Species and Specimens: Exploring Local Biodiversity

FNA
Flora of North America

In this lesson, appropriate for middle through high school, students practice skills essential to all scientific investigation: carefully observing and collecting data. Students become field biologists in a series of hands-on activities to collect and identify specimens, and survey and calculate the diversity of plant species in their local environment.

Learning goals: identifying and naming plants (recognizing variation in nature, using keys, identifying species); counting biodiversity (conducting research, collecting and comparing data)

Key concepts and terms: biodiversity, taxonomist, binomial nomenclature, classification system, identification keys (dichotomous and interactive keys), species richness, introduced (and invasive) species, endangered species, extinction

Background

Researchers exploring biodiversity (short for biological diversity) want to understand the variety of life. This includes the kinds and numbers of organisms on Earth, their genetic relationships, and their ecological roles (sometimes set apart as species diversity, genetic diversity, and ecological diversity). The first step in understanding biodiversity is to find out what organisms exist.

The work of cataloging life on Earth is ancient, much older than the first rock paintings. Despite intensive exploration over hundreds of years, the total number of organisms present today is an educated guess. Only 1.5 million species have been identified and named. Anywhere between 14 and 100 million species may exist worldwide—it's difficult to estimate the unknown. Most of the undiscovered species are small, difficult to observe organisms: viruses, bacteria, fungi, algae, and invertebrates. Taxonomists have the large job of naming organisms according to the rules of binomial nomenclature and classifying them.

Botanists estimate about 320,000 plant species exist worldwide; about 270,000 are known so far. Many of the new plant species will be found in the tropics, well known for dazzling high diversity.

What about North America? The discovery of the New World sparked excitement around the world. A strong tradition of botanical exploration in North America soon followed. By the 1660s, American plants were an important part of European collections and grown in European gardens. During the 1804–1806 Corps of Discovery expedition, Lewis and Clark collected more than 230 plant specimens along their historic route to the West. North America might appear well explored, but the pace of plant finds isn't slowing much. Over 1,190 vascular plants were discovered between 1975 and 1995. That's about 41 new taxa per year. As many as 1,900 vascular plants are undiscovered in North America. Mosses, liverworts, and marine macroalgae are also waiting in the wings to be discovered.

Ready for more surprises? You don't have to be a professional biologist working in a remote area to discover a new species. Consider these examples. Lowell Ahart wanted to know all the plants growing on his sheep ranch in the Sacramento Valley, California, and his survey revealed two taxa new to science. Bill Ott found an unknown species of terrestrial leech while mowing his lawn in New Jersey. And many volunteers are making significant contributions to survey all organisms in the Great Smoky National Park. In three years of sampling, 427 species are new to science and more than 2,000 species are newly recorded in the Smokies. Who will be the next lucky person to extend a distribution range, find a new species, or rediscover one thought extinct?

The diversity we see is the result of 1.5 billion years of evolution since life emerged on Earth. Biodiversity is not static: It varies from place to place, and over time. Field biologists conduct surveys in hopes of finding new species, but also to

1. **map patterns of diversity** — e.g., California and the Southeast are species-rich areas.
2. **track the spread of introduced species** — Introduced species make up at least 25% of the U.S. flora. Almost 400 species, including saltcedar, kudzu, water hyacinth, cheatgrass, and purple loosestrife, are invasive in North America.
3. **monitor the health of endangered and threatened species** — Of the 1,263 species on the 2002 U.S. list of endangered and threatened species, 745 are plants. Thirty U.S. plants were confirmed to be recently extinction on the 2003 I.U.C.N Red List.

Rapid species loss has spurred biologists to complete the catalogue of life as soon as possible. Today's extinction rates are faster than those recorded before modern times. Mass extinctions occurred 440 million years ago, 370 mya, 255 mya, 200 mya, and 65 mya. Experts place the responsibility for the current 6th mass extinction squarely on human shoulders. Some 0.2% of plants around the world have become extinct since 1600. We live in a new age of exploration. But the time available to discover new species is critically short.

