

The Species/Area Curve Lab

Conservation Biology

This week, we will examine one of the fundamental assumptions of modern ecology -- that there is a positive correlation between the number of species in an ecosystem and the size of that ecosystem.

Today's Lab

_____ Complete the pre-lab starting on page 13.

Today in lab you should:

In the field:

_____ Determine the number of plant species in each of 13 plots.

If you have enough time during lab, you should also:

In the computer lab:

_____ Enter the data and produce the species/area graph.

On your own:

_____ Answer the questions.

Objectives:

This lab should teach you how ecologists first determined the mathematical correlation between the number of species present in an area and the size of that area. You will learn about graphs and their importance in understanding data. You should also learn how computers are used in biology and, most importantly, how the species/area correlation is involved in conservation issues today.

Introduction

One of the most intractable problems facing humanity today involves balancing human needs with those of ecosystems. Neither extreme is palatable; we would not want to live in a world in which all natural ecosystems had been replaced by human-altered landscapes, and we would not be willing to give up all the amenities of our civilized world for a completely "natural" world. In addition, it is already too late to turn down the latter path; there are simply too many humans already to be supported by unaltered ecosystems. We have no choice but to alter some land to optimize its production of human food. The question becomes: How much land are we willing to preserve in its natural state? Some would argue that ecosystems themselves, not just

their constituent species, are unique and deserve the same protection we give to species. How many ecosystems are we willing to preserve? An emerging viewpoint in the conservation community is that it makes more sense to concentrate on preserving whole ecosystems rather than individual species.

From a practical standpoint, whether it be ecosystems or species, land (and water) is the limiting resource, and it is reasonable to ask how much land will it take to preserve an ecosystem or a species. Biologists are beginning to grapple with this problem in several ways. One of the most dramatic is an ongoing project in the Brazilian rainforest. Headed by Thomas Lovejoy, the Biological Dynamics of Forest Fragments Project (abbreviated here as the FFP), has been gathering data for over 20 years (Wilson, 1992). This project was made possible by a Brazilian law that requires those that clear land to leave at least 1/2 uncut (Cousteau, 1980). Lovejoy and others persuaded the landowners to cut their forests in a particular way; the loggers left square plots ranging in size from 1 to 1,000 hectares in size (Wilson, 1992). These areas were sampled before logging and were still being studied years later (Wilson, 1992). Many of the effects were correctly predicted in advance by scientists (Wilson, 1992), but other, new, perplexing questions have arisen. Our lab today will concentrate on one of the areas where an existing theory was supported.

In 1963, Robert H. MacArthur and Edward O. Wilson presented a theory that addressed a topic that had been on the minds of biologists for many years. It was no secret that the larger a land mass, the more species the land mass would have. MacArthur and Wilson (1963) put this relationship into a mathematical perspective by developing the **species-area curve** (their theory, based on comparison of islands, also addressed a number of other relationships such as the effect of distance from the mainland on the number of species present on an island). The **theory of island biogeography**, as it is known, has withstood the test of time, and is an important tool used by ecologists today in determining the size of an ecosystem needed to sustain a desired number of species. The figures below illustrate some of their results:

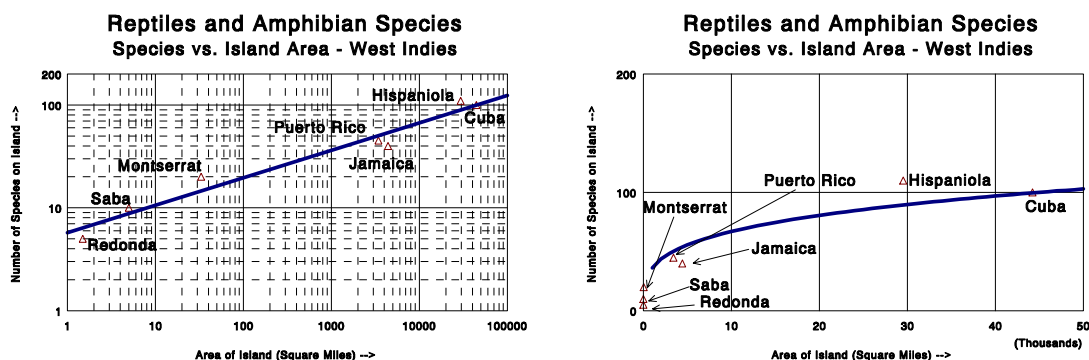


Figure 1. Reptile and Amphibian Species vs. Island Area for the West Indies. Redrawn from Wilson, 1992.

