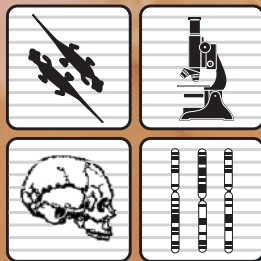


# BioMath

## Habitat: An Organism's Environment

Student Edition



*COMAP*



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# Habitat: An Organism's Environment

## Overview

As human populations increase and spread into areas shared with other organisms, more and more **species** are added to the endangered species list. As awareness increases about the impact of human activities on the **environment**, many questions are asked. Are there ways to lessen the negative impact that humans have on other organisms? Can human developments be designed to prevent the demise of other populations of organisms? Could a new community golf course be built to limit its negative impact on other species or even possibly have a positive impact on the environment? In order to answer these questions, it is necessary first to understand the problem at a deeper biological level. Then, mathematical tools can be used to state the problem in precise language and to help one to arrive at a satisfactory solution.

## Unit Goals and Objectives

Goal: Develop a deeper understanding of the effects of ecological and environmental components on habitat selection by an organism

Objectives:

- Use the proper terminology when describing environmental components.
- Recognize the effects of human encroachment and influence on the natural populations.
- Understand the challenges of habitat design in conservation.

Goal: Use models and graphs to represent, analyze and explore habitats.

Objectives:

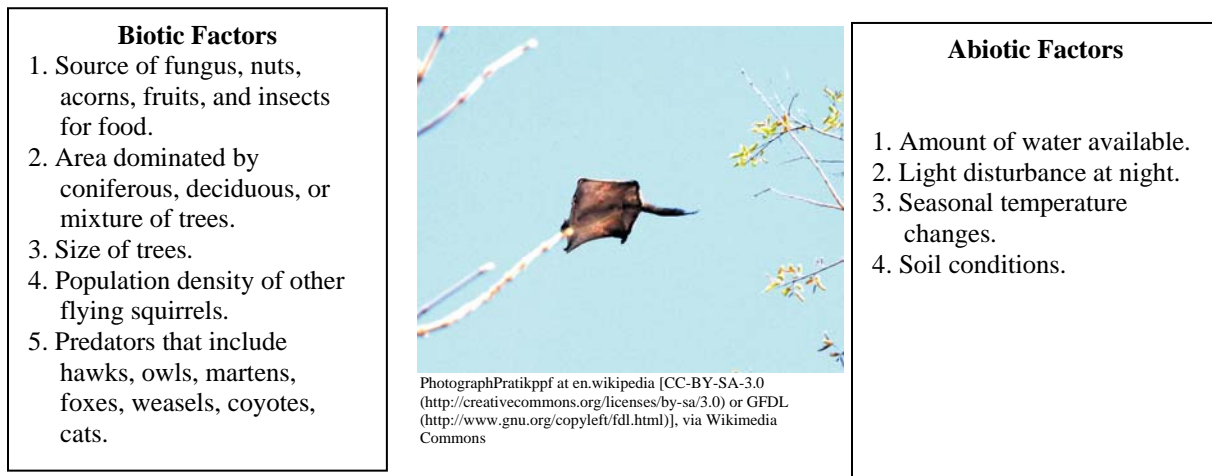
- Characterize the relationships between dependent and independent variables with an equation.
- Understand how to create a descriptive model representing observed data.
- Understand how to use a descriptive model as the basis for a predictive model.
- Understand how to employ predictive modeling to solve an applied, real-world problem.
- Use technology to facilitate solving problems in biology.

# Lesson 1                      Modeling Habitat Selection

Have you ever seen a flying squirrel? Most likely, you have not. The northern flying squirrels were added to the endangered species list in 1985. Human lumbering activity in the Appalachians between the 1880's and the 1920's reduced the amount of available forest for the flying squirrel from 500,000 acres to 200 acres. Researchers have been studying the flying squirrels to learn more about them in hope that possible interventions could prevent their extinction.<sup>[1]</sup>

## Habitat

To study this species, it is important to understand the factors, both living and nonliving, that affect the northern flying squirrel. **Biotic factors** are the living components of the environment. Examples of biotic factors include plants, animals, fungus, disease and products that come from them including their secretions, wastes and dead remains. As a result, things like food, population density, secure nesting sites in dead trees and predators are included in this category. **Abiotic factors** are physical factors that affect organisms in the environment. Examples of abiotic factors include temperature, rainfall, light intensity, humidity, soil composition and pH of water or soil.



**Figure 1.1:** Factors Influencing Flying Squirrels

Researchers must determine which factors are of the most critical importance to the species. To do this, the researchers look at as many of the different factors as possible in the squirrels' habitat. The **habitat** is the natural environment of an organism and contains both the biotic and abiotic factors. The habitat is often used to refer to the plant community that an animal lives in. The habitat of the flying squirrel may be referred to as a coniferous forest (trees with needles) or a deciduous forest (trees that lose their leaves). To cite another example, the habitat of a clownfish is a coral reef.

## Questions for Discussion

1. Define biotic factors. Give two examples relative to the flying squirrel.

2. Define abiotic factors. Give two examples relative to the flying squirrel.
3. What is a habitat? Give two examples of habitat.

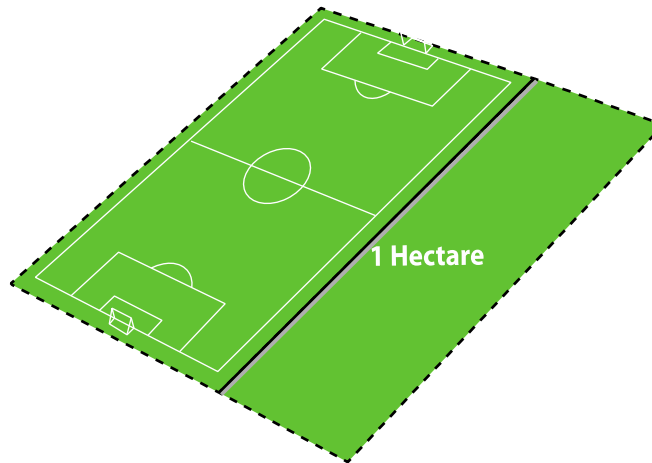
### **Making the Biology Math Connection**

The researcher collects as much data about the habitat as possible. Since this can be a considerable amount of data, it is useful to quantify the data and determine if there is a relationship between a characteristic of the habitat and the squirrel population. To determine if a relationship exists, a **scatter plot** of the data is made. Then the relationship between the habitat characteristic and population is classified as a positive relationship (e.g. an increase in the size of habitat corresponds to an increase in the squirrel population), a negative relationship (e.g. an increase in the size of habitat corresponds to a decrease in the squirrel population) or no relationship (e.g. an increase in the size of habitat corresponds to little or no change in the squirrel population). Describing the relationship between the characteristics of the habitat using mathematical means is called **descriptive modeling**.

It is important to keep in mind that what we are doing is characterizing a relationship between two **variables**. In the example above, the size of habitat and the squirrel population are both variables. Other examples of variables are the mouse population, the amount of water available or the temperature. Remember; a strong relationship only tells you that two sets of data are strongly related, not that one causes the other. The relationship between variables isn't necessarily causal. It is merely an indication of association. A strong relationship might indicate some causality exists, but might also indicate that both variables are caused by some other, unexplored factor. For example, an increase in forest habitat causes an increase in both mice and squirrel populations. As a result, there is a strong association between mice and squirrels, but neither causes the other to increase. In fact, it is possible that there is no detectable reason at all for the association to appear, even if it always does. When that happens, each variable can still be used as a good indicator of the other, but it's important to remember that it's a consistent coincidence, instead of a relational necessity.

Not only is understanding this type of relationship useful for describing existing data, but it may make it possible to predict what the numbers "should be" for habitats that haven't yet been studied. For example, if it is believed that an increase in the size of habitat increases the squirrel population, based on a study of two habitats of different sizes, then it may be possible to predict what will happen with a third habitat. Let's say there were 4 squirrels in an area of 40 square meters and 7000 squirrels in an area of 70,000 square meters, then one can hypothesize that there should be about 30 squirrels in a habitat of 300 square meters without ever having observed an area of that size. Using a relationship that is already determined to make educated guesses about things that have not been measured is called **predictive modeling**. This will be discussed in more detail later.

Consider a fictional area called Frostbite Falls. Data of the number of trees per hectare (10,000 square meters = 100m x 100 m) and squirrel population in Frostbite Falls are shown in Table 1.1. To visualize the size of a hectare relative to a soccer field, examine the picture below.



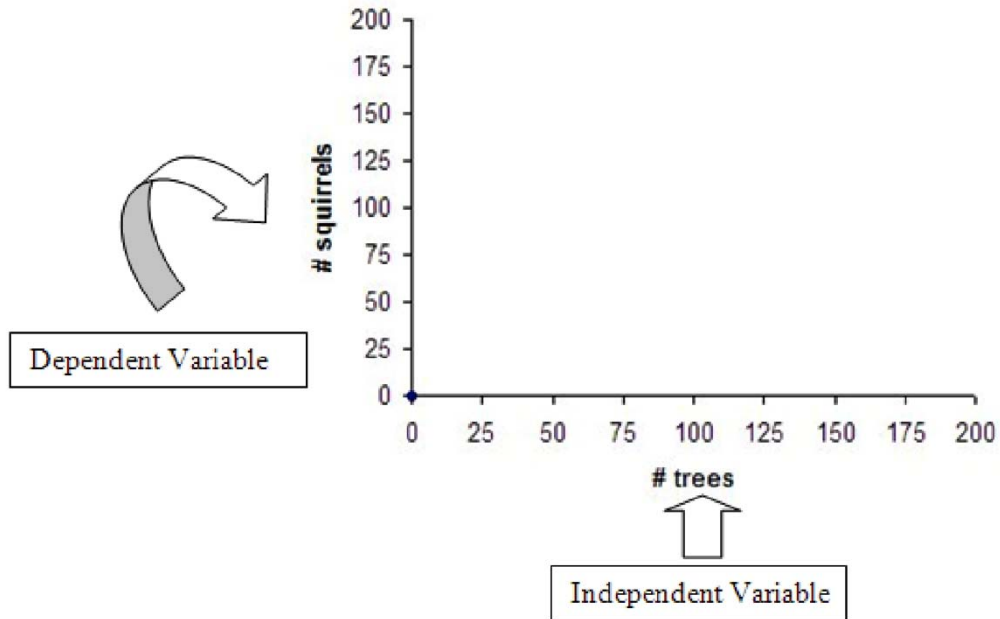
**Figure 1.2:** Visualization of One Hectare to the Size of a Soccer Field

If we divide Frostbite Falls into 100m x 100m grid squares, we can quantify forest maturity by counting the number of “big” and “little” trees found per square and count the squirrels. The data of squirrels and trees found in the grids are recorded in Table 1.1.