Hands-on Activities and Minds-on Worksheets

Several class periods are needed to complete all of the class or team activities. The plant collecting and surveying activities may be done together, perhaps by separate teams. If possible, repeat the activities at different times of year and locations, or with new classes over several years. That would enhance students' ability to observe variation in nature and make comparisons.

- *Collecting and preparing plant specimens* (Student Handout)
- *Using and writing identification keys* (Student Handout)
- *Conducting and analyzing biodiversity surveys* (Student Handout)

  [See also the Plant Ecology and Plant Identification sections of the *Biodiversity Counts* curricula, which cover using a key, collecting, and surveying. It is available from the American Museum of Natural History at http://www.amnh.org/education/resources/biocounts/ecology.php]

Enrichment Activities

- Many American plants have been named in honor of important pioneer naturalists, e.g., *Lewisia* and *Clarkia* immortalize Lewis and Clark of the Corps of Discovery. Select a naturalist who has been honored this way. Use library or internet resources to prepare a brief profile about his/her contributions (time period, regions explored, species discovered, etc.).
- With a classmate create an illustrated portfolio on extinct or endangered plants and new discoveries. Include at least two plant species that are now locally or globally extinct (or currently endangered): map where they once occurred and describe the factors that lead to their extinction (or the threats they currently face). Include at least two species discovered in recent decades: map where they occur and describe how they were found.
- A new field of bioinformatics has emerged to manage today's vast wealth of biological information. Links to several online biological databases are given below. Search the web to describe at least four kinds of biological data. Prepare a brief profile on the skills and background needed for a career as a bioinformatics specialist.
- Natural history museums, botanical gardens, zoos, aquariums, and herbaria are storehouses of information of Earth's biodiversity. Hardly musty relics of the past, they address vital social issues such as climate change, public health, biological invasions, and environmental contaminants. Visit a local institution and find out how their biodiversity studies serve society. Present your view on the value biodiversity in a 1-page editorial for your school paper.

- In today's world, the management of biodiversity is as much a concern as its discovery. Contact your state department of conservation, local chapter of the Nature Conservancy, or other conservation organization. Ask about the cost and effectiveness of removing invasive species, restoring native habitats, and reintroducing endangered species. Choose a local project. Evaluate its success and propose two concrete ways the project could improve.

Explore more!

Organizations conducting diversity surveys and studying biodiversity

All Taxa Biodiversity Inventory (ATBI)
Approximately 200 scientists and volunteers are documenting all species living in the Great Smoky National Park. The ATBI website provides updates on their discoveries.
http://www.dlia.org/atbi/

BioBlitz
Across the nation, researchers and citizens are teaming up to conduct 24-hour biodiversity surveys. Check out the 2004 St. Louis Bioblitz. Find out if there's one near you at the USGS site.
http://www.stlbioblitz.com/
http://www.mp2-pwrc.usgs.gov/blitz/blitzlink.html

Discover Life in America, Inc.
The aim of this program is to help individuals identify plants and animals through interactive keys and maps, and report findings of local surveys to add to the body of web-based knowledge.
http://www.discoverlife.org/

All Species Project
The goal of this project is to document global biodiversity.
http://www.allspecies.org/

Species 2000
Species 2000 is an international initiative to catalogue every living species within twenty-five years and to make the information available online.
http://www.species2000.org/

Organizations managing information on biodiversity

Natural Sciences Collections Alliance
This consortium of science collections provides links to biodiversity databases covering animals, plants, fungi, bacteria, viruses, and more.
http://www.nscalliance.org/bioinformatics/databases.asp

Global Biodiversity Information Facility (GBIF)
The aim of this international organization is to coordinate biodiversity information and databases.
http://www.gibif.org/

Why Taxonomy Matters
This global network presents examples of taxonomic knowledge benefiting society.
http://www.bionet-intl.org/case_studies/

IUCN Red List of Threatened Species
The World Conservation Union's (IUCN) regularly updates its list of plants and animals threatened with extinction across the globe.
http://www.iucnredlist.org/