There are two plots here, one is of the data plotted on a normal scale, the other is placed on **logarithmic** a scale. Note that the two plots are from the same data; only the scales have been changed. One of the most important points to note is that the relationship between the size of the area and the number of species is **not** a straight line when plotted on normal axes. The lines on the graphs represent a statistical fit of the data to an equation or **model**. For the log-log plot this is a simple linear regression, for the normal data it is a power function as described below.

The species area curve is expressed mathematically as this model:

$$S = c A^z$$

Where:

S = number of species c = constant (= y-intercept)
 A = area z = constant (= slope of the log plot)

Our lab will involve experimentally determining the constants c and Z for plants growing on the lawns outside. Think of c as the minimum number of species in the smallest sampling area - a place to start. The constant z varies for different types of organisms, and in different settings. The constant z tends to be between 0.15 and 0.35. Birds on tropical islands will have a different z than will grasses on a lawn or fish in ponds. As a **general rule of thumb**, it takes a **tenfold** increase in the **size** of a habitat to produce a **doubling** of the number of **species**. This rule of thumb does not hold in all cases, and, in fact, may not hold in our exercise today.

The data above, from MacArthur and Wilson (1963) produced a fairly tidy chart. Often the data is a bit "messier". The plots below show a portion of the data from 258 sampling sites in Ohio. It should be noted that river drainage area (watershed), all the area upstream from a given point, is *not* a good predictor of the amount of habitat that the fish will have available to them. Still, this data does show some fit to the general model.

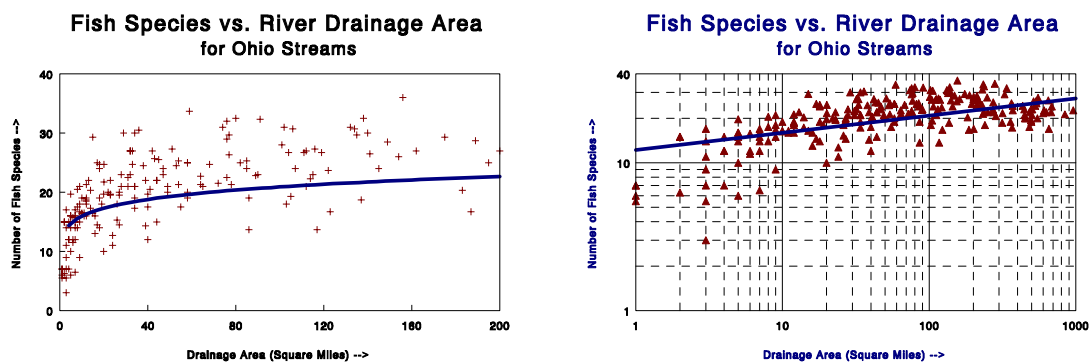


Figure 2. Number of fish species taken at a site vs. the drainage area above that site. Data from Ohio EPA, 1988.

When we speak of the species area curve, we are referring to the characteristic shape of the plot that occurs when the data is graphed normally. However, it is difficult to determine if data plotted on normal axes really fits the model (equation) above. To remove any doubts, it is customary to prepare a **log-log plot** by taking the logarithms of

both the area and the number of species and plotting these values. If the data fit the model above, the points should fall in a straight line. If they do not, the data probably don't fit the model. The two figures above, particularly Figure 2, show clearly how the log-log plot makes the fit of the data to the model more obvious.

One of the reasons that the species-area curve model is so important is because data of species distribution and area taken from the real world almost always fit the model. It is not really critical that you understand the mathematics involved in the species area curve, but it is important that you understand its basic applications and implications.

Central to the application of this theory in many applications today is the realization that many ecosystems effectively behave in the same way an island does. For instance, to many organisms a pond is an island of water surrounded by an ocean of inhospitable land. Likewise, a remnant of tropical rain forest, perhaps on a hilltop, is an island of trees surrounded by grassland in which many arboreal species cannot survive. Yellowstone National Park, as well as many other parks, are also islands of relatively undisturbed ecosystems often surrounded by highly altered ecosystems. Modern ecologists, when planning nature preserves, are often challenged to create preserves which will protect as many of the native species as possible. The species-area curve gives the ecologists a tool to predict how many species can survive in a given area. These values can then be used in the decision-making process.

