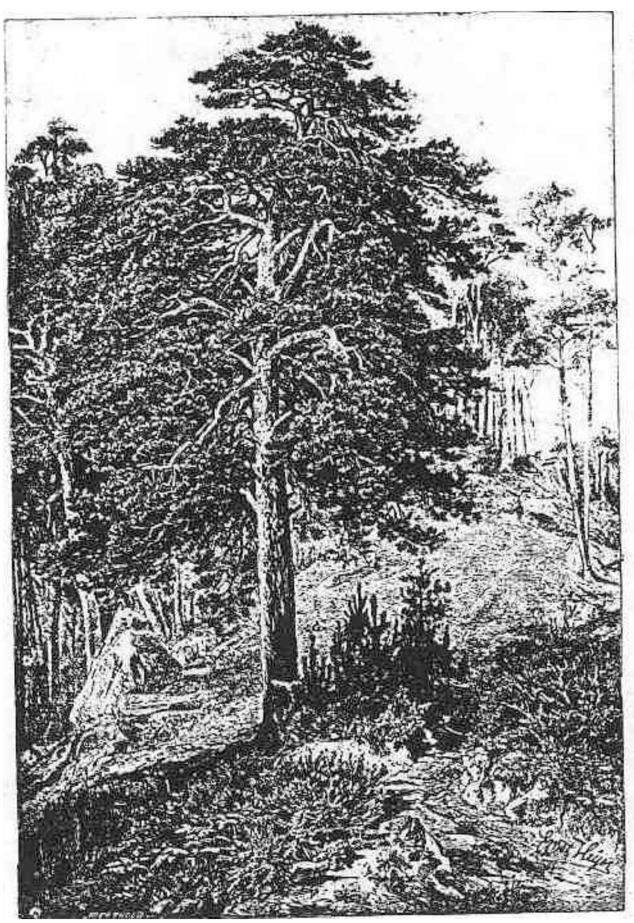
Rates of tree regeneration (Are the large, canopy trees reproducing, or are they being replaced by different species of trees?) are an important component of the forest ecosystem in terms of sustainability, productivity, and aesthetics.

Sampling technique: Walk into the forest, perpendicular to the edge, for 15m. After 15m, continue walking until you find a large tree, one that reaches the forest canopy and stands within 15 m on each side of your transect. This will be your witness tree. Determine its genus (oak, maple, elm, etc.) and use it as the center of a circular plot that is 30 m in diameter. You may use flags to mark the plot. Count all seedlings (stems at least 30 cm tall but <2.5 cm in diameter) and saplings (stems 2.5 to 12.5 cm dbh) within that circular plot. Diameter at breast height of saplings is measured 1.37 m above the ground. Each seedling and sapling should be identified to genus (oak, elm, etc.). You may stop when you reach the outer edge of the plot or when your count reaches 100. Record the data on Student Page 2.

Monitoring Tree Damage

Damage to trees by insects, pathogens, air pollution, natural changes, and human activities can act singly or in combination to cause a measurable decline in the overall health of a forest. Information on tree damage contributes data to several key attributes of the forest ecosystem: biological integrity (Are all the components in place and functioning properly?), sustainability, and aesthetics.

Sampling technique: Use the same plot that was used for sampling lichens. Begin in the center and count all trees >12.5 cm dbh. Note trees that have one or more open wounds, are leaking resin or sap, have a broken trunk, have exposed broken roots, or have lost a top (growing tip). Calculate the fraction of all trees in the plot that have these wounds.



Student Page 2: Data Sheet—Forest Health Name

The idea of a mathematical model may be new to you. A mathematical or scientific model is an equation or series of equations with one or more variables that uses information gathered from direct observation to understand how nature works, to predict future events or trends, or to assess a current condition in a quantitative way (for example, a numerical value to indicate forest health). Models can be quite complex or relatively simple. In this exercise, we will use a simple algebraic statement to assess the health of a forest.

Lichen Data*
Total number of lichens found m a circular plot 30 m in diameter: ___

Tree Regeneration Data
Identity of witness tree (oak, elm, maple, etc.):

Sapling/Seedling Identity Number of individuals

Fraction of saplings/seedlings of same identity in plot = $\frac{\text{saplings/seedlings of same identity}}{\text{total number of saplings/seedlings}}$

Tree Damage Data Total number of trees in plot:__________

Total number of trees with damage (open wounds, leaking sap, broken trunk, exposed broken roots, lost growing tip): ___________

Fraction of trees damaged = $\frac{\text{damaged trees}}{\text{total trees m plot}}$

*Lichens may be counted in two ways. If individual lichens can be counted, simply record the total number found in the 30-m plot. When lichen blankets are found and individual lichens cannot be counted, you will need to estimate the number of lichens. For example, if you estimate that 40% of the 100-cm trunk band is covered with lichens, record 20 lichens for that tree. For more specific information about this sampling technique, see Student Page 1. Use the space below to keep your tally. Estimate lichen blankets until you reach a count of 100 lichens or until you have covered the 30-m plot. You may use a combination of actual lichen counts and an estimation based on percent coverage. All data, however, is recorded as number of lichens.

Student Page 3: Determining Forest Health   Name

Model for Determining Forest Health Index Value

Variables	Rating
Lichen Monitoring	
>100 lichens in circular plot 30 m in diameter	+1
40-100 lichens in circular plot 30 m in diameter	0
<40 lichens in circular plot 30 m in diameter	-1
Tree Regeneration Monitoring	
>75% of seedlings and saplings same genus as witness tree	+1
30-75% of seedlings and saplings same genus as witness tree	0
<30% of seedlings and saplings same genus as witness tree	-1
Tree Damage Monitoring	
< 25% of trees >12.5 cm dbh with wounds	+1
25-50% of trees >12.5 cm dbh with wounds	0
>50% of trees >12.5 cm dbh with wounds	-1

Forest Health Index Value (FHIV) = IX + 2Y + 3Z
FHIV = 1( ) + 2 ( ) + 3 ( )
FHIV=

Health Scale

-6 -5	-4 -3	-2 -1 0 +1 +2	+3 +4	+5 +6
Very Unhealthy	Moderately Unhealthy	Intermediate Health	Moderately Healthy	Very Healthy