Endangered Species Program, U.S. Fish and Wildlife Service
Track the yearly changes in American plants and animals listed as endangered and threatened; read about profiled species; and find out how the Endangered Species Act protects species.
http://www.endangered.fws.gov/

The Invasive Species Council of the United States Government
Learn about the U.S. government's efforts to manage invasive species and inform the public about this growing concern.
http://www.invasivespecies.gov

Organizations dedicated to conserving plant diversity

Center for Plant Conservation

This national network of botanical gardens and arboreta conserves native plants. [The CPC's *Plants in Peril* has excellent biodiversity dilemmas and math puzzlers for middle school students.]

http://www.centerforplantconservation.org/
http://www.centerforplantconservation.org/peril/perilmnu.html

Global Strategy for Plant Conservation

Parties to the Convention on Biological Diversity describe the plan to halt the worldwide loss of plant diversity. More than 150 nations signed this treaty in 1992 at the United Nations Conference on Environment and Development held in Rio de Janeiro, Brazil.

http://www.biodiv.org/

Botanic Gardens Conservation International

This site is a gateway to the discoveries, conservation, and education efforts of botanic gardens around the world.

http://www.bgci.org.uk/

Suggested Readings and Resources

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Students might enjoy these general audience pieces.

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NRC Content Standards: Unifying Concepts & Processes 1.1; Science as Inquiry 2.1; Biological Evolution 4.3; Science as a Human Endeavor 8.1

Grades and Levels: middle through high school

Collecting and Preparing Plant Specimens

Create your own collection of dried plants. Plants collected and prepared for study purposes are called **specimens** or **scientific vouchers**. Any collection of plant specimens is an **herbarium** (plural, herbaria).

Become a plant collector in a few simple steps

1. Surround yourself with plants – a field or even your backyard will do.
2. Find a choice plant, collect parts of the plant useful in identification, and record in your notebook the plant's collection number, information about its appearance, habitat, and location.
3. Carefully position the plant sample on a newspaper, then fold the newspaper over the plant; write the plant's number from your notebook on the newspaper.
4. Place samples in the plant press, tighten the straps after adding a new batch of samples.
5. Place the plant press in a sunny place to dry.
6. Identify the dried specimens using field guides and floras or the help of botanists.
7. Mount and label the dried specimens.
8. File the specimens in a safe storage system.
9. Get back into the great outdoors.

Materials for Collecting Plant Specimens	
❑ *Field notebook*	❑ *Old newspapers*
❑ *Permission to collect*	❑ *Pencil or permanent ink pen*
❑ *Field press*	❑ *Field guide or flora for your region (helpful in identifying your collections)*
❑ *Pruning shears or sturdy scissors*	

Professional botanists usually carry a number of other useful tools: magnifying lens, compass, altimeter, maps, global positioning system unit, camera, pruning poles, and materials for collecting samples for later anatomical or DNA study.

What to collect? As a plant collector, your responsibility is to prepare samples useful for posterity (that's a long time – specimens collected in the 1700s can still be studied in herbaria).

If possible, select plants with flowers and fruits. They make attractive specimens. But more importantly, many plants are impossible to identify without these parts. Also choose plants that look typical for the species and avoid plants damaged by insects or disease.

Plants come in a wide variety of sizes and shapes, some easier to collect than others. Collecting small herbs is easy. Just pull the entire plant out of the ground by its roots. Fold over a portion of the herb if it doesn't fit on a piece of newspaper (but try not to hide important characters). When collecting shrubs or trees, snip off a branch about the size of a plant press. Spiny plants require special care when handling, and very fleshy plants and large fruit may difficult to fit in a press.

A note on responsible collecting: Respect nature and your fellow human when collecting. No matter where you collect plants, get permission and take only the amount needed to make good specimens. Some plants live only in America's extensive park system. To collect plants on city, state, and federal lands obtain a collecting permit from the authorities. Plants protected by the U.S. Endangered Species Act are very rare and can be collected only with a special permit. Ask for the owner's permission to collect on private property.

What to record in a field notebook? For each plant collection, record

- Location – Give enough information that someone else could find the same location again. Botanists usually record the state, county, nearest town, longitude, latitude, and elevation.
- Date of collection and names of all collectors.
- Habitat type and other plants present; note if the plant grows on rocks or in rivers.
- Description of features that can't be seen on a dried specimen, such as plant height, flower color and odor, pollinators visiting flowers, etc.

Number each plant collected: Begin the notebook with #1 and continue numbering consecutively. The notebook may record the collecting effort of an entire class, a collecting team, or an individual collector. This number is very important. If the plant cannot be identified with the help of a field guide, the plant is known by its number until a plant specialist can name it.

Collecting can become a passion and a career. Tom Croat has collected more than 85,000 specimens in his 3 decades with the Missouri Botanical Garden. (See Tom and others on the Frontiers of Discovery at http://www.mobot.org/MOBOT/research/unseengarden/fronteir6.shtml.)

Once the plants are collected they must be dried, or they will mold and rot.

Materials for Preparing Plant Specimens	
❑ *Corrugated cardboard*	❑ *Permanent ink pen*
❑ *Newspapers*	❑ *Index cards or paper labels*
❑ *Place to dry plants*	❑ *Glue*
❑ *Sturdy paper or thin, white cardboard*	❑ *Small envelopes (optional)*

A few days sitting in a sunny area with good air circulation will dry most plants. Prepare the plant samples for drying by placing corrugated cardboard or several newspapers between each plant specimen. The corrugated cardboard allows air to flow through the plant press, helping the plants dry. After a few days check the specimens. Remove the dried specimens; rebuild the plant press, replacing any damp corrugates with fresh ones.

In the field, botanists use a number of techniques to dry their plants quickly. Where warmth of the sun is in short supply, botanists often use heat lamps or gentle heat from a stove. Too much heat can be dangerous: The plants can catch fire. Traveling botanists sometimes strap the plant presses onto a car's roof rack, letting the wind dry the plants.

Dried plant specimens are ready for mounting. Glue the plant specimen onto your good-quality paper (or thin cardboard such as a shirt box). If flowers or fruit come loose from the specimen, place them in a small envelope and attach the envelope to the mounting paper. Glue the specimen label (index card or paper label) on the lower right-hand corner of the mounting paper. Fill in the specimen label with the plant's name, collection location and habitat, description, date of collection, collector's name and number.

Decide how to organize your plant collection. Put similar kinds of plants together or arrange the collection alphabetically by plant family, genus and species, or arrange by geographical location. Inspect your collection regularly for insect and mold damage.

For tips on working with a field guide or flora, see the fact sheet How do You Use a Flora?

For more collecting activities and links to online plant collections, see the lesson From Curiosity Cabinet to Museum Collection.

Using and Writing Identification Keys

Suppose you take a walk in the woods and encounter a plant you've never seen before. How would you identify this mystery plant? – That is the focus question for this activity.

Following the clues of an identification key that match your mystery plant is a sure and fun way of finding out the plant's name. Flipping through a field guide until you see a picture almost matching your mystery plant isn't nearly as satisfying. Identification keys lead you through a series of contrasting choices. At each set of options you eliminate similar but unconvincing suspects. Eventually the clues lead not to another set of choices but to the plant's name. Mystery solved!

Dichotomous keys were first used in 1778, and they remain the "industry standard" in reference books. At each step in a dichotomous key, there are 2 contrasting choices, no more and no less. Each choice in the series determines the next possible options.

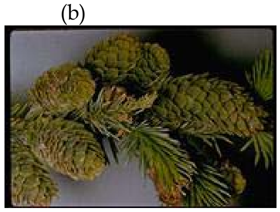
Can you identify these North American trees? How does a larch tree differ from a pine tree?


(a)


(b)


(c)


(d)


(e)


(f)

Photo credits: (a) © D. Nickrent; (b), (d), (e) & (f) C. Webber © California Academy of Sciences; (c) G. & B. Corsi © California Academy of Sciences

There are six members of the pine family (Pinaceae) in North America.

All these conifers have needle-shaped leaves and seed cones, but with important differences that help to identify the trees.

Follow the dichotomous key below.

1. Leaves are in bundles of 2 or more.
    2. Bundles have 10 to 60 leaves; plants are deciduous; scales of seed cone have without a protrusion .... Larch (*Larix*)
    2. Bundles have 2 to 5 leaves; plants are evergreen; scales of seed cone have a prickle or protrusion at tip .... Pine (*Pinus*)
1. Leaves are solitary.
    3. Leaves attach directly to stem; stem has smooth, round scars after leaves fall.
        4. Seed cones sit upright; cone scales without prominent lobes .... Fir (*Abies*)
        4. Seed cones hang down; cone scales with 3 lobes .... Douglas-fir (*Pseudotsuga*)
    3. Leaves attach to peglike projections on stem; stem has stubby pegs after leaves fall.
        5. Leaves are flattened or four-sided and usually have a sharply pointed tip ....Spruce (*Picea*)
        5. Leaves are flattened and have a rounded or notched tip .... Hemlock (*Tsuga*)

You can now identify these genera!

There are 38 pine tree species in North America. How can you tell them apart?

Try these tips for using an identification key

- Look up unfamiliar words in a glossary. Botanists may use a technical term to say something simple; for example, undulate means wavy. Expand your vocabulary and impress your peers.
- Read all the options before deciding which leads to follow.
- Examine more than one sample of the unknown plant. This allows you to observe how individuals within a species vary. For example, petals may range from white to pink. Leaves may have 3 or 4 lobes. Some plant samples may be incomplete, missing a critical leaf, flower, or fruit.
- Examine a plant with flowers or fruits if possible. These may be necessary for a correct identification.
- Use a ruler to determine the length and width of plant parts. Species differ in leaf, flower, or fruit size.
- Use a hand lens to examine small details such as hairiness.
- Take careful notes about your mystery species and its environment. Compare your notes to leads in the key and descriptions in a field guide.

Now write your own identification key

Writing a key is easiest when you can closely examine live specimens. Plants offer many opportunities to design keys. Base an identification key on different types of fruits or leaves or twigs. If your class prepared plant specimens, you can design a key using a variety of characteristics, just like a professional botanist.

Materials for Designing a Key

- ❑ *6 or more different types of plants, at least 2 samples of each type*
- ❑ *Pencil and paper*
- ❑ *Ruler*
- ❑ *Hand lens*
- ❑ *Field guide for your region (optional)*

Steps to Designing a Dichotomous Key

Make preliminary observations Look closely at your plant samples. What patterns do you see? Do they differ in the number of petals, number of leaf veins, arrangement of leaves along the stem? Sort the samples into like kinds. How do they differ in shape, color, size, texture?

Get down to business Work in teams of two. Consult with your partner to decide the characteristics you will use to identify the different plants. Write a dichotomous key, continue dividing groups using the selected characteristics until each type of plant is sorted and named (use a common name if you don’t know the plant species). Each team member could be responsible for one lead per couplet, or team members could take turns writing couplets. Finished? Now, try using the key to identify each plant type, revise your key as needed.

Test it Trade materials with another team. First examine the new samples. Then use the key to identify each plant type. How could the team improve its key? Are their other ways of grouping the specimens, of ordering the options? Swap materials and lists of suggested improvements.

Refine it Take into consideration the suggestions you received. Refine your key.

Photo answers: (a) = Larch; (b) = Pine; (c) =Fir; (d) = Douglas-fir; (e) = Spruce; (f) = Hemlock

New tricks of the trade Interactive, multi-access keys are increasingly common online. Multi-access keys differ from dichotomous keys because they allow you to consider the options in any order. That is helpful if a specimen lacks an important part, making it impossible to decide between particular options. Although fun and easy to use, multi-access keys are time-consuming to write.

If you have access to the web, take a look at these websites <http://pick4.pick.uga.edu/mp/20g?guide=Wildflowers; http://geo.cbs.umn.edu/treekey/; http://www.virtualherbarium.org/treepuzzle/navikey/navikey.html>.

Conducting and Analyzing Biodiversity Surveys

How many kinds of plants live around you? Which plants are common and which are rare? Are some areas more diverse than others? What is the average tree size? When does plants flower? How can you answer these questions? Conduct a plant diversity study.

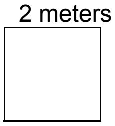
Before you head into the field Surveying the diversity of life on Earth is a big task. It requires good teamwork and sound research. Field biologists must make practical decisions about what organisms to study, what size and number of plots will be needed for an accurate survey, and how long will the work take.

Brainstorm with your fellow students and decide what you want to learn about the biodiversity in your local area. Would you like to maintain a permanent plot for future classes? In addition to noting changes in the number and kind of plants present, your school could monitor changes in flowering times from year to year.

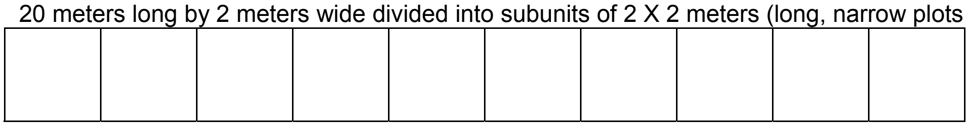
As field biologists looking at local plant diversity, you and your classmates also need to plan your research. Are there too many plant species in the local environment – whether the schoolyard or city park – to survey them all? Your class can decide to survey the trees only or the trees and shrubs or the herbs only. Would similar-sized plots work equally well for surveying trees or herbs?

Below are some sample plot designs. Discuss the advantages and disadvantages of different plot designs. Determine a size plot to fit the goal of your class survey.

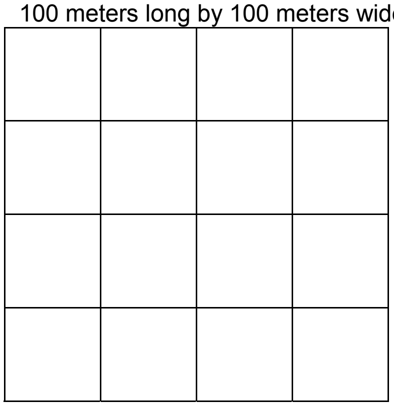
2 meters long by 2 meters wide



20 meters long by 2 meters wide divided into subunits of 2 X 2 meters (long, narrow plots are transects)



100 meters long by 100 meters wide divided into subunits of 25 X 25 meters



In your field notebook, write down the research questions and the plans your class devised to answer them. Try to imagine problems that might complicate your plans to survey plant diversity. Develop strategies to deal with these problems should they arise.

Study a local field guide to learn some plants you'll likely encounter is your survey.

Now you're ready for fieldwork

Materials for Surveying Plant Diversity	
❑ *Tape measurers or meter sticks, string, compass and stakes to mark plots (or frame for small plots)*	❑ *Datasheets, pencils, and permanent pen* ❑ *Map of the area (optional)* ❑ *Field guide for your region (optional)*

1. Look over the survey site, considering the variety of plants and habitats. Make a guess about how many kinds of plants are present in the area.

2. As a class, determine where to mark out the plots (or place a frame for small plots). Aim to survey at least three plots. If possible, survey more than one habitat type.

3. Work in large teams to mark out the plots. Place a stake in each corner, measure the correct length and width, and mark off straight lines of the plot using string and a compass. Mark off subplots with string and stakes or draw distinct lines on the string with a permanent pen.

4. Work in teams of three to six students to conduct the survey. Each team will be responsible for collecting data on a small area within the plot or a small plot.
   - One team member will record the data (use the sample sheet or create your own).
   - One or two members will inspect each plant in the survey area and report the information to the data recorder. Work carefully to avoid counting the same plant twice or dead plants. If you do not know the name of a plant and cannot identify it using a local field guide, give the plant a preliminary name such as Mystery tree #1 or Unknown shrub # A and note a general description of the plant.
   - If your class is collecting specimens in conjunction with the plant survey, additional team members will be responsible for collecting and pressing the specimens.
   - If your class is asking questions about the distribution of plant species within the local environment, one team member will be responsible for mapping where on the plot the plants are found.
   - If your class is collecting information about when plants produce flowers, fruits, and new leaves, one team member will be responsible for recording this information.

5. Complete the survey and analyze the data.

How close was your guess to the number of plant species recorded from the survey?

Get the most from your survey data by crunching the numbers. Find out which plant is the most common in each plot and calculate the biodiversity of your local area. Before moving on to the next step, make sure you know the size of the area you surveyed. Why do you think it is important to know the total area surveyed?

Calculate it

Materials for Analyzing and Presenting Plant Data	
❑ *Calculator* ❑ *Graph paper and pencils (or computer)*	❑ *Data from survey* ❑ *Map of the area (optional)*

For each plot, calculate:

Density = the number of individuals per unit area (also called abundance)

Diversity = the number of species per unit area (also called species richness)

Combine all plot data to calculate:

Relative density = $\frac{\text{the number of individuals of species A}}{\text{the total number of individuals}} \times 100$

(also called relative abundance or frequency)

Frequency rate = $\frac{\text{the number of plots with species A}}{\text{the total number of plots}} \times 100$

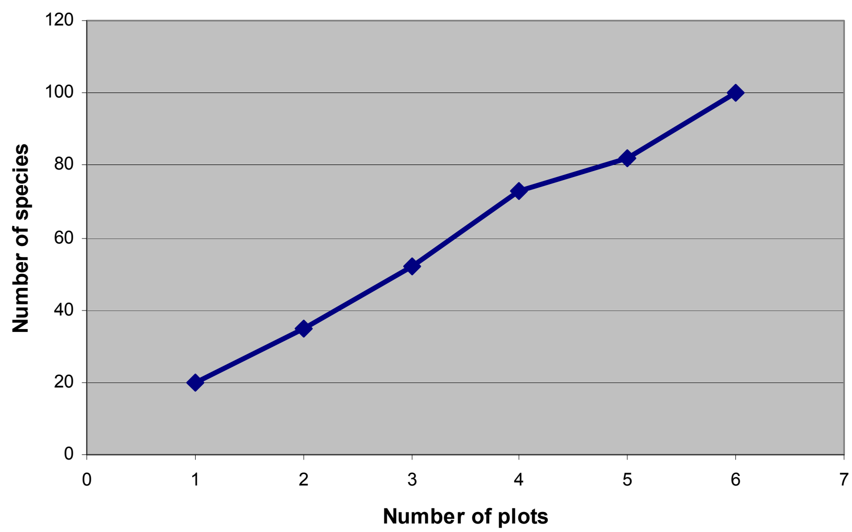
Interpret it

Were some plots more diverse than others? Compare and contrast the plots and habitats studied. List some possible differences between the plots and give some reasons why some areas have higher diversity (species richness) than others. How would diversity differ in a city park, an old field, a forest, or a prairie?

Do you think your survey data accurately describes the plant diversity in your area? What might influence whether a survey is accurate or biased?

What does the graph at right show?

How is this important to biodiversity surveys?



Think about biodiversity a bit more…

How do humans influence the abundance and diversity of plants in different areas?

Why does diversity matter? Does high plant diversity have advantages? How do animals rely on plants? Design a study to test the hypothesis high plant diversity leads to high animal diversity.

Are some plants common in all plots and others found only in a few plots? Do different kinds of plants grow in different areas (e.g., in the shade near a stream or south-facing slopes or clay soils)? In addition to answering questions on diversity, surveys provide data on the distribution of plants in the environment. What biotic and abiotic factors influence where plants grow locally? What variables would you record to test these ideas?

Plant diversity data sheet

Survey team members: ____

Date: ____________ General survey location: ______________________________

Description of survey site (e.g., habitat, environmental conditions): ________________
____

Kind of plants included in survey (e.g., trees or herbs): ___________________________

Size of survey plots: _______________ Number of plots surveyed: ______________

Plot # 1 **Description of plot location and site:** ___________________________

Plant number	Plant name (common name, scientific name)	Collected?	Plant size*	Other notes

* Botanists often record the height of a plant or its diameter at breast height (dbh).