The decision-making process might go as follows. A government might want to preserve some rainforest while developing the area around it. The area under consideration for development is 1,000,000 hectares (1 hectare = 100 meters x 100 meters = 10,000 square meters = 2.471 acres). Ecologists could derive a species-area curve and be able to say "If you set aside 10,000 hectares you will preserve 50% of the species, but if you preserve 1,000 hectares you will preserve only 25% of the species."

Other interesting questions arise. It is not just the total area preserved but the physical arrangement of that area that is important (Wilson 1992). For instance, a park of 100,000 contiguous (adjacent, touching) hectares would normally contain more species than 10 separate parks of 10,000 hectares each, even though the total area is still 100,000 hectares. Note that this would not hold true if the ten separate areas were chosen to include widely different habitats or ecosystems as compared to a single large area dominated by one type of ecosystem. Another tradeoff between a single large park and many smaller ones is that in the event of a catastrophe, a single large park may be destroyed, but one of the smaller parks is likely to survive, even if several of the small parks are destroyed. Single large parks may be the only areas able to sustain large predators such as grizzly bears. Corridors linking small preserves might help some species survive, if they are able to take advantage of the corridors (some species may not be able to take advantages of corridors due to the "edge effect").

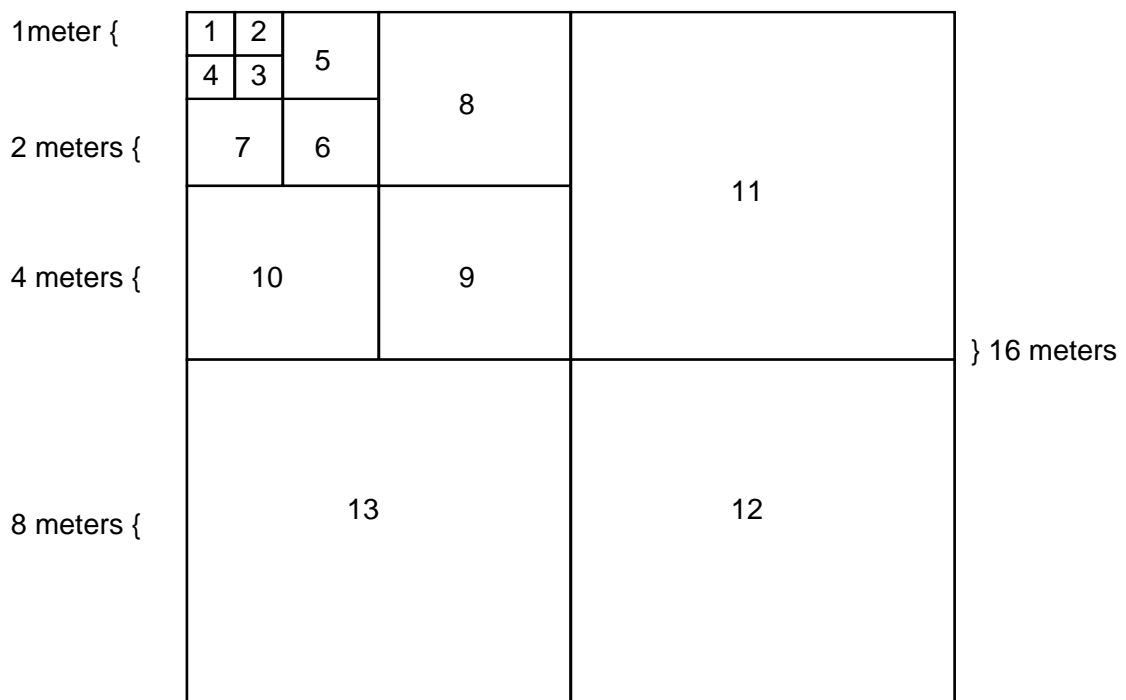
While the actual applications of the species-area curve are complicated, the derivation of the curve is very straightforward. The principles are the same whether the ecosystem involved is the ocean, a tropical rain forest, or the lawn outside the building. Today, of course, we will examine the latter. In addition, of all of the different organisms that we could study, we will study only the plants. For our purposes, the plants are superior since they won't move around while we are sampling.

Not all of the lab will be done in the field. When you are done in the field, you will need to enter your data into a computer for analysis. This will occur in the Biological Computing Laboratory on the third floor of Bartlett. The computer will allow you to plot the actual species-area curve. You will then use this plot to answer a series of questions. Computers have greatly simplified the work of biologists by facilitating computations and data storage. This lab gives only the briefest introduction to the vital role computers play in biology.