37 little trees 21 big trees 29 squirrels	91 little trees 54 big trees 143 squirrels	87 little trees 21 big trees 97 squirrels	5 little trees 48 big trees 70 squirrels
28 little trees 34 big trees 67 squirrels	19 little trees 27 big trees 50 squirrels	48 little trees 47 big trees 100 squirrels	63 little trees 52 big trees 118 squirrels
10 little trees 0 big trees 8 squirrels	0 little trees 24 big trees 31 squirrels	28 little trees 111 big trees 147 squirrels	52 little trees 73 big trees 136 squirrels
23 little trees 12 big trees 34 squirrels	12 little trees 53 big trees 79 squirrels	42 little trees 89 big trees 149 squirrels	23 little trees 94 big trees 141 squirrels

**Table 1.1:** North Side Frostbite Falls Data

In an experiment, the **dependent variable** is what is being measured in the experiment based on the **independent variable**. In this case, the number of squirrels is “dependent” on the number and size of the trees, the independent variable. Experiments cannot have a dependent variable without having at least one independent variable. When graphing on a Cartesian coordinate graph, the independent variable is most often plotted on the horizontal,  $x$ -axis and the dependent variable is plotted on the vertical,  $y$ -axis. In this experiment, the number of trees is the independent variable and will be plotted on the  $x$ -axis and the number of squirrels is the dependent variable and will be plotted on the  $y$ -axis.



**Figure 1.3:** Cartesian Coordinate Graph

### Questions for Discussion

4. State whether each of the following examples is descriptive modeling or predictive modeling.
  - a. As the number of coyotes in a grassland increases, the number of rabbits decreases.
  - b. After studying that grassland for several years, the researcher predicts that another grassland in a nearby area with 17 coyotes will have 232 rabbits.
  - c. Fields with more clover have larger populations of bees.
  - d. An apiary (bee farm) has two hives. The farmer predicts that if he adds another acre of clover he will be able to add another hive of bees.
5. A student is monitoring the height of young bean seedlings over a two-week period.
  - a. To show these data in a graph, which variable should be plotted on the  $x$ -axis?
  - b. To show these data in a graph, which variable should be plotted on the  $y$ -axis?

## Lesson 2                      Trend Lines

While the data on a scatter plot displays the measurements of the variables, it is the underlying relationship between the independent and dependent variables that is truly interesting. Finding a “**line of best fit**” or **trend line** helps to define this relationship. A line of best fit is a line that most accurately represents a general relationship that would produce that distribution of data.

### Line of Best Fit

Data measurements in the real world always show at least some small differences from an ideal outcome, so even if the explanatory relationship is perfect, the data cannot be expected to lie perfectly along a line. It is possible to find a line that comes close to fitting the observed data.

### **ACTIVITY 2-1 Creating Your Own Trend Line**

**Objective:** Given a set of data, determine trend lines and the equations for those lines to represent relations among the variables involved.

**Materials:**

Handout HE-H1: Creating Your Own Trend Line Activity Worksheet  
Access to computer or calculator with spreadsheet program/regression capability

1. Use the Frostbite Falls data from Table 1.1.
  - a. Determine the variables represented by the data.
  - b. Identify one other variable by combining two or more of the variables in part a.
  - c. Create a data table showing the number of little trees, big trees, total trees, and squirrels.
2. Consider the data for little trees and squirrels.
  - a. Plot the data using graph paper or a computer. Put the independent variables (number of little trees in this case) on the  $x$ -axis and the dependent variable (number of squirrels) on the  $y$ -axis.
  - b. Determine if there is a relationship between the two data sets. To do this, it is necessary to draw the line of best fit or trend line for the data points on the graph. If doing it by hand, the dots should not be connected. Instead draw a line that gets as close to as many of the points as possible. Spreadsheet programs like Excel will do this automatically. However, it is important to be able to do this without a program. This is said to show the “trend” of the data.

It is not always easy to estimate the best fit line. If many of the data points are close to the line, then this line is a really good fit and provides a good explanation for the relationship. A positive slope suggests a positive relationship between dependent and independent variable; an increase in the independent variable leads to an increase in the dependent variable. A negative slope suggests a negative relationship; an increase in the independent variable leads to a decrease in the dependent variable. If many of the data



points are not close to the line, then it may mean that a line is not a good way of describing the relationship between the variables.

c. Compare your trend line with one or two other groups in class.

d. Which of the three lines is the “best” mathematical representation of the data? Explain.

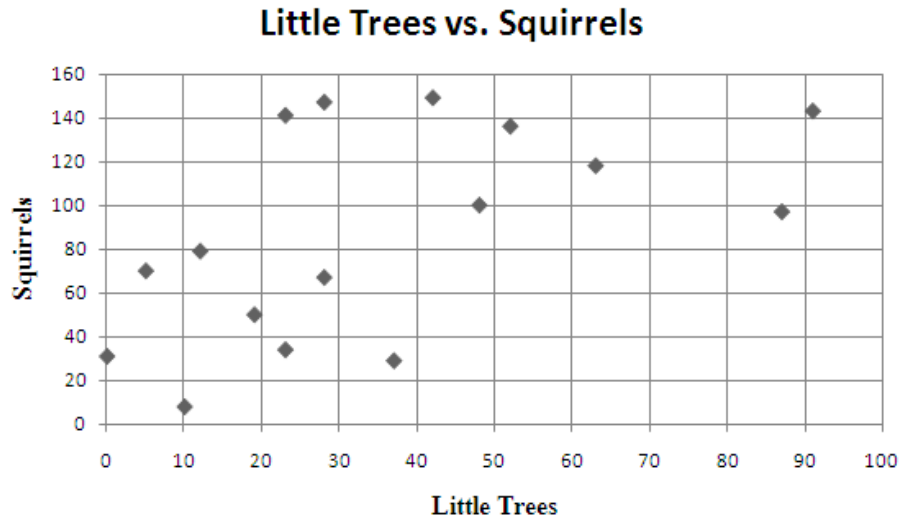
### Placement of Trend Line

To find an appropriate placement of a trend line, it is helpful to first find a point on that line. One way to do this is to find the mean of the  $x$  values (number of little trees) and the mean of the  $y$  values (number of squirrels). To calculate the **mean**, sum the values and divide by the total number of data points. This has been done in the Table 2.1 below.

	Little trees (x)	Squirrels (y)
	37	29
	28	67
	10	8
	23	34
	91	143
	19	50
	0	31
	12	79
	87	97
	48	100
	28	147
	42	149
	5	70
	63	118
	52	136
	23	141
sum	568	1399
mean	36	87

**Table 2.1:** Little Trees and Squirrels

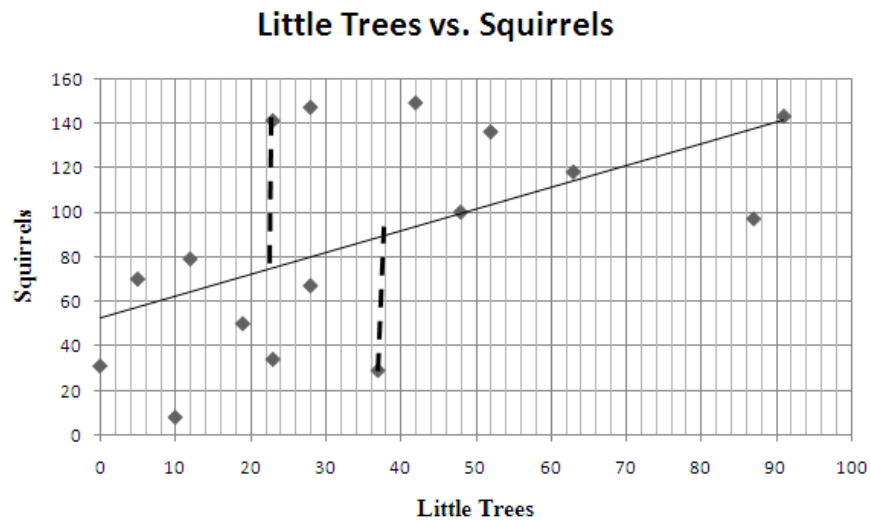
3. On the graph below, plot the point (36, 87). The trend line should pass through this point, the mean. Now draw a line on the graph through that point that comes as close to the data points as possible.



**Figure 2.1:** Little Trees vs. Squirrels

### Whose Line is the Best?

The graph below shows two examples of drawing a vertical line from the trend line to a respective data point (the  $y$ -distance). Measure the length of all of the vertical distances from the trend line to the data points. Total the distances as positive numbers. The trend line resulting in the least total length has the best fit for these data using this method.



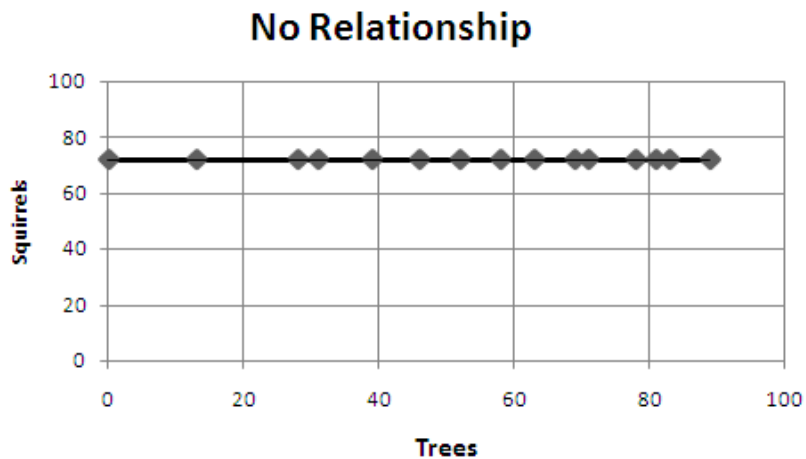
**Figure 2.2:** Example Vertical Distance Measurement

4. Use the method described to find the sum of the distances from your trend line to your data points. Compare your total with other groups.

## Least Squares Regression

To find the best possible line, a mathematical technique called **least squares regression** is used. This technique is similar to the method in Activity 2-1 as it computes the  $y$ - distance of each point to the line. It is different in that it then squares that number and then sums all of the squares. A computer or calculator will minimize the sum of the squares of these distances over all possible lines to give the best line. By summing the squares of the distances rather than summing just the distances, the regression method prevents positive distances from canceling out negative differences.

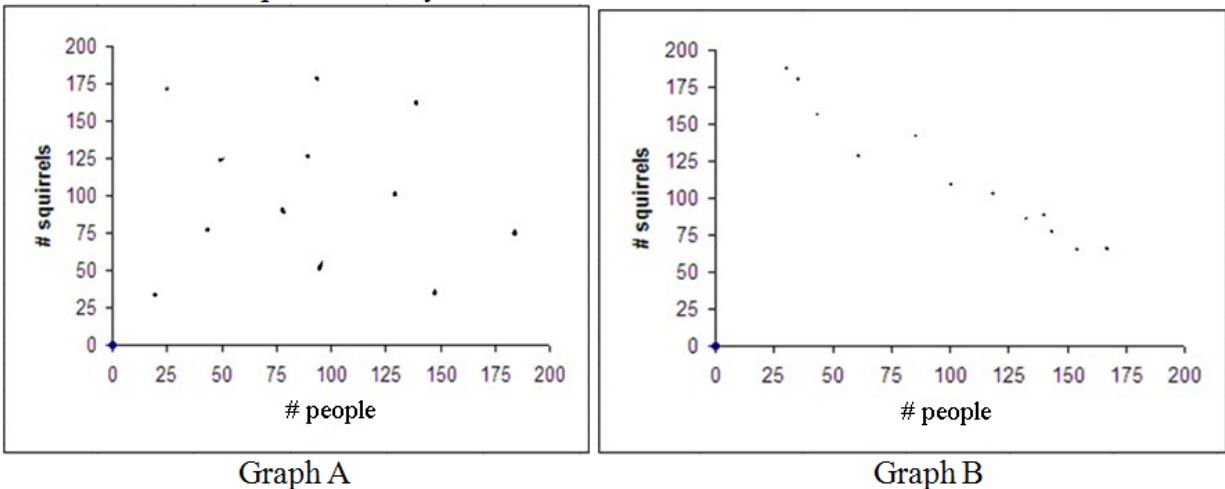
It is possible to have a really good fit for the explanatory relationship, even if there is no relationship between the independent and dependent variables. For example, all of the data points could be along an observed number of 72 squirrels no matter how many trees there were. In this case, as shown in Figure 2.3, the fit of the line would be perfect for  $y = 72$ , but there is no relationship between the number of trees and the expected number of squirrels. As a result, when scientists interpret data, they look both at the strength of the relationship (absolute value of the slope of the line) and at the “goodness” of the fit of the relationship to the observed data (how close to the line the data points are).



**Figure 2.3:** Example Data with No Relationship

## Question for Discussion

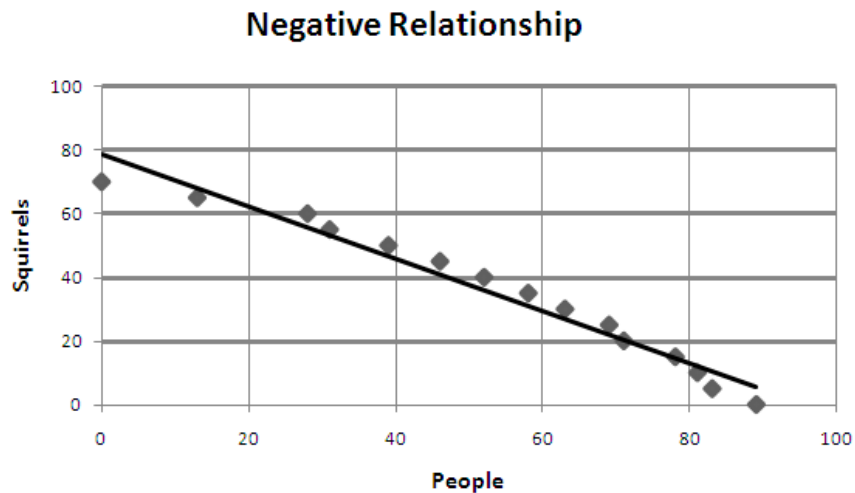
1. Which of the graphs in Figure 2.4 clearly shows a relationship between the number of people and the number of squirrels? Why?



**Figure 2.4:** Example Tree vs. Squirrel Data

In the case of our little trees vs. squirrels graph, the trend line has a positive slope. That is, it starts in the lower left area of the graph and goes to the upper right area of the graph. When the trend line has a positive slope, the two variables have a positive relationship. This describes the situation where, in general, as one increases so does the other.

If the trend line starts in the upper left area of the graph and goes to the lower right area of the graph, the trend line would have a negative slope, and the two variables would have a negative relationship. This describes a relationship where, as one increases the other decreases. Figure 2.5 shows a negative relationship between people and squirrels.



**Figure 2.5:** Relationship between People and Squirrels

## Question for Discussion

2. Which of the graphs in Figure 2.6 shows a positive relationship between the number of trees and the number of squirrels?

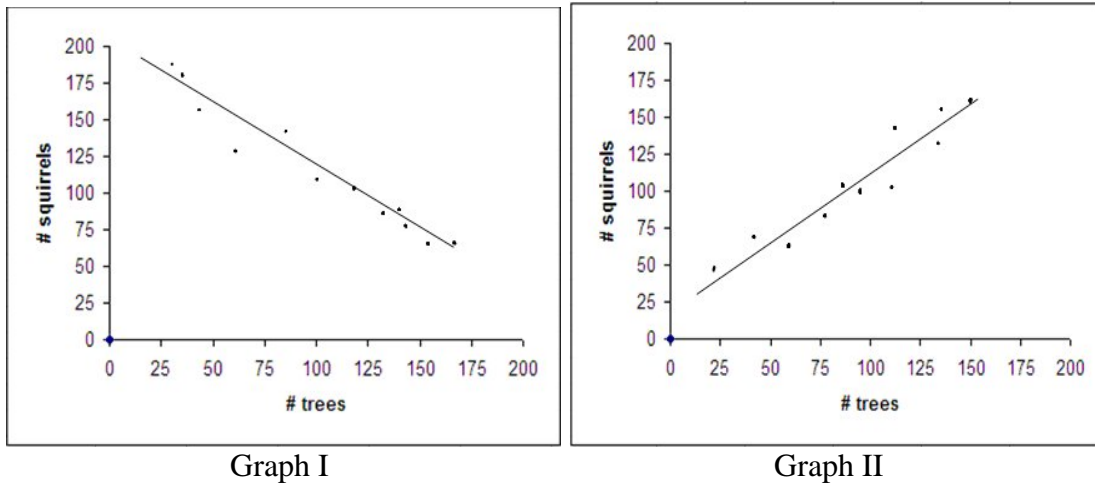


Figure 2.6: Trend Lines

## Linear Trends

A line of best fit can always be determined, but a very important assumption about the data is already made: “There is a linear trend in the data.” If the actual relationship isn’t directly linear (e.g., it curves), the trend line may not describe the relationship well. However, even if the trend line does not fit the data well, the data may still be related - it may simply suggest that a line is not a good descriptive model for the relationship between the independent and dependent variables.

**Extrapolating** for values outside of the **domain** (as shown in Figure 2.5) is more of a hypothesis than a prediction and would require more experimental testing to validate. In the case of little trees, no predictions for squirrels should be made when the number of little trees in an area is much more than 91. **Interpolating**, the process of creating new data points between known points, is acceptable. A squirrel data point for 75 little trees can be created based upon the trend line.

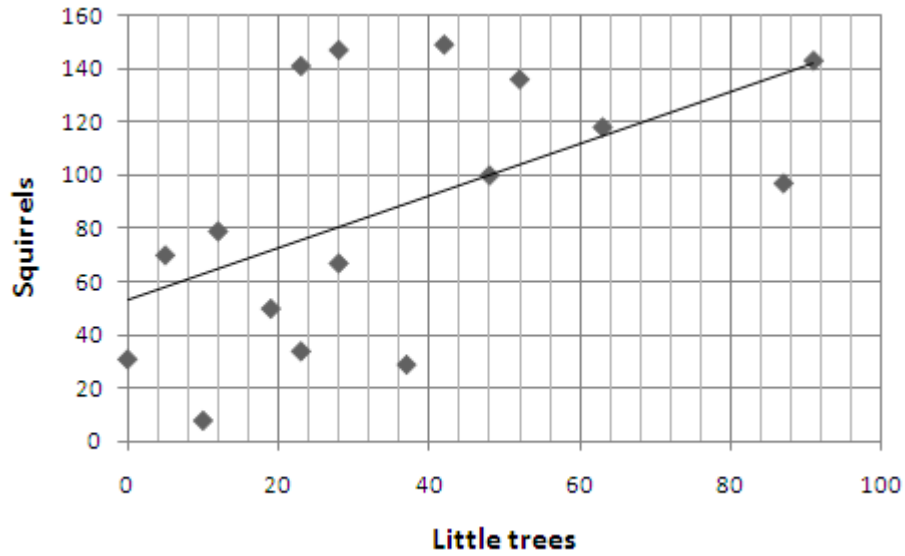
## ACTIVITY 2-2 Determining the Equation of the Trend Line

**Objective:** Review determining the equation of a line and interpret the resulting line.

### Materials:

Handout HE-H2 Determining the Equation of the Trend Line Activity Worksheet  
Graph paper or access to Excel

1. Use the line on the graph in Figure 2.7 below.



**Figure 2.7:** Example Trend Line

a. Begin by choosing two points on the trend line and use the following formula to determine the slope ( $m$ ).

$$m = \frac{(y_2 - y_1)}{(x_2 - x_1)}$$

b. Use the **point-slope form** of a line to determine the equation of the line.

**point-slope form** of a line is  $y - y_1 = m(x - x_1)$

Begin by substituting the value calculated for  $m$ . Then choose a data point on the line to use for  $x_1$  and  $y_1$ .

c. Solve for  $y$  to obtain the **slope-intercept** representation of the same line in the form  $y = mx + b$  where  $b$  is where the line intercepts the  $y$ -axis.

2. How might scientists use the equation of the trend line in squirrel research?

3. Using the table you created in Activity 2-1, plot the number of big tree versus number of squirrels on a graph and determine the equation for the line of best fit (trend line) using the steps outline above.

4. Does the fit of the line indicate a relationship probably exists? If so, is the relationship positive, negative or neutral?

5. Which of the two graphs would you expect to more precisely describe the relationship: big trees vs. squirrels or little trees vs. squirrels, and why?

## Practice

1. Using your table from Activity 2-1, plot the total number of trees versus the number of squirrels on a graph, draw a line of best fit (trend line), and determine the equation for the trend line.
2. What is the slope of your trend line?
3. Interpret the slope in context of the relationship between squirrels and total trees. Include units.

## Lesson 3                      Mathematical Modeling

As we try to model various situations it is sometimes necessary to place a **quantitative** measure on a **qualitative** description in order to categorize or classify data.

### How Big is a Big Tree?

In deciding the size classification of trees into big and small groups, a somewhat arbitrary decision was made about where the cutoff occurs between a big tree and small tree. Should a big tree have a circumference of over 120 cm or 150 cm? Does it make sense that if a tree has a diameter of 120 cm it is considered big, but a tree with a circumference of 119 cm is small? Is a one-centimeter difference really significant? Squirrels do not use a tape measure to determine which trees they prefer, but they may have general classes of preferences. If we, as biologists, don't know whether or not squirrels are using size as a characteristic to evaluate tree quality, then data can be analyzed to see if any particular cutoffs for a category provide the greatest sensitivity.



Photograph by Kaitlyn Gabric.

**Figure 3.1:** *Okay, so maybe the really smart squirrels use tape measures!*

There are two major reasons to classify the data. One objective of classifying data is to arrange large data sets so that it is easier to visualize their differences and similarities. Another is to build a **mathematical model** where the mathematical representation fits the biological reality. Perhaps squirrels are using the trees for different purposes such as “trees large enough to build nests in” vs. “trees too small for nests, but still providing food.” If so, the squirrels are making a distinction, and the mathematics should reflect that distinction. Of course, this works the other way as well. It doesn't make sense to break the size of trees down into 200 classifications with differences of 10 mm in circumference, if it's not thought that the squirrels themselves are distinguishing the trees at that level of detail.



It is important to make sure that we break data into groups or intervals based on some biological reason. Different classifications can be created and tested to determine how well the line fits the data and to see whether or not some particular classification helps explain the observed data better than others. In a study done on flying squirrels in Yosemite National Park, California, biologists found that 81% of nest trees were greater than 120 cm in diameter at breast height. [2] Based on this research for flying squirrel habitat preference, trees that have a diameter of at least 120 cm are classified as big, and those that have a diameter less than 120 cm are classified as little.



**Figure 3.2:** Squirrel Tree Choices

### More About Size

Every researcher must carefully examine the data before making classification determinations. For example, consider the Cooper's hawk, which in most environments prefers other birds as prey rather than rodents. It is possible to place the prey into a large prey category (flickers, jays, and doves) and a small prey category (sparrows, starlings and wrens). This data at first appears confusing. Some hawks prefer large birds and others prefer small birds as prey. Further study by scientists found that female hawks prefer the larger prey. Since they are larger than the male hawks, they can handle the kill of the larger prey. The smaller males prefer smaller prey, perhaps because they are easier for the hawk to handle.



**Figure 3.3:** Collecting Data on Prey Preferences

Another case of prey size preference is seen in cheetahs. Cheetahs can bring down prey up to 60 kg. Adult prey could be classified by size as large: impala (40 kg), Grant's gazelle (40 kg), lesser kudu (40 kg); or small: Thomson's gazelle (15 kg).<sup>[3][4]</sup> These herbivores are cited in *Kingdon*<sup>[5]</sup> as being common prey for cheetah, and are all under 60 kg—an upper limit on the size of prey that can be brought down by a cheetah.<sup>[5]</sup> The average mass of these cheetah-prey herbivores is 32 kg.<sup>[6]</sup> Classifying prey as small and large therefore may be misleading in this case since another prey organism, the gerenuk (25 kg), falls between the two classifications. Classifying it as small may skew the data in one direction, while classifying it as large may skew it in the other. It may make more sense to classify these data into three divisions of large, medium, and small. It is important to carefully consider classifications on a case-by-case basis.

### Questions for Discussion

1. What are two reasons why data could be split into classes in a scientific study?
2. What issues may result due to classification of data? Provide an example.

### ACTIVITY 3-1 Putting it Together: An Examination of Clownfish

**Objective:** Apply habitat concepts and ideas to a new population: clownfish.

**Materials:**

Handout HE-H3 Putting it Together Activity Worksheet  
Graph paper or access to Excel

The common clownfish is a tropical marine fish found in parts of Asia and Australia. The clownfish is found living on coral reefs or in sheltered lagoons no deeper than 15 meters. It lives amid the tentacles of a sea anemone eating the anemone's leftovers. The anemone paralyzes a fish with pneumatacysts (acts like a toxin) contained in its tentacles and then eats the fish. The clownfish eats the bits of fish left uneaten, but will also eat dead anemone tentacles, anemone parasites and plankton. The clownfish is left unharmed by the sea anemone's poison because of the mucus covering a clownfish body, and the clownfish actually gains important protection from its predators because the poison kills the predators. Clownfish eggs are laid and fertilized during the full moon and usually in the morning. This timing may be due to stronger water currents for distribution of the young fish, greater food supplies and overall increased visibility. Clownfish are not considered endangered; however, the coral reefs where they live are in trouble. Coral reefs face many issues including increased sediments due to run off from the land, fertilization run off, damage done by collectors and divers, and water temperature increases due to power plants and global warming. As coral reefs decline, clownfish will ultimately be affected.<sup>[7]</sup>

1. What is the **habitat** of the clownfish?
2. In the diagram below, list the **biotic** factors that affect a clownfish in the appropriate box and the **abiotic** factors in the other box.



Photograph by Ritiks (Own work) [CC-BY-SA-3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons

**Figure 3.1:** Biotic and Abiotic Factors for Clownfish

3. If a researcher was doing a study similar to the study of squirrels, what variables might the researcher collect data on to determine if there is a relationship between the sea anemone and the clownfish population?
4. Which of these variables is the dependent variable? Which are the independent variables?
5. If the researcher chose to look at the number of anemones and the number of clownfish, predict whether the relationship between the two would be a positive relationship, a negative relationship, or no relationship. Explain your reasoning.
6. Predict which of the biotic factors or abiotic factors would result in a negative relationship. Explain your reasoning.
7. Suggest a factor that would result in no relationship, and explain why there is not a relationship.
8. Classifying the sea anemones by size may be useful in the analysis of data if sea anemone size is important to the clownfish. Explain how the researcher might determine what would be considered “big” and “small” anemones.

## Lesson 4

## How Happy Is That Squirrel?

A **community** of organisms and the physical environment in which they interact is called an **ecosystem**. Ecosystems come in many sizes. Ecosystems are divided into two types: aquatic (water based) and terrestrial (land based). Some examples of ecosystems are a forest, a lake, a grassland and a stream. The boundaries are not defined but often are fairly clear. In the case of the northern flying squirrels' ecosystem, the edge of the forest is the boundary. Abiotic factors such as sunlight, soil type, amount of rainfall and temperature play an important role in the type of ecosystem that will exist. The interaction of all of the abiotic factors in a particular area therefore will help determine the type of ecosystem. The biotic parts of the ecosystem will also determine the type of ecosystem. Each ecosystem will have a distinctive group of plants, animals, fungi and other organisms.

### Question for Discussion

1. Name at least three additional examples of ecosystems.

### Ecological

It is very important for organisms to survive and reproduce if the **population** of that species is to be maintained. For organisms to survive and reproduce, they require the appropriate biotic and abiotic factors for which they are adapted. Species tend to live in habitats where others of the same species are living. This is called **conspecific attraction**. They must have the right environment that provides such things as suitable temperature range, appropriate amount of water, food resources and necessary shelter if they are to survive. The sum of these requirements is called the ecological **niche** of an organism. The niche is the organism's role in the environment and the way it lives its life.

An organism's niche includes:

- a. The resources it uses in the ecosystem. This may include such things as food, water, oxygen, space and twigs to build a nest.
- b. Other species with which it competes for resources.
- c. What resources it contributes to the ecosystem, which may include such things as carbon dioxide, recycling of nutrients, food for a predator or decomposer and seed dispersal.

Some facts known about the niche of the northern flying squirrels include:<sup>[8]</sup>

- a. They are strictly nocturnal. Northern flying squirrels are active for about two hours, beginning an hour after sunset, and again for an hour and a half to two hours before sunrise.
- b. They are clumsy on the ground, but can glide gracefully from tree to tree.
- c. The home range of a northern flying squirrel ranges from 0.8 hectares to 31 hectares.
- d. They use some of the same nesting materials and nesting sites as other species of squirrels that live in the same area.
- e. Their food consists predominantly of fungi, lichens, nuts and seeds.
- f. They nest in conifers 1 to 18 meters above the ground.
- g. They use lichens, moss and leaves to make their nests.

- h. They are an important prey species for the endangered spotted owl, martens, fox and lynx.
- i. They are important in the spread of spores of fungi that improve the health of the trees that they live with and therefore improve the health of the entire forest.

### **Question for Discussion**

2. Classify the above facts about the niche of the northern flying squirrel by writing the number of the fact next to the term that describes it.
- a. Resource needed by the squirrels
  - b. Food
  - c. Competitors
  - d. The squirrels' contributions to the environment

### **Returning to the Squirrels at Frostbite Falls**

Nocturnal animals, such as the flying squirrel, often use darkness to avoid predators. For example, it may be safer to feed at night. Animal orientation can also be affected by additional lighting. They may be attracted to the lighting or they may avoid it. As a result their feeding behaviors, reproduction, communication, and other behaviors may be affected. If lighting does not affect the animal directly, it may affect it indirectly by changing the behaviors of other organisms in its environment. This can have a ripple effect throughout the ecosystem.

Shortly after the first survey of squirrel populations on the north side of Frostbite Falls, another survey was done on the south side of Frostbite Falls, where more people live. Since some of the area is suburban, the number of streetlights were counted to determine if lighting in the area has an effect on the squirrel population.

### **Question for Discussion**

3. Hypothesize whether the relationship between the squirrels and streetlights will be positive, negative or neutral. Explain your reasoning.

### **ACTIVITY 4-1 Introducing Streetlights to Frostbite Falls**

**Objective:** Graph and analyze data obtained from a site survey.

**Materials:**

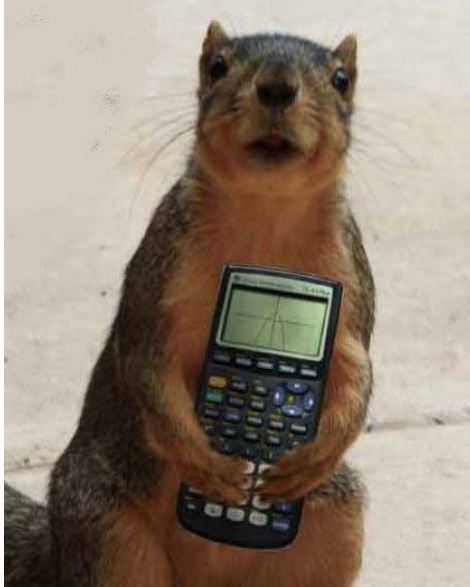
Handout HE-H4 Introducing Streetlights to Frostbite Falls Activity Worksheet  
Graph paper or access to Excel

The results of a site survey of the south side of Frostbite Falls are contained in the following table.

28 little trees 30 big trees 11 streetlights 21 squirrels	30 little trees 24 big trees 12 streetlights 15 squirrels	20 little trees 7 big trees 12 streetlights 0 squirrels	35 little trees 22 big trees 11 streetlights 14 squirrels
46 little trees 28 big trees 9 streetlights 22 squirrels	33 little trees 35 big trees 10 streetlights 26 squirrels	37 little trees 18 big trees 14 streetlights 8 squirrels	21 little trees 38 big trees 7 streetlights 30 squirrels
27 little trees 68 big trees 7 streetlights 58 squirrels	21 little trees 48 big trees 6 streetlights 40 squirrels	26 little trees 72 big trees 2 streetlights 65 squirrels	25 little trees 33 big trees 5 streetlights 28 squirrels
32 little trees 63 big trees 3 streetlights 57 squirrels	64 little trees 93 big trees 2 streetlights 88 squirrels	97 little trees 107 big trees 0 streetlights 106 squirrels	118 little trees 112 big trees 0 streetlights 112 squirrels

**Table 4.1:** Data Set 2 from the South Side of Frostbite Falls

1. Use the data from table 4.1 to graph the number of streetlights vs. the squirrel population.
  - a. What is the independent variable?
  - b. What is the dependent variable?
  - c. Graph the data and draw the trend line.
  - d. Does the trend line indicate a positive relationship, negative relationship, or no relationship? Explain your reasoning.
  - e. What is the equation of the line of best fit for the number of streetlights vs. squirrel population graph?
  - f. Do your findings support your hypothesis?
2. Graph the number of little trees vs. the squirrel population. Determine the line of best fit. What is the equation of the line of best fit for little trees vs. squirrel population?
3. Graph the number of big trees vs. the squirrel population. Determine the line of best fit. What is the equation of the line of best fit for big trees vs. squirrel population?



Photograph by Kaitlyn Gabric.

**Figure 4.1:** *Okay, so if these calculations are right guys, we should live right over there!*

### Three Equations, One Squirrel Population: What's Next?

In order to summarize the results in a concise manner, the following algebraic notation for the variables and the equations using this notation are given below.

$L$  = number of little trees

$B$  = number of big trees

$S$  = number of streetlights

$y$  = number of squirrels

The following are trend line equations derived from the graphs of the data from Frostbite Falls.

The equation for the number of squirrels based on the number of little trees is

$$y = 0.9658L + 3.2868.$$

The equation for the number of squirrels based on the number of big trees is

$$y = 1.0649B - 9.9876.$$

The equation for the number of squirrels based on the number of streetlights is

$$y = -6.9627S + 91.428.$$

How can these three equations help predict how attractive an area will be to squirrels? For convenience, this predicted habitat attractiveness to squirrels will be called “squirrel happiness” ( $H$ ). The total squirrel happiness will depend on many factors not explored in this problem, but for our purposes we will use our three factors of streetlights, big trees and little trees. A happiness measure will give us a way to characterize the quality of a habitat from the perspective of a squirrel. A good model representing squirrel happiness will then give us insight into the size of a squirrel population one can expect in a habitat of a particular quality.

### Three Variables, One Equation

In describing squirrel happiness, it would be useful if a single value of happiness existed for any combination of values of habitat measurement. Such an equation needs to include some contribution from each of the individual factors influencing squirrel happiness. This equation will, therefore, have more than one independent variable. Based on the values of these independent variables, we can compute the value of the dependent variable. To accomplish this, three possible equations are examined to predict squirrel happiness. The construction of these three equations will become clearer during the rest of the section, though many other possible equations could be used. From these three, one will be chosen to continue the model.

The new possible happiness equations are:

#### Equation 1

$$H = 0.9658L + 1.0649B - 6.9627S$$

#### Equation 2

$$H = 0.9658L + 3(1.0649)B - 2(6.9627)S$$

#### Equation 3

$$H = \frac{0.9658L + 3.2868 + 1.0649B - 9.9876 - 6.9627S + 91.428}{3}$$

#### Equation 1

Take the slope from each of the trend lines with the associated variable derived from the data of Frostbite Falls and add them together. This results in the following equation:

$$H = 0.9658L + 1.0649B - 6.9627S$$

This equation defines a descriptive model. Several other descriptive models will be compared to this one to see which one is best.

### Questions for Discussion

4. Equation 1 uses the slopes, but not the constants from the three original equations. Why would it not make a difference if the constants were added to the equation?

5. To get a feel for how happy squirrels are in an area, calculate the  $H$  values for the south side of Frostbite Falls given the previous data as shown in Table 4.2. The first two grid squares are completed. Calculate the  $H$  values for the remainder of the squares. Do you notice any patterns?

$$H = 0.9658(\mathbf{28}) + 1.0649(\mathbf{30}) - 6.9627(\mathbf{11}) = -17.6003$$

$$H = 0.9658(\mathbf{30}) + 1.0649(\mathbf{24}) - 6.9627(\mathbf{12}) = -29.0208$$



28 little trees 30 big trees 11 streetlights 21 squirrels $H = -17.6003$	30 little trees 24 big trees 12 streetlights 15 squirrels $H = -29.0208$	20 little trees 7 big trees 12 streetlights 0 squirrels $H =$	35 little trees 22 big trees 11 streetlights 14 squirrels $H =$
46 little trees 28 big trees 9 streetlights 22 squirrels $H =$	33 little trees 35 big trees 10 streetlights 26 squirrels $H =$	37 little trees 18 big trees 14 streetlights 8 squirrels $H =$	21 little trees 38 big trees 7 streetlights 30 squirrels $H =$
27 little trees 68 big trees 7 streetlights 58 squirrels $H =$	21 little trees 48 big trees 6 streetlights 40 squirrels $H =$	26 little trees 72 big trees 2 streetlights 65 squirrels $H =$	25 little trees 33 big trees 5 streetlights 28 squirrels $H =$
32 little trees 63 big trees 3 streetlights 57 squirrels $H =$	64 little trees 93 big trees 2 streetlights 88 squirrels $H =$	97 little trees 107 big trees 0 streetlights 106 squirrels $H =$	118 little trees 112 big trees 0 streetlights 112 squirrels $H =$

**Table 4.2:** Happiness – Data Set 2 – Equation 1

The  $H$  just calculated was the sum of the three separate pieces,  $H = 0.9658L + 1.0649B - 6.9627S$ . But maybe squirrels care about some individual factors more than others.

### Equation 2

Try the same exercise again, but this time, try a different descriptive model (using equation 2) to see if it is a better predictor:

$$H = 0.9658L + 3(1.0649)B - 2(6.9627)S.$$

### Questions for Discussion

6. This equation tells a slightly different biological story. Explain what this equation means in terms of the effects of the independent variables (little trees, big trees, and streetlights) on squirrel happiness, and how it is different from the previous equation.

7. Now compute  $H$  for the same data, but with the new equation. Again, the first two grid squares of Table 4.3 are filled in already. Do you see any patterns?

28 little trees 30 big trees 11 streetlights 21 squirrels <b><math>H = -30.296</math></b>	30 little trees 24 big trees 12 streetlights 15 squirrels <b><math>H = -61.458</math></b>	20 little trees 7 big trees 12 streetlights 0 squirrels $H =$	35 little trees 22 big trees 11 streetlights 14 squirrels $H =$
46 little trees 28 big trees 9 streetlights 22 squirrels $H =$	33 little trees 35 big trees 10 streetlights 26 squirrels $H =$	37 little trees 18 big trees 14 streetlights 8 squirrels $H =$	21 little trees 38 big trees 7 streetlights 30 squirrels $H =$
27 little trees 68 big trees 7 streetlights 58 squirrels $H =$	21 little trees 48 big trees 6 streetlights 40 squirrels $H =$	26 little trees 72 big trees 2 streetlights 65 squirrels $H =$	25 little trees 33 big trees 5 streetlights 28 squirrels $H =$
32 little trees 63 big trees 3 streetlights 57 squirrels $H =$	64 little trees 93 big trees 2 streetlights 88 squirrels $H =$	97 little trees 107 big trees 0 streetlights 106 squirrels $H =$	118 little trees 112 big trees 0 streetlights 112 squirrels $H =$

**Table 4.3:** Happiness – Data Set 2 – Equation 2

Notice how these first two different equations result in totally different predicted outcomes for squirrel happiness. How the equation is defined tells a story about the importance of these three factors to squirrel happiness. The accuracy of the story depends on how well the model equation fits the data, the additional variables that could be considered, and the interactions between variables.

A great deal of time can be spent trying different equations to determine which model for squirrel happiness most accurately predicts the relative squirrel population. This unit is content with the equation that gives a measure of how happy the squirrels will be in an area, assuming the contribution of each of the measured environmental factors is proportional to its coefficient. This squirrel happiness value can be compared to the squirrel happiness values of other areas to get a relative measure of how attractive those areas would be to squirrels. The next lesson looks at how to use these values to determine whether or not an area would be capable of sustaining a squirrel population at the desired level. Let's look at our last equation.

### Equation 3

Try a descriptive model using the third equation, which includes the constant factors and weights each of the original equations equally (1/3) to describe squirrel happiness.

$$H = \frac{0.9658L + 3.2868 + 1.0649B - 9.9876 - 6.9627S + 91.428}{3}$$

### Question for Discussion

9. Once again, this equation tells a slightly different biological story. Explain what this equation means in terms of the effects of the independent variables (little trees, big trees, and streetlights) on squirrel happiness, and how it is different from the previous equation.

### ACTIVITY 4-2 Evaluating Our Happiness Model

**Objective:** To determine if our model of squirrel happiness predicts relative population.

**Materials:**

Handout HE-H5: Evaluating Our Happiness Model Activity Worksheet

Use the model for  $H$ , squirrel happiness, shown below (equation 3).

$$H = \frac{0.9658L + 3.2868 + 1.0649B - 9.9876 - 6.9627S + 91.428}{3}$$

1. Reduce the equation to simplest terms.
2. To determine if this is an acceptable predictor for squirrel happiness, calculate the values of  $H$  for each of the areas in Table 4.4 using this third equation. Do you see a pattern?

28 little trees 30 big trees 11 streetlights 21 squirrels $H =$	30 little trees 24 big trees 12 streetlights 15 squirrels $H =$	20 little trees 7 big trees 12 streetlights 0 squirrels $H =$	35 little trees 22 big trees 11 streetlights 14 squirrels $H =$
46 little trees 28 big trees 9 streetlights 22 squirrels $H =$	33 little trees 35 big trees 10 streetlights 26 squirrels $H =$	37 little trees 18 big trees 14 streetlights 8 squirrels $H =$	21 little trees 38 big trees 7 streetlights 30 squirrels $H =$
27 little trees 68 big trees 7 streetlights 58 squirrels $H =$	21 little trees 48 big trees 6 streetlights 40 squirrels $H =$	26 little trees 72 big trees 2 streetlights 65 squirrels $H =$	25 little trees 33 big trees 5 streetlights 28 squirrels $H =$
32 little trees 63 big trees 3 streetlights 57 squirrels $H =$	64 little trees 93 big trees 2 streetlights 88 squirrels $H =$	97 little trees 107 big trees 0 streetlights 106 squirrels $H =$	118 little trees 112 big trees 0 streetlights 112 squirrels $H =$

**Table 4.4:** Data Table with Happiness Values

3. Compare squirrel happiness from the model with the squirrel population to see if the relative happiness model we are using is a good predictor of relative population by filling in the

Comparison table below. For each of two grids in the Data table above, determine whether happiness goes up, goes down or remains the same. Then determine if squirrel population goes up, goes down or remains the same. Finally, determine if there is an agreement. The Comparison table below refers to grid squares named in the form (column, row). For example, (2,3) is the grid square in row 2, column 3 of the Data table above. The first line of Table 4.5 is completed for you.

Grid Names (A) to (B)	Grid A Pop.	Grid B Pop.	Trend	Grid 1 Happiness	Grid 2 Happiness	Trend	Agree? (Y or N)
(1,1) to (1,2)	21	15	down	22.3757	18.56	down	Y
(1,1) to (1,3)							
(3,2) to (3,3)							
(2,1) to (2,2)							
(4,3) to (4,4)							

**Table 4.5:** Comparison Table

4. Do all of the grid square population changes agree with the grid square happiness changes? If not, where do they not agree?

This now leads to the question of whether or not this is an ideal model. The answer is that it is perhaps not that good. It is good at predicting the attractiveness of an area to squirrels, but it is not perfect.

5. What other method might you use to investigate whether this is a good predictive model or not? Explore and describe another method you might use.

We could continue to try different models to see if there is a better model using the data at hand, but the science of the situation is that there are other factors involved in determining the number of flying squirrels living in an area. These include predators, fungal mass, seasonal temperature changes, and amount of water. Working within the limitations of time and budget, we have come up with a model that in general predicts the attractiveness of the area to the squirrels to fit the researchers' needs.

## Lesson 5                      Predictive Modeling

How can the equations created in the first four lessons about known conditions be used to make predictions about areas that are unknown? When the results of a specific **habitat design** are predicted, it is referred to as predictive modeling. The first limitation of predictive modeling is that the data may not be extrapolated beyond the limits of what was measured. For example, if the largest trees at Frostbite Falls were 200 cm, then the equation using tree size will not be used to make predictions about how happy squirrels would be with tree trunks of 250 cm. It might be used to make a first guess, but it would only be a guess. It is important to actually measure squirrel happiness with trees of that size or larger to see if that guess is accurate.

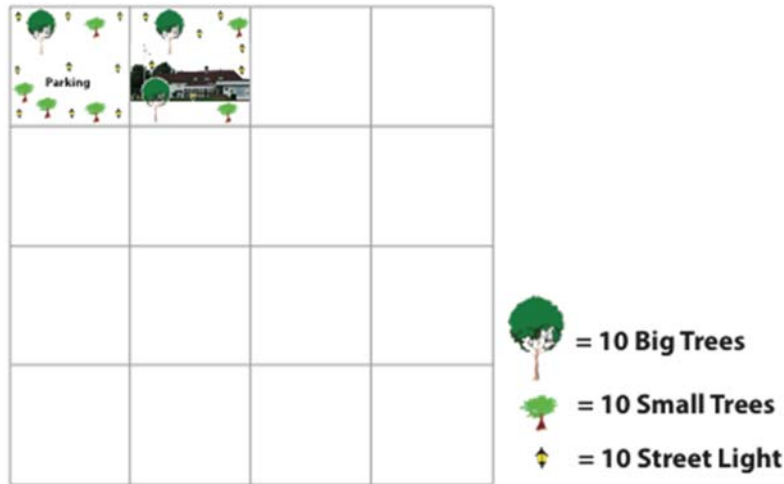
As discussed earlier, species live in an ecosystem with many other species. This lesson is concerned with how to predict the impact of habitat characteristics on only one species, but biologists can also look at similar questions for many species at a time. For this unit we develop equations to make predictions about the effect that human encroachment will have on the squirrels' habitat. We attempt to predict whether there can be a happy coexistence of humans and squirrels. Sometimes biologists are more concerned with making sure a single species does not go extinct, and sometimes they are more concerned with maintaining the ecosystem and its biodiversity.

### Designing a Golf Course

Can a golf course be designed to make humans and squirrels happy? If the squirrel happiness in an environment where the squirrel population is at an acceptable value is calculated, and the same equations are used to calculate the squirrel happiness in another area, then a similar squirrel population is expected (but not guaranteed) given a similar value for squirrel happiness. With a target value of squirrel happiness determined by descriptive models of areas where squirrels are successfully coexisting with humans, can the number of trees required by the squirrels and the number of acceptable lights be calculated without reducing squirrel happiness below the determined minimum?

In Lesson 4, the third equation to calculate squirrel happiness predicted a total squirrel happiness of 690. This is found by summing the happiness values for all of the grids. If humans are going to develop an area of exactly the same size with flying squirrels, environmentalists and government agencies may place the limitation of not displacing the endangered species in the area and require the developer to maintain a sustainable squirrel population. Assuming that this model captures the most critical factors of squirrel happiness, then the developer can support the claim that the population is sustainable by showing that the design has a squirrel happiness of at least 690. This is the same happiness as another area where a population of flying squirrels is surviving. The developer will want to come as close as possible to the target of 690, since the resources that make squirrels happy are in the way of the construction, and many of the improvements that would make a profit for the developer are likely to reduce squirrel happiness. Note: This direct comparison can only be done because the two areas are exactly the same size. If the target area for happiness is for a larger or smaller area, then it is necessary to increase, or decrease the happiness target proportionally.

With these limitations in mind, a developer is designing a golf course for an area inhabited by flying squirrels. The area is the same size as the south side of Frostbite Falls. He will begin the project by drawing a 4 x 4 square grid. A parking lot is needed in one section of the grid. This section will have only a few little trees and even fewer big trees. Parking lot lighting will require many streetlights. A second square of the grid will house the clubhouse area. It will also have only a few little and big trees and, again, will also need many lights. With these constraints on two of the grid squares, the remainder of the course can be developed to achieve the target squirrel happiness of 690.



**Figure 5.1:** Proposed Golf Course Grid

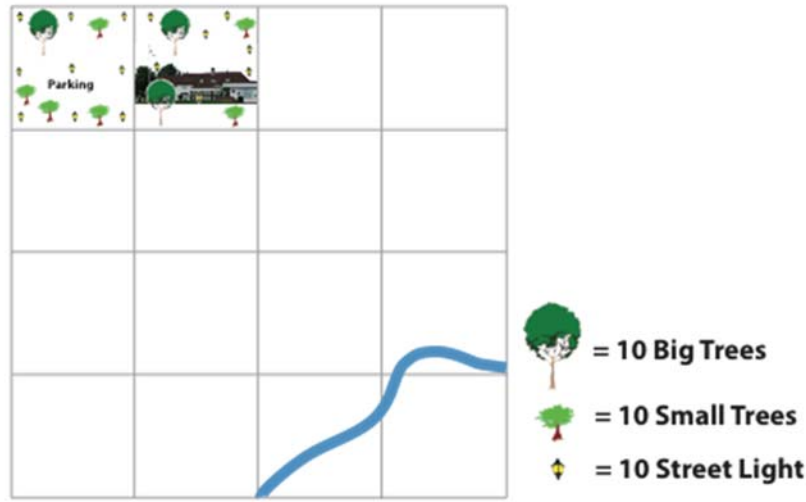
There are 14 grid squares left to provide the bulk of the happiness value. To acquire a total squirrel happiness of around 690, an average squirrel happiness of a little less than  $690/14 = 49$  is needed for each grid square. Since the golf course will need significant open areas with no trees, happiness values for the grid squares may vary significantly. Working on the assumption that it is better to place the trees on the edges of the course away from the fairways and perhaps not too close to the clubhouse where squirrels could become pests, a quick table is made with general descriptions in each grid square.

parking area; few trees	clubhouse; few trees	few trees	some trees
few trees	few trees	few trees	many trees
some trees	few trees	few trees	many trees
many trees	many trees	many trees	many trees

**Table 5.1:** Grid Description

Depending on the layout of the holes, and to take advantage of natural features such as streams, golf course designers can adjust their tree plan. For example, a stream across one of the corners of the course could be a natural water obstacle the designers want to use as part of the course.

This could modify our course sketch to be:



**Figure 5.2:** Revised Proposed Golf Course Grid

parking area; few trees	clubhouse; few trees	few trees	some trees
few trees	few trees	few trees	many trees
some trees	few trees	some trees	stream; some trees
many trees	many trees	stream; some trees	many trees

**Figure 5.2:** Revised Grid Description

Use Figure 5.2 as the basis for the course design. Can enough trees be put in to support a squirrel happiness of 690?

**ACTIVITY 5-1 Designing a Squirrel Friendly Golf Course**

**Objective:** Practice predictive modeling to make design decisions.

**Material:**

Handout HE-H6: Designing a Squirrel Friendly Golf Course Activity Worksheet

Using the 16-square grid developed in Lesson 5 for our golf course, we add a few trees and significant light to the parking area and clubhouse squares as shown below. We then look at the four grid squares that adjoin the clubhouse and parking area. Assume only 4 lights are required to provide sufficient lighting for those areas. Use 25 little and 30 big trees each in those areas to produce the following plan.

<b>parking area</b> little trees 10 big trees 2 lights 21 H =	<b>clubhouse</b> little trees 6 big trees 3 lights 24 H =	<b>few trees</b> little trees 25 big trees 30 lights 4 H =	<b>some trees</b> little trees big trees lights H =
<b>few trees</b> little trees 25 big trees 30 lights 4 H =	<b>few trees</b> little trees 25 big trees 30 lights 4 H =	<b>few trees</b> little trees 25 big trees 30 lights 4 H =	<b>many trees</b> little trees big trees lights H =
<b>some trees</b> little trees big trees lights H =	<b>few trees</b> little trees big trees lights H =	<b>some trees</b> little trees big trees lights H =	<b>some trees</b> little trees big trees lights H =
<b>many trees</b> little trees big trees lights H =	<b>many trees</b> little trees big trees lights H =	<b>some trees</b> little trees big trees lights H =	<b>many trees</b> little trees big trees lights H =

**Table 5.3:** Activity Grid Description

1. Use our happiness equation below to determine the total happiness value provided by the six grid squares designed above.

$$H = 0.3219L + 0.3550B - 2.3209S + 28.2424$$

2. What is the total happiness value needed from the remaining ten grid squares? What is the average happiness value needed per square?

3. Look back at the numbers of trees (big and little) and streetlights in Frostbite Falls from Lesson 4 and describe the following in terms of range of trees.

a. Few Trees: \_\_\_\_\_ < little trees < \_\_\_\_\_  
 \_\_\_\_\_ < big trees < \_\_\_\_\_  
 \_\_\_\_\_ < total trees < \_\_\_\_\_

b. Some Trees: \_\_\_\_\_ < little trees < \_\_\_\_\_  
 \_\_\_\_\_ < big trees < \_\_\_\_\_  
 \_\_\_\_\_ < total trees < \_\_\_\_\_

c. Many Trees: \_\_\_\_\_ < little trees < \_\_\_\_\_  
 \_\_\_\_\_ < big trees < \_\_\_\_\_  
 \_\_\_\_\_ < total trees < \_\_\_\_\_

4. In which grid squares would you put lights? How many and why?

5. Analyze your plan.



- a. Fill in the golf course grid with your values for little trees, big trees and lights.
- b. Determine the happiness H value for each grid square.
- c. Determine the total happiness H value for the golf course.
- d. How can you adjust your plan and still meet the requirement of a happiness value of  $H = 690$ ?
- e. The golf club members want to put a swimming pool near the clubhouse. Describe the adjustments you would make to make sure you remained above a happiness value of  $H = 690$ .

### **Other Considerations of Design**

Of course, there are many reasons why the golf course designers might want to have certain things in particular areas. Only the aesthetics and human use aspects are discussed in our example, but economic costs and benefits are also frequently important. It's possible that each extra light costs \$1000 dollars to install, but the extra light makes people happier playing golf on the course, and is expected to generate \$4000 worth of extra business over the life of the light. This might mean that designers are more willing to add lots of extra trees everywhere to help keep the squirrels happy enough, despite having lots and lots of lights around, if it can be done. This type of analysis can help designers consider alternatives.

### **Questions for Discussion**

1. How many small trees need to be planted on the course to make up for the extra unhappiness caused by ten extra lights? Instead can a few really big trees be planted in only some places and still make up for the extra unhappiness from the lights? What are the equivalent alternatives?
2. Planning is critical. How else can the designers of the golf course save money in terms of using the existing terrain and vegetation?

This same method works in reverse for species that aren't endangered, but that humans consider "pests" or "dangerous." It is frequently used for things like keeping geese away from airports. When humans want to keep a species away from an area, the happiness can be kept **less** than the least value that allows the other species to live there. This means that any scenario that made people happy and kept the other species' happiness below the goal number would be good.

In practice, any particular single goal number is probably too specific to actually be correct. If the concern is conservation, it's probably best to provide a buffer around the goal value. How sensitive (i.e., large) the buffer should be depends on the happiness equation, since that determines how large an effect a small change would have on the happiness of the species in question.


## Lesson 6 Exploring Habitat Preferences Lab

What are the abiotic preferences of the common house cricket, *Acheta domestica*?

### Background Information

Look carefully around your yard, in a nearby wooded area, or even in your basement and you are likely to find crickets. Many people often confuse them with grasshoppers because of their similar body structure, especially the hind legs that are adapted for jumping. Some species prefer a cool dark and damp habitat that explains why they like your basement. In the wild, they tend to spend their days hidden in dark areas and wait until night to come out and feed. Different species of crickets will prefer different habitats. Crickets are omnivores and scavengers, meaning that they feed on plant and animal material as well as decaying plant material and fungi. They help to renew the minerals in the soil by breaking down plant material. They are also an important source of food for numerous other animals such as birds, lizards, amphibians, and spiders.

Crickets are insects and are classified in the family Gryllidae. There are about 900 species of crickets. Some of the more common are seen in the table below.

Common Name	Scientific Name	
House Cricket	<i>Acheta domestica</i>	
Field Cricket	<i>Gryllus</i> spp.	
Short tailed Cricket	<i>Anurogryllus</i> spp.	
Lesser Field Cricket	<i>Miogryllus</i> spp.	
Tropical House Cricket	<i>Gryllodes sigillatus</i>	
Japanese Burrowing Cricket	<i>Velarifictorus micad</i>	

Cricket Photo by Brian Gratwicke [CC-BY-2.0 (<http://creativecommons.org/licenses/by/2.0>)], via Wikimedia Commons

For this experiment, any species of cricket will work. Common house crickets are the easiest to obtain since they may be bought from various vendors. Crickets are often sold as pet food for lizards and amphibians in pet stores. Some also use crickets as bait, so they be found in bait stores too. House crickets often spend their entire life living in a house or building. All they need is warmth, food, and enough moisture. If raising common house crickets, they prefer a hot dry environment (26-32 C) with a water source and direct light in which to bask. They also require moist soil in which to lay their eggs. Cricket food can be bought at a pet store, but a money saving alternative is to feed them ground up dry dog or cat food as the main energy source. The crickets will also appreciate some raw vegetable scraps.

## Questions for Discussion

1. In what type of habitat would common house crickets be found?
2. What are the biotic requirements of these animals?
3. What are the abiotic requirements of these animals?
4. If graphing crickets and temperature, which is the dependent variable?
5. If graphing light and crickets, which is the independent variable?

## Activity 6-1 Cricket Lab

**Objective:** Explore the habitat preferences of a species (crickets).

**Materials:**

Handout HE-H7: Cricket Lab Activity Worksheet

For each group: Crickets, a large plastic container (cardboard will also work) approximately 60cm L x 40cm W x 30cm, a heating pad, cold pack/ice pack, masking tape, thermometer, 3 cardboard boxes (shoe box may work) that will fit inside the larger container, White plastic bag

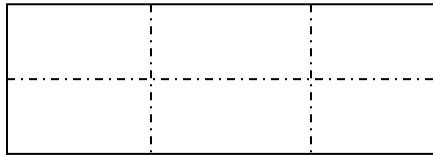
### Part I.

#### Hypothesis

Write a hypothesis about the temperature preference of house crickets based on the background information that has been provided.

#### Experimental Procedure

1. The large container will serve as a microenvironment. Using the masking tape create a 2 x 3 grid in the bottom of the container.



2. Temperature will be tested within three different ranges to test for cricket preference. Try to get the temperature in these ranges.

Setting	Temperature range
High	The temperature will be greater than 25 °C, but less than 35 °C.
Medium	The temperature will be greater than 15 °C, but less than 25 °C.
Low	The temperature will be less than 15 °C

3. To create the different environments, keep one side warmer than the other. This can be achieved by placing cold packs under the 2 grids on the left and a heating pad under the 2 grids on the right. The middle 2 grids will be left at room temperature. Record the temperatures of the 3 temperature zones.

cool	warm	warmer
cool	warm	warmer

Many variations for this exist depending on the materials available. Be creative.

4. Release 20-30 crickets into the middle of each container and allow them to move freely about. If the container is plastic and 30cm high, the crickets will not be able to jump out. Do not disturb the chamber at this time as it may frighten the crickets and inhibit their movement.

5. After 5 minutes, record the number of crickets in each grid. Turn the container around 180 degrees to cool the warm side and warm the cool side. After 5 minutes, record the number of crickets in each grid.

6. Remove the crickets from the container and return to cricket cage.

**Data**

Record your data in the following table. Write the number of crickets found in each grid during each 5 minute time interval.

Trial 1			Trial 2		
cool	warm	warmer	cool	warm	warmer
cool	warm	warmer	cool	warm	warmer

**Analysis**

1. Use graph paper to graph the data. Use temperature in Celsius as the independent variable and the number of crickets as the dependent variable. Remember to put the independent variable on the x-axis. There will be four data points at each temperature setting.

2. Create a trend line.

3. Determine the slope-intercept form of the equation for the line,  $y = mx + b$ .

4. Rewrite the equation as  $C_T = mT + b$ , where  $C_T$  is the number of crickets and T is setting of temperature.

**Part II.**

**Hypothesis**

Write a hypothesis about the light intensity preference of house crickets based on the background information that has been provided.

## Experimental Procedure

1. Repeat the experiment in part A by testing a different condition, light intensity. Light intensity will be tested at three different settings within the following ranges to test for cricket preference.

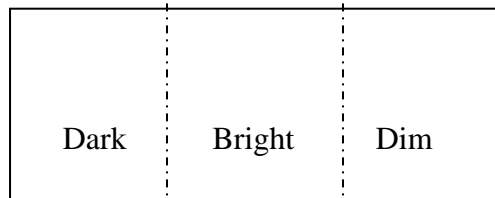
Setting	Ranges
High	All room light is allowed into the container (800-1000lux)
Medium	Some light is blocked from the container (400-600lux)
Low	No light enters the container (0-200lux)

2. To create an environment with very little or no light, the first cardboard will only have 2cm cut off one of the long edges. This will allow crickets to crawl under this box. The box will be placed inside the larger container with the bottom of the box up and blocking out light.

The cardboard box in the middle will have 2cm cut off both of the long edges to allow crickets to crawl through either side. The bottom of the box will be cut out and left open to allow all light in.

The third cardboard box will have 2cm cut off one of the long edges to allow crickets to crawl into this box. The bottom of the box will be cut out and covered with a white plastic bag to allow some light in.

3. Release 20-30 crickets in the middle box with the open lid and allow them to move freely about. Do not disturb the chamber at this time as it may frighten the crickets and inhibit their movement.



4. After 5 minutes, record the number of crickets in each box. Return the crickets to the center box and repeat the trial.

## Data

Record your data in the following table. Write the number of crickets found in each grid during each 5 minute time interval.

Trial 1			Trial 2		
Dark	Bright	Dim	Dark	Bright	Dim

### Analysis

1. Use graph paper to graph the data. If a lux meter with probes is available record the measurement. If a lux meter is not available, light intensity will be graphed as 100 lux for low light, 500 lux for medium light, and 900 lux for high light. Remember to put the independent variable on the x-axis. There will be two data points at each light setting.
2. Create a trend line.
3. Determine the slope-intercept form of the equation for the line,  $y = mx + b$ .
4. Rewrite the equation as  $C_L = mL + b$ , where  $C_L$  is number of crickets and  $L$  is setting of light.

### Practice

1. Recall from Lesson 4 that three different variables were combined into a single equation to predict squirrel happiness. The 2 variables tested in Parts I and II of this lab will be combined in the equation below. This equation predicts cricket happiness,  $C_p$ , due to both temperature and light.

$$C_p = \frac{C_T + C_L}{2}$$

Calculate  $C_p$  for the given values of temperature and light intensity. In the table below, record  $C_p$  for all of the possible combinations of temperature and light.

	10°C	20°C	30°C
100 lux			
500 lux			
900 lux			

2. **Hypothesis.** Write a hypothesis that predicts which combined conditions of light and temperature will result in the greatest cricket happiness.
3. **Experimental Procedure.** Design an experiment to test your new hypothesis. Use the larger container with the 3 boxes to control light and the ice packs and heating pad to control temperature. Multiple trials with variations may need to be run. Run each experiment for 5 minutes.
4. **Data.** Label the grids with the appropriate combinations of temperature and light and record your data.


5. **Analysis.** Compare the predictions made for  $C_p$  with the results of the experiments after 5 minutes. Note any similarities and differences that occurred.

6. **Conclusion.** Write a conclusion for part C of the experiment. The conclusion should begin with a restatement of the original problem and be followed by a very short summary of the 3 experiments. The length should only be a few sentences. Then restate your hypothesis for part C and explain why it was selected. Finally, does your analysis support your hypothesis or refute it. Explain why this is so. What was learned from this experiment? What further experimentation or mathematical analysis could be done to further your understanding of this topic?

## Lesson 7 Building a Ski Resort Project

A company wants to build a ski resort near Frostbite Falls. They have an area that they have divided into a  $4 \times 6$  grid (24 grid squares). On the side of the mountain, the existing trees are sparser, and conservationists have set the target squirrel happiness for this area at 1000.00. Since there are few preexisting big trees, none of the areas can have more than 80 big trees. There will have to be an area for parking and one grid square devoted to the ski lodge. You are preparing a presentation for the city council.

1. Design the resort with the restrictions described above.
2. Prepare a diagram of the ski resort. Be sure to include a legend.
3. Write a letter to the city council or prepare a slide presentation describing the resort with explanations for your design decisions and mathematical evidence that you have satisfied the conservationists' requirements. Include information on lighting, parking, the lodge, the number of ski slopes and ski lifts, and any other information you want to relate to the city council.



## **Glossary**

**Abiotic** – of or having to do with non-living chemical or physical characteristics.

**Absolute value** - the numerical value of a number without its sign.

**Biotic** – of or having to do with living organisms or living systems.

**Community** - a set of coexisting populations.

**Conspecific attraction** – the attraction of individual organisms to other organisms of the same species.

**Correlation** – the extent of correspondence between two variables.

**Dependent variable** – a variable whose value is determined by the value of another (independent) variable; this variable is traditionally graphed along the vertical-axis of a coordinate graph.

**Descriptive modeling** - the creation and implementation of a mathematical representation of a system for purposes of quantifying the observed relationships between measurable characteristics.

**Domain** - the set of independent variable values for which a function is defined.

**Ecosystem** - all the interacting biotic and abiotic factors within a single environment.

**Environment** - the external surroundings of an organism, consisting of living and non-living factors that affect the life of the organism.

**Extrapolation** – the creation of data points by extending or projecting the set of known data points.

**Habitat** - the region (either spatial or ecological) of the environment occupied by a particular species.

**Habitat design** - the planning and execution of intentional human manipulation of a habitat to fit the needs of a particular species or ecosystem.

**Independent variable** - a variable whose value determines the value of other variables; this variable is traditionally graphed along the horizontal axis of a coordinate graph.

**Interpolation** – the creation of a data point between known data points in a data set.

**Least squares regression** – a method for determining the line of best fit by measuring, squaring and summing distances between data points and the line.

**Line of best fit** - a line drawn through a set of data points, which minimizes the sum of the squares of the y-distances from each point to the line drawn. It indicates whether two variables appear to be correlated. (Also see **trend line**.)

**Mathematical model** - a mathematical representation of a real-world situation or phenomenon.

**Mean** - the arithmetic average of a set of numbers.

**Niche** – the role, activities and relationships of an organism within a community of organisms found in the same habitat. This is frequently used to examine competition of species for the same space or resources.

**Population** - the group of individuals of a single species living together and isolated from others of their species by either behavior, space, or physical barrier.

**Predictive modeling** - the creation and implementation of a mathematical representation of a system for purposes of investigating the response to hypothetical or future scenarios.

**Qualitative** – related to describing or measuring the quality or distinction of something (without using numbers or numerical measures).

**Quantitative** – related to describing or measuring the quantity of something (using numbers or numerical measures).

**Scatter plot (also called a scatter graph, scatter diagram, scatter chart)** - a type of graph that displays a collection of dots or some other symbol at points representing coordinate pairs (the values of two variables).

**Slope-intercept** - one form of the equation for a line; e.g.  $y = mx + b$  where  $y$  is the dependent variable,  $x$  is the independent variable,  $m$  is the slope of the line, and  $b$  is the y-value of the y-intercept.

**Species** - a classification of a group of similar organisms, frequently based on the ability to interbreed successfully, as well as on a limited internal genetic variance.

**Trend Line** - a line drawn based on the set of data points, which minimizes the sum of the squares of the y-distances from each point to the line drawn. It represents a relationship between the dependent and independent variables. (Also see **line of best fit**.)

**Variable** - a quantity or condition that can change its value, usually represented by a symbol such as  $x$  or  $y$ .

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[http://animaldiversity.ummz.umich.edu/site/accounts/information/glaucomys\\_sabrinus.html](http://animaldiversity.ummz.umich.edu/site/accounts/information/glaucomys_sabrinus.html).