Technology has become increasingly important in many different scientific disciplines. In biology, examples range from the use of gel electrophoresis and polymerase chain reaction (PCR) machines in DNA "fingerprinting" to imaging techniques such as magnetic resonance imaging (MRI) in the neurosciences. Technological advances have also been important in the environmental sciences such as ecology and conservation biology. For example, remote sensing techniques and geographic information systems (GIS) have allowed ecologists and conservation biologists to address questions at the "landscape" scale and have been pivotal to the development of the field of landscape ecology. Incorporating technology into science education should be an important goal of science curricula because it will both teach students about modern approaches to research questions, and will contribute to increasing the general "technological literacy" of students.

One barrier to the use of technology in science courses is that much of the equipment is too expensive for often limited course budgets. Digital image analysis software is one technological tool that can be used with many existing computer systems, and the National Institutes of Health has made one such package for Macintosh computers, NIH Image, available as "public domain" (e.g., free) software. Image analysis software has a variety of uses for biological research in general and the environmental sciences in particular. This type of software can be used to measure linear distances, area, angles and many other features of interest from digitized images. Images can be digitized by the use of video cameras with "frame grabber" equipment, or more simply from images that have been imported with the use of computer scanners. Images generated from drawing or painting software can also be analyzed. To list just a few examples, these types of software packages can be used to analyze animal size, morphology, and behavior, plant leaf area, banding patterns in gel electrophoresis or color differences between different flowers or animals.

Species-area relationships

One exercise that I have used with success in an aquatic ecology course uses NIH Image to examine the relationship between the size of a habitat area and the number of species found in the area. The simple exercise outlined in this paper demonstrates the ecological concept of "species-area relationships" and how technological tools can be utilized in the environmental sciences. The unit can easily be extended as an exercise in presenting data and writing a scientific paper based on data that students have generated.

Species-area relationships were first recognized in the 1960's by researchers comparing island and mainland habitats, and refer to the general trend of increasing species diversity with increasing island size. Figure 1 demonstrates the relation-

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Eric F. Maurer, Ph.D.; Center for Ecology, Evolution, and Behavior; 101 Morgan Building; University of Kentucky; Lexington, KY 40506.
Figure 1. Species-area relationship for plants found on different islands of the Azores.

adapted from Begon et al., 1990

ship for the number of plant species found on different islands of the Azores. The figure illustrates the typical curved shape found for species-area relationships. Plotting the size of the area on a log scale generally results in a straight line relationship as is seen in Figure 2 for bird species found in two different island systems. Species-area relationships are not limited to oceanic islands. Further research in a variety of systems has demonstrated that the same trends can be found for other "island" types such as mountain tops, isolated forest tracts, caves, and even lakes. Figure 3 shows the species-area relationship for the number of mollusc species found in New York lakes of different surface areas.

Lakes can be useful "islands" for illustrating these concepts because of the presence of discrete boundaries. There are several generally accepted methods for analyzing lake size, and as part of the exercise, I have students compare the species-area relationship for four different size measures: i) maximum depth, ii) surface area, iii) maximum length, and iv) maximum width. Maximum depth is simply the deepest point measured in a lake basin, and can often be obtained from published reports or resource management agencies. The remaining three measures can be obtained with the use of the image analysis software and digitized maps. Maximum length is defined as the longest distance across the lake surface without crossing land (Figure 4). Maximum width is then defined as the longest distance across the lake perpendicular to the maximum length axis (Figure 4). The organisms used can be fish, zooplankton or algae, and the number of species in each lake may also be
obtained from published reports or resource management agencies.

**Computer image analysis**

NIH Image can be used on most Macintosh computers with at least two megabytes of memory ("RAM") and a video monitor that can display 256 shades of gray or colors. Image can read (and write) several different file formats, and contains the typical Macintosh drawing and painting tools. Image supports a variety of image processing tasks such as smoothing and contrast enhancement, and several different measurement tools. Results from analysis can then be printed or saved to a disk.

The measurement of lake size is a simple task using Image. There are four steps to go through for each lake image. The first step is to calibrate the screen units to real units. Then for maximum length and width students simply draw lines across the image of the lake surface and tell the software to measure the lines. The simplest technique is to have the students measure the length and width several times and to use the longest measure for each. Finally, students use a tool to outline the lake perimeter and tell the software to measure the surface area of the lake.

I use a series of ten arctic lakes from northern Alaska that I have digitized and the number of zoo-plankton species found in lake surveys that were part of a large research project I participated in. I provide the students with the maximum depth of the lakes, the species found in each, and the scale that they can use to calibrate the image analysis software to "real world" units. I then assign a short paper that they are to write in scientific journal format complete with four species-area figures.
Figure 3. Species-area relationship for the number of mollusc species found in New York lakes.

![Graph showing the species-area relationship.](image)

*adapted from Begon et al., 1990*

Species area relationships have important implications for the conservation of biological diversity, and can be used to demonstrate the need for large nature preserves and park lands. Increased fragmentation of habitats results in "islands" of natural areas separated by human developments, and the smaller the available habitats the fewer species that may be found in those habitats. The simple exercise outlined above can be used to illustrate these concepts and to

Figure 4. Example of defined maximum length and width of a lake.

- Maximum width
- Maximum length
Further information

General background and information about species-area relationships can be found in most ecology textbooks. Three examples include:

Two sources of information on conservation biology are:

For information about digital image analysis:

The program NIH Image can be obtained from numerous public domain software computer sites on the Internet across the country. One example is the software server at Stanford University, California (sumex-aim.stanford.edu) or at the National Institutes of Health (zippy.nimh.nih.gov). Those without access to Internet may find NIH Image on computer bulletin boards, or can contact the author at the given address for information or for a copy of the arctic lakes project.