Part One - Field Work

This lab is based on an exercise outlined by H.S. Horn (1993). The class will be divided into four teams to complete this lab. One team of three will be the "curators" who have the final say on the identification of any specimen. They will also count the species in plot one (see below). Each of the other teams will be responsible for counting 4 plots. The lab section with the best results will receive a bonus! Before leaving lab, be sure your team has both a **surface to write on** and **pencils**.

Outside, an area will be set up as shown below:



Group 1 will maintain the "museum" and will count the species in plot 1. Group 2 will count the species in plots 2, 5, 8 and 11. Group 3 will count the species in plots 3, 6, 9 and 12. Group 4 will count the species in plots 4, 7, 10 and 13.

We are not concerned with actually identifying the plants; instead we will concentrate on differentiating between species. Still, it is important to be sure that everyone is naming species consistently. Therefore, group 1 will maintain a "museum" of each species as it is identified. The procedure will work as follows: Each time you think you have a new species, take it to the curators. They will maintain a set of cards with samples of each species. If your specimen is different, a new card will be prepared and you will get to name the species. Thereafter, this will be the name used by everyone in the class for that species.

To count the species in a block, work carefully, moving on your hands and knees. The object is to determine how many species are in that block. Each time you find a species in a block, make a check in Table 1. After this, you can ignore that species in that block. Every time a block is completed, consolidate your data and record it on the "master list" maintained by the curators. The master list will be copied and placed in the computer lab for your use. **Be diligent! This lab will not work if any one group doesn't do a good job!**

Part Two - Computer Analysis

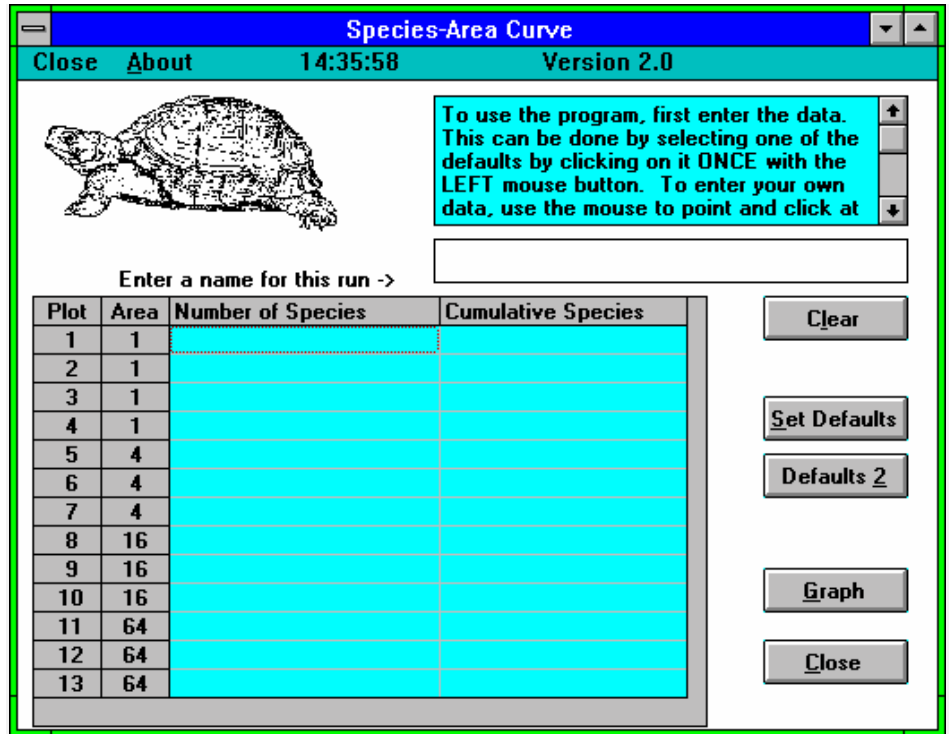
In the stone age, when your instructors were in school, the next step would have been to graph the results by hand on paper, and do further calculations as necessary. *Some* (we won't mention Dr. Hogan or Dr. Tschunko here) didn't even have calculators. A computer was something that you fed IBM cards into and waited around for a printout of your results. Biologists today have access to computers that greatly reduce the effort needed to analyze data.

To analyze the data you gathered in the field, you will use the computers in the computer lab on the third floor of Bartlett. The software was written especially for this lab by Dr. McShaffrey; the College and the National Science Foundation have provided computers for use in biology labs.

I have given separate instructions on getting the computers started, as well as the basics of their use. The program you will use is called *Specarm*, and is found by going to the **start** menu, then **Biology 103** and finally **shortcut to Specarm**.

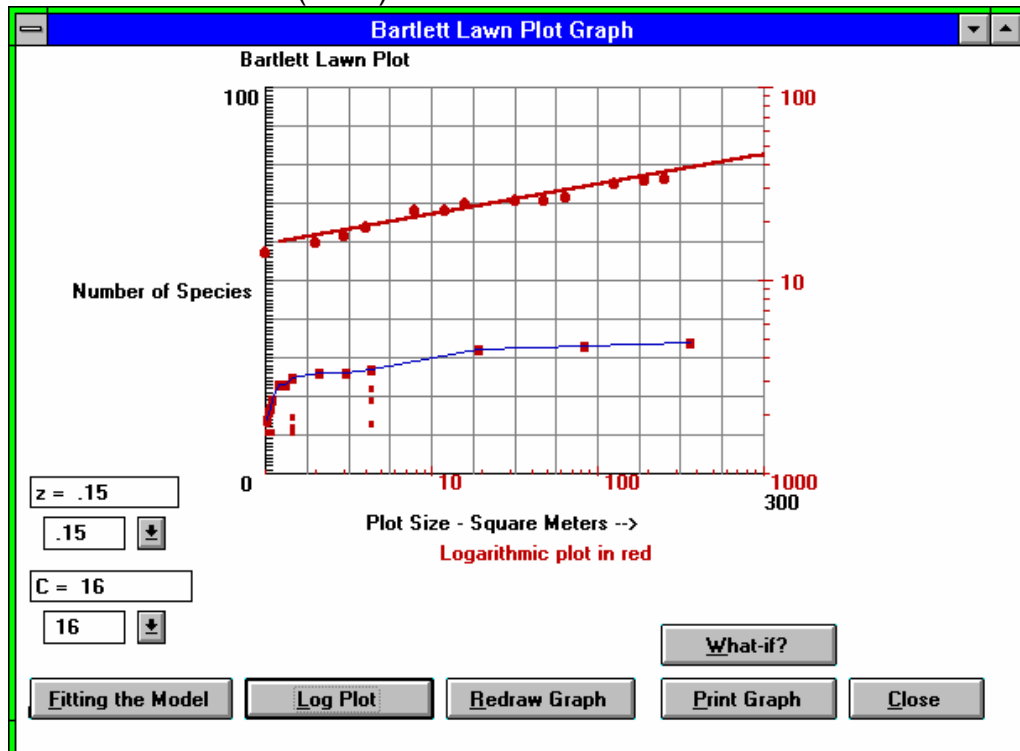
Once opened, the program will appear like this -->

You might want to experiment a little with the features of the program by clicking on the "Set Defaults" button. This will place the data from Horn's paper into the program. Once this is done, several additional "buttons" will appear. Click on the one marked "Graph". This will bring up a screen



similar to the one below. In order to make your screen show both the normal and logarithmic plots, click on the "Log Plot" button along the bottom row.

At this point, barring last minute reprogramming, your screen should be very similar to this one from Horn (1993):



After plotting the log values, another button, "**What-if?**", appears. This button, when clicked, opens yet another window, which allows you to determine either how much area is required for a given number of species, or how many species would be expected in a given area. Due to annoying technical difficulties, *these values are to be trusted over those you might determine by looking at the graph*, in other words, the data from the "What-if?" boxes might differ from the graph and you should trust the data in the boxes. To end your tour, close all the boxes you have opened by clicking on the "**Close**" buttons near the lower right corners of each box. If you click each of these, you will close the program as well, which is fine.

Step 1 - Entering your Data

Reopen the program by double-clicking on its icon. Next, enter a name for your graph. This can be anything you want, **but it must include your name**. Move the cursor to within the box for the title and click, then type in the title. Next, move the mouse to the uppermost box in the "Number of species" column and click once to place the cursor in that box. For each plot, you will enter the number of species in the left blank column, and the cumulative number of species in the right blank column. You can move between boxes by using the mouse or the arrow keys; correct mistakes by using the Backspace (←) key. Once you have entered the data, click the **graph** button. Once the graph appears, click the **log plot** button.

Step 2 - Fitting the model to your data - adjusting c and z

If the straight line falls through the middle of the log points, you are in good shape. If it falls above or below the line, however, you will have to make adjustments to the z and c values. This can be done in two ways. The simplest is to click on the **down arrow** to the right of the box which contains the parameter you want to change. This will open another box, with a range of values. This new box also has **scroll bars** on its right edge; to see more values **click and hold on the up or down arrow**. To select a value, **click once** on the value you want. The second method for changing values allows you to enter values other than those in the box. To do this, **highlight** the current value. To highlight, move the cursor to a position just in front of the current value. **Click and hold** the left mouse button and slowly move the mouse to the right. As the cursor moves over the text, its background will change color; it will be highlighted. When the entire value is highlighted, **release the left button**. It takes practice to highlight just the material you want to. With the value highlighted, simply **type in the value** you want. Use your judgment; a value drastically different from those suggested may cause an error and require that you start over. However you change the value, a new line will be produced on the screen. If it fits the points better, good; if not, try again. You may need to change both the c and z values to get the line to fit the data. If the screen gets too messy, click on the "**Redraw Graph**" button to remove all but the most recent plot.

It may be that your data do not fit the model. If the log points do not fall in a reasonably straight line, or if the number of species decreases in conjunction with increased area, it will be impossible to get a good fit. Do the best you can.

You are now ready to answer questions. Before doing so, print the graph (use the "**Print Graph**" button); this way, if you screw up later at least you'll have something saved.

Step 3 - What if?

You're on your own for this part. Don't neglect the what-if? button as you work your way through the questions. Note that you have to **think** and answer some of the questions - the computer won't answer them for you!

Acknowledgments:

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The lab was adapted from an article by Henry S. Horn (Horn, 1993).

Literature Cited

Cousteau JY. 1980. The Cousteau Almanac. The Cousteau Society, Norfolk, VA. 838 pp.

Horn HS. 1993. Biodiversity in the backyard. *Scientific American*, January, pp. 150-152.

Ohio EPA. 1988. Biological Criteria for the Protection of Aquatic Life: Volume II: Users Manual for Biological Field Assessment of Ohio Surface Waters. Division of Water Quality Monitoring and Assessment, Surface Water Section, Columbus, Ohio. Data from Appendices A-1 to A-3.

Wilson EO. 1992. The Diversity of Life. Belknap/Harvard University Press, New York, 424pp. (See especially pp. 220- 242)

Table 1 - Tally of Plant Species Present in the Plots

Species	Plot												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1													
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30													
31													
32													
33													
34													
35													
36													
37													
Total per block:													
Cumulative total:													
Area of block:	1	1	1	1	4	4	4	16	16	16	64	64	64
Cumulative area:	1	2	3	4	8	12	16	32	48	64	128	192	256

In - Lab Assignment

-----> Name _____

Complete the following *after* lab:

Turn in a copy of your graph as printed by the computer. Answer these questions:

1. How many species total were found?
2. If you wanted to preserve 90% of these species, how many square meters would it take?
3. If you wanted to preserve twice as many species, how many square meters would it take?
4. If you wanted to preserve 10% of the species, how many square meters would it take?
5. Does our data fit the generalization that it takes a tenfold increase in area to double the number of species? Explain.
6. How many species would you expect to find in an acre?
7. How many species would you expect to find if the whole campus were covered by lawn (instead of buildings, parking lots, sidewalks, and bare places where lazy people walk or ride their mountain bikes) as compared to the plot we surveyed?

How representative is the 256 square meter sample of the 120 acre Marietta College campus? Explain your answer in a paragraph or two.

Pre - Lab Assignment

-----> Name _____

Complete the following *before* lab:**QUESTIONS**

1. How big is Jamaica? (Use figure 1 to answer this question.)
2. How many species of reptiles and amphibians are there in Jamaica?
3. How many square meters are there in an acre?
4. If Pennsylvania is twice as large as Ohio, would you expect to find twice as many species of trees in Pennsylvania? Explain.
5. If southeastern Ohio comprises 1/10 of the area of Ohio and has 45 species of trees, how many tree species would you expect the entire state to have? Explain.

Question #6 is on the back

6. An experiment is conducted where 10 duckweed plants are placed in an aquarium and counted every 10 days. The results are shown in the table below:

Days	Total Plants	Days	Total Plants
10	2	60	35
20	5	70	50
30	10	80	65
40	15	90	80
50	25	100	100

Plot the data above on the graphs below (put the independent variable on the horizontal (x) axis and don't forget to label the axes). Plot all of the data on both of the graphs:

