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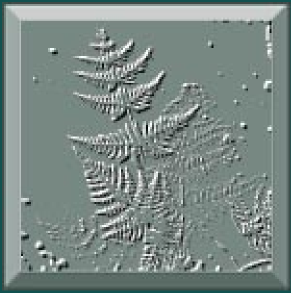

Plants

by
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Overview

This section describes trends in two of the major kingdoms of life on earth: the green plants of the Kingdom Plantae and the molds, lichens, and mushrooms of the Kingdom Fungi. Members of the plant and fungal kingdoms have both economic and ecological importance. Plants transform solar energy into usable economic products essential in our modern society and provide the basis for most life on earth by generating oxygen as a product of photosynthesis. Fungi not only mediate critical biological and ecological processes including the breakdown of organic matter and recycling of nutrients, but they also play important roles in mutualistic associations with plants and animals. Members of the Kingdom Fungi also produce commercially valuable substances including antibiotics and ethanol, while other fungi are pathogenic and cause damage to crops and forest trees. Because fungi and plants play such fundamental roles in our lives, it is important to have a comprehensive knowledge of the taxa comprising these groups. However, at a time when we are increasingly recognizing the importance of these groups, we are impoverishing our biological heritage. Rates of species loss are reaching alarming levels as ecosystems are degraded and habitat is lost. This erosion of biological diversity threatens the maintenance of long-term sustainable development and protection of the earth's biosphere.

Questions involving biological diversity are now of major concern to scientists, the general public, and government agencies with mandates for natural resource protection. Much of this concern has been directed toward tropical forest systems because of their high levels of biodiversity, although other regions, including the United States, deserve our immediate attention. Certainly, a first step toward conserving biological diversity must be based on a firm knowledge of the numbers and distribution of existing species. Developing good estimates of species diversity is also important in describing historical and current trends of species dynamics. Unfortunately, despite the existence of various state and regional surveys, the efforts of taxonomists and natural historians, and the publication of various floras, we still do not have precise estimates of the status of plant and fungal taxa in the United States. Estimates for vascular plant taxa in the United States range upward from 17,000 species (Morin, Morse et al., this section). In contrast to this well-studied group, only 5%-10% of an estimated 1.5 million fungal species have been described worldwide (Rossman, this section).

Even though the bulk of information about our native vascular flora was collected in the 19th and early 20th centuries, significant data about the status of plants in the United States continue to be collected as species expand their ranges, as other species thought locally extirpated are rediscovered, as poorly surveyed areas are explored, and as species become extinct. Even in states like New York, which has a long and currently active program of botanical exploration, additional species of vascular plants continue to be documented as poorly surveyed areas are given more comprehensive coverage (Miller and Mitchell, this section).

Herbaria and museums continue to be important repositories for this information because collecting by their personnel represents a significant effort at inventorying plant and fungal species in this country (Morin, this section). Unfortunately, their role is increasingly at risk as support for collecting declines. In other cases, a shortage of trained specialists will prevent an adequate inventory of biotic diversity. Although many regional checklists exist as well as excellent manuals that cover bryophyte systematics, floristic inventories of bryophytes have been hampered primarily by a lack of trained professionals (Merrill, this section).

The flora of the American countryside has been much changed since European settlement. Over the past 20 years alone, more than 200 species of non-native vascular plants have been recorded in New York state; these species represent an important risk to native plant communities (Miller and Mitchell, this section). Human activities are responsible for the introduction of these invasive exotics as well as the extinction of some species with small geographic ranges or those restricted to unique habitats.

If current trends in land-use continue, however, even species with more widespread distributions will be at risk. For example, lichens as a group are declining in many areas from the effects of air pollution. It is estimated that as much as 80%-90% of the original lichen flora has disappeared from urbanized areas (Bennett, this section). Likewise, marked declines in macrofungi have been documented in Europe although similar trends in this country have not been published because, in part, of the incomplete inventory and lack of monitoring of these groups in the United States (Mueller, this section). Among the more completely documented vascular plants, The Nature Conservancy reports that 9.8% of native species have been lost from at least one state, more than 200 native species have become extinct in the United States, and an additional 403 native plant taxa need protection under the United States Endangered Species Act (Morse et al., this section).

The articles in this section represent an important step in describing the status of the plant and fungal taxa in this country. They provide a snapshot illustrating our knowledge of past and current distributions of plants; the importance of developing a more comprehensive data base for various groups, especially the fungi; and the need to develop a comprehensive inventory of the continually changing and evolving flora of the United States. If we are to understand the causes underlying the changes in patterns of diversity and make predictions about the threats of anthropogenic (human-caused) activities, we must have a quantitative understanding about the nature and distribution of the taxa composing our flora.

Microfungi: Molds, Mildews, Rusts, and Smuts

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Fungi are a group of organisms that exist as a vast network of tiny threads growing in and out of all kinds of organic matter. As they grow, the threads secrete enzymes that break down the substances around them, releasing nutrients into the environment. Without fungi, the world would be completely covered with organic debris that would not rot, and nutrients would not be available for plant growth. All plants would die.

Microfungi include the organisms that are called molds and mildews as well as rusts and smuts, which cause plant diseases. They grow in all substrates, including plants, soil, water, insects, cows' rumen (*see* glossary), hair, and skin. Microfungi are said to be small because only part of the fungus is visible at one time, if at all. The visible parts produce thousands of tiny spores that are carried by the air, spreading the fungus. Most of the fungal body consists of microscopic threads extending through the substrate in which it grows. The invisible fungal structure may be extremely large, often extending for miles as, for example, the "humongous fungus" occurring in the north-central United States (Rensberger 1992).

Among the multitudinous molds are humble servants such as *Penicillium notatum*, the source of penicillin, and *Tolyposporium niveum*, a producer of cyclosporin, the immune-system suppressant used for organ transplant operations. In sustainable agriculture the fungal performers are agents of biological control and crop nutrition, helping the environment through the reduced use of chemical pesticides and fertilizers. Fungi can stop a hoard of locusts by attacking the chitinous insect exoskeleton or control nematodes that destroy the roots of crop plants (CAB 1993). Although strains of fungi can degrade plastics and break down hazardous wastes such as dioxin (Jong and Edwards 1991), only a fraction of these fungi have been screened as beneficial organisms.

Microfungi can also be harmful, causing the irritating human affliction known as athlete's foot as well as disastrous diseases of crops and trees. The potato famine in Ireland during the mid- to late 1800's was caused by a fungus called *Phytophthora infestans* that rotted the potato crops for several years (Large 1962). Because of this disease, many Irish immigrated to the United States. Once the nature of the disease was determined, a solution based on fungus control was found. Knowing what fungi exist, where they occur, and what they do is essential.

Diversity of Microfungi

The microfungi are the most diverse group of all the fungi but the least understood or documented. Only about 5%-10% of all fungal species have been described, much less characterized and put to use or controlled. Investigations to explore the diversity of microfungi have shown that they are much more diverse than previously thought. Very small samples of tropical rainforest leaf litter yielded up to 145 different species of microfungi (Bills and Polishook 1994). About 200,000 fungal species have been described worldwide (Reed and Farr 1993), yet an estimated 1-1.5 million species may exist (Hawksworth 1991; Rossman 1994).

Within the United States, information has been published about 13,000 species of microfungi on plants or plant products (Farr et al. 1989), probably only a fraction of the species thought to exist. Specimens of microfungi are housed in the U.S. National Fungus Collections and other institutions that serve as reservoirs of information and documentation about our nation's natural heritage. By comparing the species reported in the literature with those represented in the collections, one can estimate the number of microfungi known in the United States at 29,000 species (Farr et al. 1989). In areas of the world where fungi have been well studied, the ratio of vascular plants to fungi is about 6 to 1, suggesting that there may actually be 120,000 species of fungi within the United States.

Internet Information

Although the numbers and kinds of fungi in the United States are not known, information about the microfungi associated with plants and plant products in the United States is available over Internet at this telnet address: FUNGI.ARS-GRIN.GOV. After the word *OK* appears on the screen, type *login user;* when prompted for a password, type *user*. By doing this, anyone can find out what fungi might occur on the flowers in his or her own backyard. Data can also be consulted on accurate scientific names of microfungi, recent literature on plant-associated fungi, specimens in the U.S. National Fungus Collections, and records of microfungi on plants throughout the world. In an instant, reports of fungi can be consulted by those making land-management decisions or helping a farmer control a disease.

Survey and Inventory Needs

Knowing which microfungi occur within the United States provides information upon which plant quarantine decisions are made. A wrong decision allowing entry of a harmful pathogen can profoundly affect this nation's biological resources. In the eastern United States, a devastating disease called chestnut blight, caused by *Cryphonectria parasitica* and unknowingly imported from Europe on logs, killed virtually all the towering chestnut trees that once dominated our forests in the last century (Anagnostakis 1987). Now on the forest floor only skeletons of the trees can be seen with decay fungi rotting the bleached "bones" of these fallen giants.

Another disease, dogwood anthracnose, occurs on flowering dogwood trees in both the eastern and western United States. The causal fungus, *Discula destructiva*, was unknown until 1991 (Redlin 1991). Still unknown is whether this fungus was imported or was already present in the United States before its appearance as dogwood anthracnose. Because microfungi are small, their existence may not be noticed until they cause serious diseases.

A program to inventory and monitor microfungi in the United States does not exist at present; thus it is impossible to determine if species of microfungi are increasing or declining. Efforts to document the biodiversity of microfungi in the United States are limited to reports by plant pathologists who encounter disease-causing organisms or search for useful biological-control organisms. Information about the occurrence and biology of microfungi will increase the ability to make accurate decisions about the importation of agricultural products, to control microfungi already present, and to determine if beneficial microfungi are being lost because of habitat destruction. With increased knowledge the unexplored world of microfungi can be put to work to solve our most pressing environmental and agricultural problems.

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Macrofungi

by
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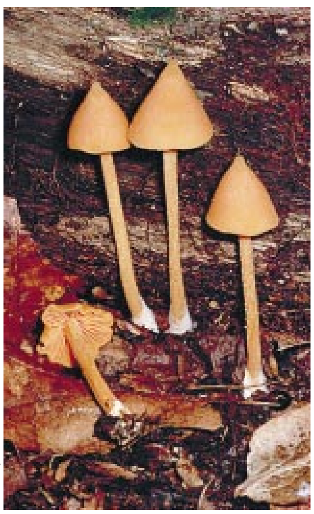
Macrofungi are a diverse, commonly encountered, and ecologically important group of organisms. Like most fungi, the major part of these organisms consists of a mass of thin, microscopic threads (termed mycelium) growing in soil, decomposing leaves, and other substrate. They differ from other fungi by forming large, macroscopic fruitbodies at some time in their life; the mushrooms sold in grocery stores are an example of these fruitbodies. This group of fungi includes all mushrooms (Fig. 1), morels, puffballs, bracket fungi, and cup fungi.

Macrofungi are vitally significant in forests; many species help break down dead organic material, such as dead tree trunks and leaves, into simple compounds usable by growing plants. Thus, they act as nature's recyclers, without which forests could not function. Some species are major plant pathogens (causes of disease) that cause millions of dollars of damage to U.S. forests each year. Still other species enter into a necessary, mutually beneficial association with trees such as oaks, pines, firs, and spruces. In this association (Fig. 2), termed mycorrhizae, the mycelium of the fungus brings water and nutrients to the tree in return for taking excess food from the tree. Neither the tree nor the fungus can survive without the other. Finally, some of these fungi form an important part of the diet of many small mammals and insects. For example, small truffle-like fungi are a major food source of the northern flying squirrel (*Glaucomys sabrinus; see* box). Because macrofungi are an indispensable component of the forest ecosystem, information on which fungi occur in the forests and on the specific role that they play is necessary for management and maintenance of our forests.



Courtesy G.M. Mueller, The Field Museum

Fig. 1. *Entoloma salmoneum*. The salmon-colored entoloma is a common recycler of forest litter in North American forests.

Courtesy G.M. Mueller, The Field Museum

Fig. 2. Mycorrhizae formed between ponderosa pine and *Laccaria laccata* in the laboratory. Note the branched pine roots and threadlike fungal hyphae.

Macrofungi also directly affect people. Though some fungi are deadly poisonous, others are prized as edibles. Commercial mushroom harvesting is a multimillion-dollar-a-year business in the United States; for example, the industry added an estimated $40 million to the Oregon economy in 1993 alone. Additionally, several thousand amateur mushroom hunters in the United States collect solely for their own enjoyment.

Number of Species

Considering the human, ecological, and economic importance of these organisms, it is somewhat surprising that there is not a good estimate of the number of species of macrofungi that occur in North America. Because there are neither checklists of North American mushrooms and their relatives nor comprehensive regional treatments, the best estimates of North American diversity are based on comparisons with numbers of these organisms reported from Europe. More than 3,000 species of mushrooms and their relatives are reported from western Europe (Moser 1983), but most scientists who study fungi (mycologists) would estimate that far more species occur in North America. For example, more than twice as many species of *Lactarius*, *Amanita*, and *Clitocybe* are reported from the continental United States (Hesler and Smith 1979; Bigelow 1982, 1985; Jenkins 1986) than from western Europe (Moser 1983).

Better estimates exist for species diversity of the other groups of North American macrofungi. Gilbertson and Ryvarden (1986, 1987) treated more than 400 species of polypore fungi, Smith et al. (1981) listed nearly 300 species of puffballs and relatives, and Seaver (1942, 1951) covered more than 350 species of cup fungi and other macro ascomycetes. Based on these data, it is reasonable to predict that there are 5,000-10,000 species of macrofungi in the United States. A compilation of herbarium records in U.S. and Canadian museums and universities would provide a good first step in predicting the diversity of these organisms.

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Courtesy G.M. Mueller, The Field Museum

Fig. 3. *Cantharellus cibarius.* The chanterelle is one of the important fungi forming mycorrhizae with pines and oaks in North American forests.

Declining Fungi

Change in the frequency of occurrence of macrofungi in Europe is well documented; many species that form ectomycorrhizae (a kind of mycorrhizae; *see* glossary) are showing a marked decline, and some species involved with wood decay show a marked increase in fruiting. More than 50% of the reported species of mushrooms in Europe occur on at least one country's "Red List" (*see* glossary: "red data book") (Arnolds and de Vries 1993), and once-common species such as *Hydnum repandum* and some of the chanterelles (Fig. 3) appear lost from some countries. Air pollution, particularly acid rain, has been implicated in this observed decline in ectomycorrhizal fungi fruiting frequency and diversity in Europe (Fellner 1993; Pegler et al. 1993). Intensive collecting of edible fungi such as chanterelles, *Hydnum*, and boletes might also be negatively affecting fruiting patterns of these fungi, but additional data are needed to document this. In any case, the observed change in fungal fruiting is correlated with a decline in forest health, but cause and effect are hard to document. Rigorous studies to determine if similar trends in macrofungi fruiting patterns have occurred in the United States do not exist.

Current Studies of Diversity

The baseline data necessary for estimating fungal diversity and for investigating trends in fruiting patterns and frequencies of macrofungi in the United States and Canada are not yet available although various methods are beginning to be used to obtain these necessary data. For example, studies of species diversity and frequency of particular fungi in Pacific Northwest old-growth forests have documented that while a single season of collecting will uncover most of the decomposer macrofungi, mycorrhizal fungi fruit much more erratically (Vogt et al. 1992). Thus, to develop a reasonable

Truffles, Trees, and Biodiversity

by
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Most Americans identify truffles as expensive, Epicurean delights from Europe, found with the aid of pigs. Because truffles are produced belowground, we remain ignorant of the rich diversity and importance of truffles in North America. Truffles (ascomycetes) and the similar-appearing false truffles (basidiomycetes) play a major role in determining the structure and function of forest ecosystems by providing nutrients to many economically valuable trees in exchange for carbohydrates from the trees. This mycorrhizal (fungus root) symbiosis is obligate; that is, truffles and trees, especially conifers, cannot survive without each other. One of the problems in reforesting large areas of the Southwest is identifying ectomycorrhizal fungi suitable for inoculation of tree seedlings destined for sites with calcareous soils.

Truffles and false truffles are food items for many animals, including many endangered or threatened species. In old-growth Douglas-fir (*Pseudotsuga menziesii*) forests, truffles not only provide soil nutrients to the trees controlling forest structure, but they also are an important link in the food web supporting the endangered spotted owl. Northern flying squirrels (*Glaucomys sabrinus*) glide down to the forest floor at night to feed on truffles. While feeding on truffles, flying squirrels become vulnerable to predation from the northern spotted owl (*Strix occidentalis caurina*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), and other predators.

Given the undeniably important role of truffles in determining the structure and function of forest ecosystems, how much is known about the distribution of truffles and false truffles? The paucity of information and potential impact of surveys on our knowledge base can be illustrated by an ongoing National Science Foundation-funded survey of the Great Basin, an area of 712,250 km^2 (275,000 mi^2) between the Sierra Nevada and Wasatch mountains and including most of Nevada and parts of California, Idaho, Utah, Wyoming, and Oregon. No truffles or false truffles had been reported from the area before the survey. Over three summers, the survey produced 1,119 collections of truffles and false truffles from 40 mountain ranges.

In addition, the survey produced evidence for extinction of many truffles in the Great Basin. A few truffles obligately associated with a single tree species outside the Great Basin have switched within the Great Basin to new tree species, providing supporting evidence for extinction of local tree species. New endemic species have been found and the geographic ranges of some species greatly expanded. Populations of some endemic species are restricted to a single mountain range.

Knowledge of truffles is important to the biodiversity in the United States. Without such knowledge, there is a danger of losing or degrading ecosystems through ignorance about the status of keystone fungal species. If ecosystems are lost, then species dependent on specific ecosystems will also be lost.

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estimate of species richness and dominance, researchers must sample over several years. These studies also have documented that certain collecting techniques work better for some fungi than others, which emphasizes the need to develop standardized sampling protocols for collecting data on fungal species' richness and fruiting patterns.

Satellite imagery has been combined with a long-term mapping program of fungal fruitbodies to assess the relative health and growth of particular tree-mycorrhiza fungus pairs in southern Mississippi (Cibula and Ovrebo 1988). This approach shows great promise for directly investigating the effect of certain fungi on tree health. These data, however, are based only on aboveground information, and there is still some question about how well the appearance of fruitbodies growing under a particular tree predicts what fungi are forming mycorrhizae with that tree at that time. To address this question, researchers have developed molecular techniques using DNA amplification procedures to compare the mycorrhizae on the roots of certain trees with fungal fruitbodies occurring near the tree (Bruns and Gardes 1993). The preliminary data documented that there is not always a one-to-one correlation between fruitbodies and mycorrhizae, and that caution must be used when using fruitbodies alone.

Further Studies

The studies mentioned in this article illustrate the range of work in the United States on assessing diversity and determining possible changes in fruiting patterns of macrofungi. More work is needed to document the status and trends of macrofungi in North America. These data are vital because of the integral role that macrofungi play in forest systems as decomposers and recyclers, plant pathogens, mutualists, and food for small mammals, and because of the growing commercial importance of these fungi.

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Lichens

by
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Lichens are a unique life form because they are actually two separate organisms, a fungus and an alga, living together in a symbiosis. Lichens seem to reproduce sexually, but what appears to be a fruiting structure is actually that of the fungal component. Consequently, lichens are classified by botanists as fungi, but are given their own lichen names.

Lichens are small plant-like organisms that grow just about everywhere: soils, tree trunks and branches, rocks and artificial stones, roofs, fences, walls, and even underwater. They are famous for surviving climatic extremes and are even the dominant vegetation in those habitats. Some lichens, however, are only found in very specialized habitats. The diversity of lichens in an area, therefore, is highly dependent on habitat diversity. Many special habitats across the United States are declining or disappearing because of human activities, and some lichen species are consequently in decline.

Lichens are very diverse in form: some grow flat and appressed to a substrate, others are more leaf-like and grow free of the substrate, and yet others have complex filamentous and blade-like forms.

Lichens are unique botanically because they lack any outside covering, or cuticle, and consequently are directly exposed to the atmosphere, which they depend upon for their nutrients and water, neither of which is derived from their hosts. Moistened lichen tissues act as blotters, soaking up chemicals or materials deposited on their surfaces. Unfortunately, this feature has also made them highly susceptible to air pollutants; lichens are perhaps the plant species most susceptible to sulfur dioxide, heavy metals, and acid rain.

Lichens play important roles in ecosystems. They break down rocks and form soil by excreting weak acids, or in arid ecosystems like deserts, they help bind the soil surface by forming crusts. They are important food sources for invertebrates and vertebrates, including reindeer that eat reindeer "moss," which is actually a lichen (Fig. 1). In addition, some birds depend on certain lichens for nest-building materials. Finally, some lichens can fix nitrogen from the atmosphere and contribute a significant portion of this to certain forest ecosystems (e.g., the Pacific Northwest).

Courtesy J.P. Bennett

Fig. 1. *Cladina mitis* and *C. rangiferina* (reindeer moss), Voyageurs National Park, MN.

A rich lichen flora in a region indicates a lack of disturbance in the area for two reasons. First, lichens can only appear in an area if both the fungus and alga are propagated there and coincide. Isolation of an area so that propagules (*see* glossary) cannot reach the area will slow down recolonization significantly. Second, lichens grow slowly, usually only a few millimeters a year. Thus, colonization of an area by lichen species typically does not occur even over the span of one human generation.

Status

The best estimates of the number of U.S. lichen species are between 3,500 and 4,000, grouped in about 400 genera. The current checklist for the United States and Canada is probably in excess of 3,600 (Egan 1987).

Some species are cosmopolitan and are found from coast to coast. Most species, however, are more limited in their geographic distributions. The percentage of species that are rare nationally is high: about one-third of more than 400 lichens described by Hale (1979) are rare, and this ratio could probably be applied to the total number for the United States. Thirty-eight percent of the lichen flora of Hawaii is considered endemic. Five lichen species have been nominated for federal threatened and endangered listing (Pittam 1991), and several states (e.g., California, Minnesota, and Missouri) have listed some species as threatened or endangered.

No state has a complete lichen flora published. Incomplete floras or checklists are known for Alaska, California, Colorado, Connecticut, Florida, Hawaii, Louisiana, Michigan, Minnesota, North Carolina, New Mexico, New York, South Dakota, Tennessee, Texas, and Washington. Most of the rest of the country's lichen flora remains unexplored. Species for these partial checklists number in the several hundreds, with the exception of California with 999 taxa. Nationally, centers of diversity for lichens include the Pacific Northwest, California, the southern Appalachians, Florida, and Maine. On a more local scale, wetlands and floodplains tend to have higher numbers of lichen species than more arid areas. The presence of a bog or a rocky outcropping in an area will typically double the number of species present.

There are about 10 lichen herbarium collections with active lichen taxonomists in the United States, and about 5 in Canada. Many of these collections are poorly funded, not computerized, and stored in inadequate or outdated facilities. Fewer than two dozen practicing lichenologists work in the United States and Canada, and very few graduate students are being trained in lichenology. Most academic botany or biology departments do not have lichenologists.

Trends

About 100 years ago, lichens had disappeared from many cities in Europe and Great Britain and the term "lichen desert" was coined to describe the phenomenon; these lichen deserts were caused by air pollution. Here in the United States, lichen deserts are well known in our cities and nearby rural areas, but are unfortunately poorly documented. Most information is anecdotal, but some studies have shown lichen deserts in eastern Pennsylvania (Nash 1975), the Cuyahoga Valley in Ohio (Wetmore 1989), northern Indiana on Lake Michigan (Wetmore 1988), Cedar Rapids, Iowa (Saunders 1976), Los Angeles (Sigal and Nash 1983), Seattle, Washington (Johnson 1979),

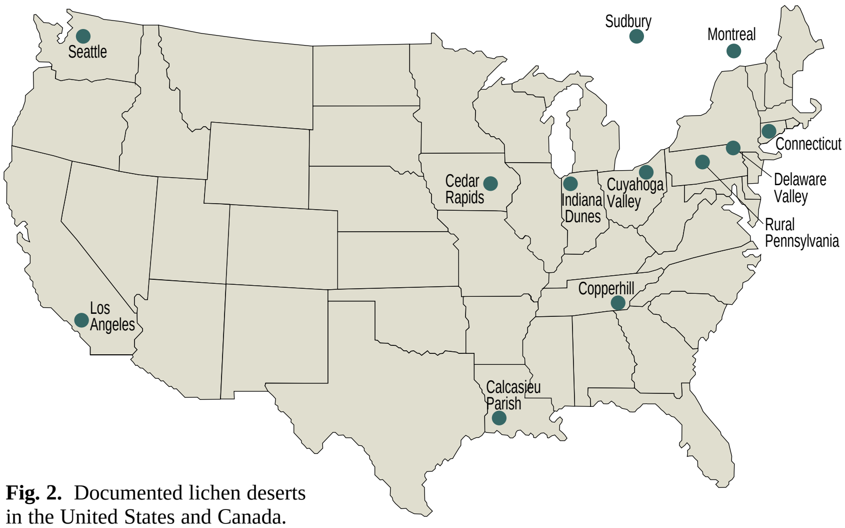

Fig. 2. Documented lichen deserts in the United States and Canada. Strong anecdotal evidence exists that lichen deserts also occur in most major cities.

Copperhill, Tennessee (Mather 1978), and in Canada in Montreal (LeBlanc and De Sloover 1970) and Sudbury (LeBlanc et al. 1972) (Fig. 2). In some of these areas, researchers estimate that as much as 80%-90% of the original lichen flora is gone (Nash 1975; Wetmore 1989). Acid rain has diminished lichen diversity in remote rural areas such as north-central Pennsylvania (Showman and Long 1992), central and southwestern Connecticut (Metzler 1980), and southwestern Louisiana (Thompson et al. 1987). Sensitive species must be studied and monitored to determine the effects of air pollutants.

Some lichens are unique to old-growth forests. *Usnea longissima*, which only grows in old-growth spruce forests, has vanished from many sites in western Europe (Esseen et al. 1992) and may be repeating this pattern in parts of the United States. Other old-growth forest lichens, including *Alectoria sarmentosa*, *Lobaria scrobiculata*, and *Ramalina thrausta*, are now quite rare in the eastern United States because of habitat destruction and loss.

In addition, scientific overcollecting may become a problem for lichens. One species, *Gymnoderma lineare*, was overcollected in Great Smoky Mountains National Park, Tennessee, in the late 1970's, and is now proposed for federal listing as endangered. Collecting is no longer allowed in certain areas (e.g., some national parks and nature preserves), and both the American Bryological and Lichenological Society and the British Lichenological Society do not always permit collecting at popular sites during their annual forays. Some hobby overcollecting of lichens for dye materials or architectural tree models is thought to be a problem in a few areas, but is not well documented.

Trends in lichenology in this country are not encouraging and are at odds with trends in the rest of world (Galloway 1992). With fewer universities offering training in the discipline, fewer surveys and lists of floras being done, less literature being published, and at the same time lichens disappearing from our ecosystems, it is clear that the science is heading the opposite direction of what is needed. Other countries, including England, Canada, the Netherlands, and Japan, are increasing funding for lichenology, training more students, publishing more literature, and conserving their lichen flora. Given the problems confronting lichen habitats, the size of the United States, and the potential flora it may have, lichen science needs more attention. A reasonable start would be a preliminary checklist for every state and an identification of priority areas for future surveys.

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Bryophytes

by
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Bryophytes (mosses, liverworts, and hornworts) are small green plants that reproduce by means of spores (or vegetatively) instead of seeds. Most are only a few centimeters high, although some mosses attain a half meter (20 in) or more. Although often small and inconspicuous, bryophytes are remarkably resilient and successful. They are sensitive indicators of air and water pollution, and play important roles in the cycling of water and nutrients and in relationships with many other plants and animals. Information about bryophytes and their ecology is essential to develop comprehensive conservation and management policies and to restore degraded ecosystems.

There are three main groups of bryophytes: mosses (Musci); liverworts, also known as hepatics (Hepaticae); and hornworts (Anthocerotae). Bryophytes rank second (after the flowering plants) among major groups of green land plants, with an estimated 15,000-18,000 species worldwide. In North America north of Mexico, there are 1,320 species of mosses in 312 genera (Anderson et al. 1990), and 525 species of hepatics and hornworts in 119 genera (Stotler and Crandall-Stotler 1977), or somewhat more than 10% of the world's bryophyte species.

Mosses are most abundant and conspicuous in moist habitats, but are also found in grasslands and deserts, where they endure prolonged dry periods. Hepatics also include some arid-adapted species, but most are plants of humid environments. In mosses and leafy hepatics, the conspicuous plant body is leafy; in some liverworts and all hornworts, the plant is a flattened, ribbon-like "thallus" that lies flat on the ground. Bryophytes have no roots but are anchored by slender threads called rhizoids, which also play a role in the absorption of water and mineral nutrients.

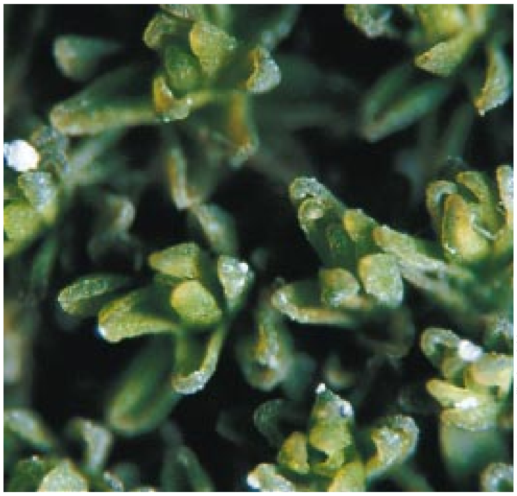
Bryophytes have successfully exploited many environments, perhaps partly because they are rarely in direct competition with higher plants (Anderson 1980). For such small organisms, the climate near the ground (microclimate) is often very different from conditions recorded by standard meteorological methods, and shifts in temperature and humidity are often extreme. A remarkable adaptation of bryophytes is their ability to remain alive for long periods without water, even under high temperatures, then resume photosynthesis within seconds after being moistened by rain or dew.

Ecological Roles

Most bryophytes appear to absorb water and mineral nutrients directly into leaves and stems, a fact that makes them extremely vulnerable to airborne pollutants in solution (*see* references in Longton 1980). Where abundant, bryophytes may constitute an important sink for moisture and nutrients. Mosses are reliable indicators of soil conditions because they tend to accumulate chemical elements somewhat indiscriminately. The analysis of concentrations of pollutants in older bryophyte specimens could be used to document increases in pollution levels over time.

Bryophytes are also closely associated with organisms as diverse as protozoa, rotifers (microscopic aquatic animals), nematodes, earthworms, mollusks, insects, and spiders (Gerson 1982), as well as plants and fungi. Direct interactions of bryophytes include providing food, shelter, and nesting materials for small mammals and invertebrates; indirectly, they serve as a matrix for a variety of interactions between organisms.

Bryophytes occur in all types of environments, except salt water. They occur on both shaded and exposed soil and rocks, the bark of living trees, and on decaying logs and litter in humid forests (evergreen and deciduous). Many are subaquatic in swamps, bogs, and fens, and some grow submerged or emergent in streams. There are no marine bryophytes, but a few grow on coastline rocks and can tolerate exposure to salt spray.



Courtesy G.L. Merrill, The Field Museum

The newly discovered moss genus and species, *Ozobryum ogalalense*, is known only from four localities in northwest Kansas and adjacent Nebraska (Merrill 1992). The species forms soft, compact cushions on exposed lime-rich outcrops in native prairie pastures. The outcrops are porous and charged with moisture, making them a magnet for several species of bryophytes in an otherwise hostile environment. *Ozobryum* underscores the fact that discoveries can still be made in areas of the country where bryophytes are poorly known.

In the moss-carpeted rainforests of the Pacific Northwest, bryophytes make up a significant proportion of the biomass. Peat moss (*Sphagnum*) is a dominant organism in northern peatland communities and is of some economic importance in horticulture and as an energy source. Bryophytes of arid grasslands and deserts are few, but there are mosses that appear adapted to prairies and to the periodic intense disturbance of grazing and fire (Merrill 1991).

Floristics and Distribution

Basic information on the distribution of bryophytes is available for at least the northeastern United States, eastern Canada, and the Pacific

Northwest. Some parts of the continent are less well known, chiefly remote areas of the Rockies, the arid Southwest, and the Great Plains. Much information about the bryophytes of the interior plains may be "irretrievably lost since most of the natural grassland, with whatever mosses it may have sheltered, is under cultivation" (Schofield 1980, p. 131), but fieldwork can still yield important discoveries (Merrill 1992) as well as basic distributional information.

A much-improved picture of bryophyte distribution in North America will emerge as the result of the preparation of treatments for Volume 13 of *Flora North America* (scheduled for publication in 1996), but much of the necessary distributional information is simply not available now.

Status

Some bryophyte species appear to thrive in disturbed habitats (both "naturally" disturbed and those due to human activity). Many bryophytes, however, are quite rare, have extremely local distributions, and are at risk. Changes in land use and loss of habitat represent the greatest threat to bryophyte diversity. Cutting forests, draining bogs and wetlands, and destroying rock faces by quarrying and road building are especially destructive.

Most bryophytes are unlikely to be picked for their own sake, but where mosses are particularly abundant, as in the Pacific Northwest, commercial harvesting for horticultural purposes can have a significant effect. The loss of bryophyte habitat is likely to have a ripple effect, since other organisms closely associated with them are also likely to be lost. Efforts at habitat restoration must take into account the difficulty of re-creating the specialized conditions that many bryophytes require.

Future Needs and Priorities

Basic floristic inventories are an essential part of any assessment of the role of bryophytes in natural ecosystems. While checklists are available that cover the whole of North America (as well as many states), and floristic works are available that make the task of identifying species easier, these do not provide information on the status of individual species. Inventories are needed to identify areas where many rare bryophytes occur; these areas should be given priority in establishing conservation reserves. In addition, trained specialists are scarce, and their numbers are decreasing. The advent of modern electronic data-base technology makes it possible to capture important distributional information contained in existing collections, but this also is time-intensive and expensive. Priorities are to support basic floristic research on bryophytes (and the training of new bryologists and information specialists needed to deal with the formidable task of documenting bryophyte diversity) and to provide support to institutions that maintain the major national resource collections of bryophytes.

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Floristic Inventories of U.S. Bryophytes

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Few floristic inventories of bryophytes have been made in the United States, primarily because of lack of trained personnel. The publication of modern manuals for the eastern United States for mosses (Crum and Anderson 1981) and liverworts and hornworts (Schuster 1966-92) has improved the situation. The paucity of manuals in the western United States is especially critical because of the uniqueness of the western North American flora. Eighty percent of the genera of bryophytes known to be endemic to temperate North America are confined to the area west of the 110th meridian (approximately the Rocky Mountains and west), but very few bryologists work there (Schofield 1980; Schuster 1984).

Mosses

Mosses are the best known of the three bryophyte groups and have the most species: 1,320 species in 312 genera (Anderson et al. 1990). The only manual of mosses that treats all of North America north of Mexico is by A.J. Grout (1928-40), but is now outdated. Although this flora is unreliable for the mosses in the


Courtesy D. Kearns, Missouri Botanical Garden

The moss *Leucolepis acanthoneuron*.

midcontinent, it covers the mosses from the eastern United States and the west coast regions well.

The eastern forest region is the strongest area for moss floristics in the United States. The United States east of the Mississippi is covered well by Crum and Anderson's (1981) flora. Most states there have recent checklists of mosses. In addition, several regional floras cover parts of more than one state (e.g., Crum [1983] for upper Michigan and nearby areas and Redfearn [1983] for the Ozark region).

The distribution of mosses in other parts of the country is not as well known. There are checklists of mosses for nearly every U.S. state (Pursell 1982), although many were published 30-40 years ago and are outdated. The Southeast has the fewest checklists; the northern parts of Mississippi, Alabama, and Georgia and the southern parts of Arkansas are poorly known.

The Southwest is also one of the least known U.S. areas. It has great diversity of habitats including mountains, grasslands, and desert habitats. Although checklists have been published for all of the states and a flora has been published for Utah (Flowers 1973), the mosses of Nevada, Arizona, New Mexico, and parts of Texas are probably still the least known in the country. The recent publication of the moss flora of Mexico (Sharp et al. 1994) will considerably aid workers in this region, but much basic floristic work needs to be done.

Good state checklists exist for the Great Plains and the Pacific Northwest, which has checklists for the entire region as well as a regional flora (Lawton 1971). The Great Plains is reasonably well covered with checklists and two regional floras for all of the midcontinent. Moss diversity in this region is low, and many of the mosses are members of the eastern moss flora. But the mosses in this region have not been extensively surveyed, and the area continues to yield surprises such as *Ozobryum ogalalense*, a new genus (Merrill 1993).

Alaska has a checklist and work has begun on a synoptic flora that will cover the Arctic area (Mogensen 1985). Floristically, however, the Arctic areas of Alaska are fundamentally different from the rest of the United States. A portion of flora can be named by using Arctic European floras; otherwise, the flora can be named only by specialists with access to the scattered literature and a good herbarium.

Liverworts and Hornworts

No part of the United States can be considered well-inventoried for liverworts or hornworts. The eastern half of the country is much better known than the West. The preparation of Schuster's manual of the liverworts and hornworts of eastern North America (1966-92), which resulted in the publication of several dozen new species (mostly from the southern Appalachians and Florida), has improved our knowledge of these plants in the East. Many taxonomic problems still need serious study, however, and known ranges of distribution are still incomplete.

Our knowledge of the liverwort and hornwort floras in the western half of the country has improved recently because of a series of local checklists (mostly of national parks and similar small floristic units) for the Pacific Northwest. For large parts of the northwestern United States, however, we still rely on a few pioneering studies from 1890 to 1940.


Courtesy D. Kearns, Missouri Botanical Garden

The liverwort *Asterella echinella*.

The most poorly known part of the country is undoubtedly the interior Southwest (New Mexico, Arizona, and surrounding regions). Data from this area are so scanty and inadequate that it is difficult to assess the regional liverwort and hornwort floras in any meaningful way. Recent studies, though, describe several new taxa and some range extensions. For instance, *Mannia fragrans*, which seems widespread in the mountains of the western United States, was not reported from any state west of Colorado before 1987. Likewise, Bischler's (1979) revision of the xerophytic liverwort genus *Plagiochasma* increased the number of species known from the United States from three to five (adding two widespread Mexican species from

Texas and Arizona). Numerous additions to the flora can be expected from this part of the country if intensive fieldwork is conducted.

Study of these plants has been handicapped by the lack of identification manuals over much of the continent. The completion of Schuster's manual (1966-92) has improved the situation in eastern North America, but there is still almost no usable literature from the western half of the country. Since the first half of the century, there have been no floristic treatments with identification aids of any kind published for any area west of the 110th meridian, with the single exception of the brief checklist of the liverworts and hornworts of Olympic National Park by Hong et al. (1989). In the whole of this large area, which makes up more than half of the country, specimens can only be identified reliably by specialists with access to rare and often outdated literature. Even in the well-studied extreme Northeast (i.e., New England and New York), new taxa continue to be found (for example, *Pellia megalospora* Schust. was not described until 1981). Further collection and study will surely provide many more range extensions. Likewise, the very distinctive endemic genus *Schofieldia* Godfrey was not described from western Washington until 1976, even though it is without close relatives and is rather common in subalpine sites from northwestern Washington north through the central part of the Alaska panhandle.

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Vascular Plants of the United States

by
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Information on the plants of the United States can be found in floras, monographs, and various lists and reports. Herbarium collections provide an invaluable record of past and current distributions of U.S. plants and form the basis for published accounts of the plants such as floras and checklists. Properly understanding and managing U.S. plant resources depend on having physical samples that document the characteristics and distributions of plants and on the scientific studies of the relationships, characteristics, distributions, and physical requirements of the plants. Although such documentation exists for some areas of the country, many areas are still poorly known, and authoritative references are still lacking for some.

About 17,000 species of vascular plants (i.e., flowering plants, gymnosperms, and ferns) occur in the contiguous United States and Alaska (Flora of North America Editorial Committee 1993); Hawaii is home to more than 1,800 species of flowering plants (Wagner et al. 1990), few of which are found on the North American mainland. Trees have been most completely documented, followed by shrubs and showy herbaceous plants. Known distributions of rare plants are generally available in computerized data bases, often maintained by state Natural Heritage Programs. Nationwide database files for rare plants are maintained by The Nature Conservancy.

Non-natives and inconspicuous natives are often overlooked by plant collectors and thus are less well documented. In much of the continent, and especially in highly populated areas, however, the native flora has been altered so completely by humans that "native" or "natural" vegetation is almost beyond conception. Because of this, the historical portrait of plant distribution that can be drawn based on herbarium specimens is extremely valuable to understand the pre-Columbian composition of our flora and the relation of plants to their environment. Modern collecting still brings many new species to light. Between 1975 and 1989, for example, 725 new taxa of vascular plants were reported from the conterminous United States alone (Hartman 1990).

The following discussions indicate what published plant information and data bases exist and describe the level of current and historical plant collecting in the United States.

Major Plant Groups

Few families or genera in the United States have been studied comprehensively throughout their range during the past 50 years, and until now there has been no source that brings together the best existing knowledge of U.S. plant taxa. To provide such a resource, plant taxonomists from the United States and Canada have established the Flora of North America project. Scientific information on the names, relationships, characteristics, and distributions of all plants that grow outside of cultivation in North America north of Mexico will be published in 14 volumes and in an online data base over the next 8 years. To date, two volumes have been published (Flora of North America Editorial Committee 1993). As information is synthesized and published, research needs can be evaluated. Checklists of North American plants are currently available (Soil Conservation Service 1982; Kartesz 1994), and the Soil Conservation Service maintains a data base of Plant List of Attributes, Nomenclature, Taxonomy, and Symbols (PLANTS) for North America.

Pteridophytes

About 500 species of ferns and fern allies are found in the United States, excluding Hawaii where about 200 occur. The most recent treatment of ferns for North America is in Volume 2 of *Flora of North America* (Flora of North America Editorial Committee 1993). Recent studies involving DNA analysis, isozyme work, and modern statistical analyses have significantly improved our understanding of genetic relationships among groups of ferns (Wagner and Smith 1993). Fern groups in the dry areas of the Southwest especially need study.

Gymnosperms

Gymnosperms, with 118 species (none native to Hawaii), include the economically important conifers. Tremendous research has been done on conifers, including detailed population studies of individual species. The most recent treatment of gymnosperms for North America is Volume 2 of *Flora of North America* (Flora of North America Editorial Committee 1993). The *Atlas of United States Trees* (Little 1971), although somewhat outdated, is still the best source for precise distributional information for conifers.

Angiosperms

Most vascular plant species in the United States are angiosperms, those plants bearing what are commonly recognized as flowers. The large sunflower family has been intensively studied over the past several decades, although work on this family is hampered by its complexity and the difficulty of identifying individual plants. In addition, more extensive surveying of the Southwest is needed to understand the family. An account of Asteraceae for the southeastern United States was published in *The Vascular Flora of the Southeastern United States* (Radford et al. 1980); Great Basin species are treated in Volume 5 of the *Intermountain Flora* (Cronquist et al. 1972-94), and Asteraceae will appear as the final published volume of *Flora of North America*.

The grass family is the most agriculturally important family in the United States, both for its forage value and as a source for crop and rangeland weeds. Researchers coordinated by Utah State University are revising the *Manual of the Grasses of the United States* (Hitchcock and Chase 1950).

Much work on the complex legume family has been done by researchers in the U.S. Department of Agriculture. Genera such as *Astragalus*, with more than 325 species, still require tremendous work to understand; it is extremely difficult to identify individual species. An international program to develop a checklist of species in this family, with distribution, growth habit, and economic information, is being carried out by the International Legume Data Information System (ILDIS); the Missouri Botanical Garden is the center for North American information for this project.

The sedge family includes ecologically important species, especially in wetlands where sedges dominate. Although sedges are being intensively studied, individual species can be difficult to identify; *Carex* alone contains more than 400 species. Cyperaceae specialists have been collaborating on common solutions to taxonomic problems in this group; volume 11 of *Flora of North America* will synthesize the best information available on the family.

Regional Floras

Hawaii

The *Manual of the Flowering Plants of Hawaii* (Wagner et al. 1990) gives excellent coverage for flowering plants. Two fern floras

Courtesy G. Yatskievych, MO Dept. Conserv.

Scleria cilata, a member of the sedge family, Cyperaceae.

All drawings by Laurie Langie; Flora of North America Editorial Committee©

The fern *Cyrtomium falcatum*.

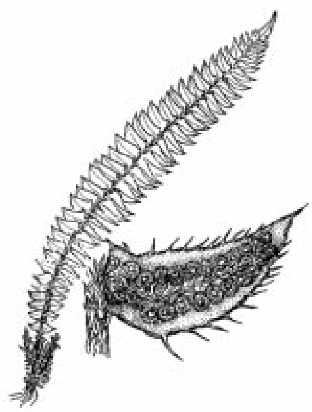
Courtesy G. Yatskievych, MO Dept. Conserv.

Bouteloua gracilis, a member of the grass family, Poaceae (Gramineae).

are in progress. In addition, the Bishop Museum, the National Tropical Botanical Garden, and the National Museum of Natural History, Smithsonian Institution, are collaboratively creating a data base for their flowering plant specimens from Hawaii, a project to be completed by 1996. The Bishop Museum has a checklist data base of native and cultivated plants in Hawaii, but additional collecting is needed to document native plants, particularly on Molokai and Kauai. Collecting is needed throughout the islands to document the introduction and spread of alien plants. Scientists at the National Tropical Botanical Garden have discovered 20 new taxa from Kauai alone since 1990, and some 200 species of naturalized plants have been discovered in Hawaii in the past 5 years.

Alaska

Alaska has such a huge area of wilderness that basic botanical exploration is essential; *Flora of Alaska and Neighboring Territories* (Hulten 1968) is a useful work. In addition, a data base for Alaskan plants is maintained at the University of Alaska Museum in Fairbanks. Rare plants are tracked by the University of Alaska, the Alaska Natural Heritage Program, and the Alaska Rare Plant Working Group (an ad hoc group of botanists from state and federal agencies, the university, and nongovernmental organizations).

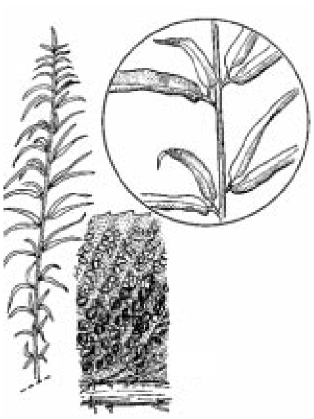


The fern *Polystichum lonchitis*.

The West

The western region of the continental United States is probably the least known. Some areas (mostly near cities with universities, along highways, and popular camping sites) are relatively well known, but in less populated areas not near paved roads, much remains to be explored.

Three excellent floras treat the plants of the west coast: *Vascular Plants of the Pacific Northwest* (Hitchcock et al. 1955-69); *Intermountain Flora* (Cronquist et al. 1972-94); and *The Jepson Manual: Higher Plants of California* (Hickman 1993). State floras for Oregon (Peck 1961), Washington (Piper 1906), and Idaho (Davis 1952) are out of date and need to be revised. A revised checklist for Oregon is in preparation (A. Liston, Oregon State University, personal communication). Specimen data bases are being developed for California, Oregon, and Idaho. California herbaria have developed a model project (Specimen Management System for California Herbaria, SMASCH) to computerize data from all their California specimens. Specimens (including lichens and fungi) in Oregon herbaria are being put into a data base.



The fern *Pityrogramma trifoliata*.

The Klamath-Siskiyou area of California and Oregon, mid-elevation Sierra, and the intermountain portion of California are the most poorly known regions. For instance, a showy new species of the genus *Neviusia*, the snow-wreath, previously known from only one species in the southeastern United States, was recently discovered in 1992 in an accessible area of northern California (Shevock et al. 1992). In addition, the rich flora of southwestern Oregon is poorly represented in herbaria, as are several counties in north-central Oregon (A. Liston, personal communication).

Intermountain Area

The number of collections from the Intermountain region has doubled in the past 20 years. *The Intermountain Flora* (Cronquist et al. 1972-94), which treats Utah, most of Nevada, southeastern Oregon, southern Idaho, and eastern California, is comprehensive; five of seven volumes have been published. An unpublished flora of Nevada exists (Kartesz 1987).

Nevada is one of the most poorly explored and documented states. Recent collectors have concentrated activity in the Great Basin mountains of Nevada and the Colorado Plateau of Utah. Even in areas seemingly well-collected, such as Zion National Park in southwestern Utah, a number of new species have been discovered and described since 1975 (Hartman 1990). *A Utah Flora* (Welsh 1993) and *Atlas of the Vascular Plants of Utah* (Albee et al. 1988) are modern and thorough treatments.

The Southwest

Although many local floras have been prepared for the Rocky Mountain areas, few have been published. Data bases on distribution of species are also being developed for individual states at the University of New Mexico, Utah State University, Colorado State University, the University of Colorado, and the University of Wyoming. A computerized checklist is being prepared for New Mexico at New Mexico State University in Las Cruces. Most of Arizona and New Mexico have been poorly collected, but these two states are thought to be the floristically richest areas in the United States, and new and surprising species are being discovered yearly. References for New Mexico (Martin and Hutchins 1980-81) are outdated or poor. In New Mexico, for instance, even frequently visited sites like the Chiricahuas still reveal treasures, such as *Apacheria*, a new genus discovered in 1973 (Mason 1975).

Northern Arizona University maintains a data base on conifers and grasses of the state; the remainder of its Arizona holdings are also being entered. In addition, the University of Arizona has a major data-base project. Areas needing more collection in Arizona include north of the Colorado River and parts of the

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Colorado Plateau (L.R. Landrum, Arizona State University, and T.J. Ayers, Northern Arizona University, personal communication).

Although much of Colorado is also poorly known, all of Wyoming will have been surveyed by 1998, with recent collection data fully computerized (R. Hartman, University of Wyoming, personal communication).

The Great Plains

The Flora of the Great Plains (Great Plains Flora Association 1986) and its associated *Atlas of the Flora of the Great Plains* (Great Plains Flora Association 1977) are the result of careful study of the region in the 1960's and 1970's. The University of Kansas herbarium contains specimens representative of the entire flora; these specimens have been recently annotated by experts. This herbarium, in combination with those at the University of Nebraska, Kansas State University in Manhattan, North Dakota State University in Fargo, and the University of Minnesota (which has specimen data online), probably has fully covered this region and has current, active collecting programs. These herbaria are collaborating to develop a Central United States Plant Inventory Database (CUSPID). South Dakota and the eastern half of Montana have been undercollected.

Great Lakes

Many poorly known and interesting species are restricted to the Great Lakes region, and other typically more northern species occur here (The Nature Conservancy 1994). Recent floras are available or are being prepared for Illinois, Michigan, Minnesota, and Ohio. The floras of Indiana and Wisconsin need to be updated. Information from specimens treated in recent volumes of the *Michigan Flora* (Voss 1972) is being entered into a data base, and the Kent State University herbarium is computerizing its collection.

The Eastern Forest

The region covered by the eastern forest has been settled longer than any other area in the United States. Habitats here have undergone tremendous alteration and many introduced species now dominate the landscape. These plants should be regularly inventoried to document the occurrence and spread of alien species and to monitor the effects of environmental change. For instance, in 1950, 20% of the species in the northeastern United States were non-native (Fernald 1950); in 1986, 36% of the flora of New York was non-native (Mitchell 1986).

Regional, statewide, and local floristic studies and publications are traditional in the Northeast, but the older work is sometimes taxonomically and nomenclaturally outdated, and many areas remain inadequately inventoried. Two standard references for the vascular plants of the Northeast are *Gray's Manual of Botany* (Fernald 1950) and the recently revised *Manual of Vascular Plants of Northeastern United States and Adjacent Canada* (Gleason and Cronquist 1991). Seymour's (1982) *The Flora of New England* is also useful.

Botanists in Maine, Vermont, New Hampshire, Connecticut, and Massachusetts are updating checklists or older floras or preparing new ones. In New York, an active collaborative flora project has produced 10 illustrated installments, plus a checklist (Mitchell 1986) and an atlas of county records (New York Flora Association 1990). For Pennsylvania, Rhoads and Klein's (1993) recent atlas is available.

A book on the aquatic plants of northeastern North America is soon to be published (G.E. Crow, University of New Hampshire, and C.B. Hellquist, North Adams State College, Massachusetts, personal communication). In addition, the Association of Northeastern Herbaria, organized in 1991, is coordinating the preparation of specimen-based electronic data bases and the sharing of data. Specimen data from herbaria at the University of Massachusetts (Amherst), the Buffalo Museum of Science, the New York State Museum, and the University of Maine are partly or completely stored electronically. A large computer-stored data base also exists for Pennsylvania plants.

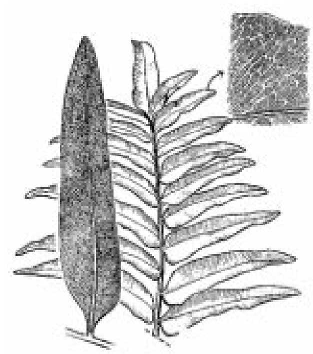
The South

The *Manual of the Vascular Plants of Texas* (Correll and Johnston 1970) is being updated. A number of regional floras and checklists have been published within the last two decades, but there are no regional floras for the Rolling Plains or the Trans-Pecos areas. Specimen records at the University of Texas at El Paso have been computerized, and type specimens at the University of Texas at Austin are computerized and online.

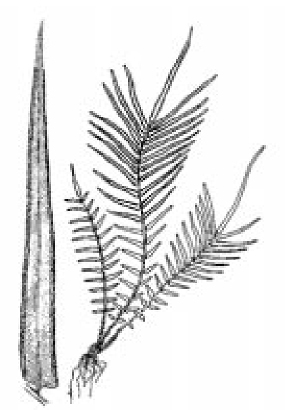
In general, local floras, checklists, and atlases are more commonly available for southeastern states than are complete state floras. In the southeast, Alabama, Arkansas, and Mississippi are the most poorly known, and northern Florida, Georgia, northwestern Louisiana, and eastern Oklahoma need considerably more study. In Alabama, in particular, the poorly collected areas are the Coastal Plain north of Mobile and Baldwin counties, north to the Cumberland Plateau. For overviews, see *The Vascular Flora of the Southeastern United States* (Radford et al. 1980), of which two of the five projected volumes have been published. *A Generic Flora of the Southeastern United States* (Wood and Miller 1958-90), which includes

Courtesy D. Boufford, Harvard

Fabaceae (Leguminosae), *Baptisa australis*, a member of the legume family.



The fern *Acrostichum danaeifolium*.



The fern *Pityrogramma vittata*.

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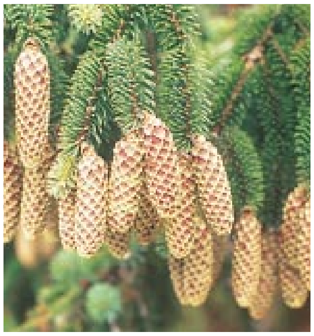


Courtesy G. Straley, University of British Columbia

Picea sitchensis, a member of the pine family, Pinaceae.

keys to genera and discussions about species and their distributions in the Southeast, is about 80% finished. The latest complete flora is Small's (1933) manual. The *Manual of the Vascular Flora of the Carolinas* (Radford et al. 1968) is a standard and reliable reference. A flora of Florida and atlas of the vascular plants of Florida are under way (R.P. Wunderlin, University of South Florida, personal communication). In addition, extensive computerized data bases on distribution, literature, and nomenclature of Florida plants exist at the University of South Florida.

In Florida, the specimen coverage is incomplete in sparsely populated areas (e.g., several eastern Panhandle counties and northeastern counties). At least one new species per year is described from Florida and these mostly have limited distributions and are in imperiled habitats.

Herbaria in the southeastern United States have formed a consortium (Southeastern Regional Floral Information System) to computerize specimen records in all southeastern herbaria. The information from this project is available online at the University of Alabama.

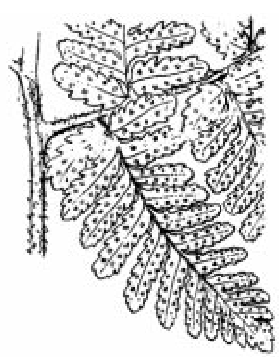
Invasion of weedy species is one of the most serious threats to native vegetation in the southeastern United States. Much better documentation of the occurrence and spread of these species is needed to control these invaders.

The fern *Phanerophlebia auriculata.*

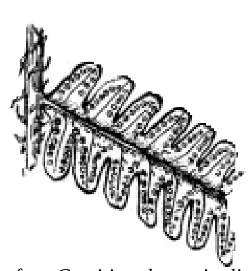
Collecting and Monitoring

Active collecting programs document and monitor changes in distribution of native and introduced species. Introduced plants and plant migrations often affect the distribution and health of native plants. At present, it can take as long as 20 years after an introduction to collect and record the species in the literature.

Long-term care of these national collections is vital; many regional herbaria no longer have curatorial support, and some have been or are in danger of being abandoned by their institutions, which will limit resources and information for studies.



The fern *Ctenitis sloanei.*



The fern *Ctenitis submarginalis.*

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Environmental Change and the Florida Torreya

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Many of the best-known cases of catastrophic decline in trees are linked to introduced pathogens that circumvent the natural defenses of their adopted host, leaving it vulnerable to attack. Notable examples of such declines include Dutch elm disease and the chestnut blight. Similarly, numerous studies have linked environmental degradation (e.g., acid rain, ozone depletion, and global warming) to altered interactions among species. In the case of plants and their pathogens, environmental degradation may result in increased disease susceptibility and mortality as is true for the general forest declines in Europe and the widespread decline of red spruce (*Picea rubens*) in the northeastern United States. Identifying the specific mechanisms for increased mortality in nonspecific tree declines is often very difficult, and debate ensues as to which sources of mortality are primary disease agents and which are merely opportunistic.

Both introduced pathogens and altered environmental conditions have been hypothesized as contributing to the decline of *Torreya taxifolia*, a narrowly restricted endemic conifer. The range of the Florida torreya spans an area of less than 400 km^2 (154 mi^2) along the Apalachicola River in northern Florida and adjacent Georgia. In the 1950's this mid-sized tree species was struck by a catastrophic decline that has left it on the verge of extinction in the wild. High mortality is reducing the population by an estimated 5% per year. Formerly a common tree within its range, there are fewer than 1,500 trees left in the wild.

The average height of a Florida torreya is currently less than 1 m (3.3 ft). The average age of the oldest stem on trees is less than 15 years. While a handful of trees produces pollen, there have been no sexually mature females observed in the wild for at least 15 years. Symptoms of disease include needle spots, needle necrosis, and stem cankers. Primary stem mortality has reduced the average height of trees by 10 cm (4 in) during the past 3 years. Thus, the Florida torreya has shown no sign of recovery or stabilization during the 35 years subsequent to the onset of the species' decline. If current patterns persist, the Florida torreya is destined for extinction in the wild.

The search for a cause for the decline of the Florida torreya began in the 1960's when a team of pathologists studying the case could find no introduced fungal pathogens. Pathologists studying the problem during the 1990's have shown that (1) there does not appear to be any viral or bacterial pathogens associated with *T. taxifolia*; (2) a very common native fungal endophyte (*Pestalotia natans*), often pathogenic in other plants, does not appear virulent on *T. taxifolia*; and (3) the less common *Scytalidium* sp., not typically noted for its pathogenicity, produces pathogenic symptoms on *T. taxifolia* and was likely introduced to the region during the late 1950's, when slash pine plantations were planted from nursery stock. Finally, growth experiments have suggested that environmental stress triggers episodes of mortality in the trees. Greenhouse experiments on Florida torreya trees derived from cuttings also suggest the likelihood that structural changes in the slope forests along the Apalachicola that have resulted in lower light levels have also stressed wild populations of Florida torreya.

The current hypothesis is that the decline of Florida torreya is a result of facultative (*see* glossary) pathogens attacking trees under conditions of increased environmental stress. Several potential stress factors, including fire suppression, climatic changes such as temperature extremes and drought, and altered hydrologic regimes in ravine forests and resultant changes in nutrient flow have also been hypothesized as contributing to the species' decline.

Despite extensive research to find a link between disease agents and environmental stress, the mechanisms for forest decline remain rather speculative. *Torreya taxifolia* has such a narrow distribution that a decline in the populations in the Apalachicola basin has brought the species to near extinction. With the increasing magnitude of abiotic environmental changes, we may expect more cases that are similar to the decline of *T. taxifolia*. Unfortunately, the lack of identification of specific disease agents and specific mechanisms has hindered action to correct potential problems that cause forest declines. Given the difficulty in delineating mechanisms for declines, we typically cannot ascertain exact mechanisms until it may be too late. Waiting to be absolutely certain of the triggers for particular forest declines before corrective action is taken is likely to be a costly strategy.

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Native Vascular Plants

Most of the familiar flora of the American landscape, such as trees, shrubs, herbs, vines, grasses, and ferns, are known as vascular plants. These plants have systems for transporting water and photosynthetic products and are differentiated into stems, leaves, and roots. Nonvascular plants—the algae, fungi, and mosses and lichens—are considered in other articles in this volume. Except in Arctic and alpine areas, vascular plants dominate nearly all of North America's natural plant communities. About 17,000 species of vascular plants are native to one or more of the 50 U.S. states, along with several thousand additional native subspecies, varieties, and named natural hybrids (Kartesz 1994).

Human activities have expanded the geographical distributions of many plant species, particularly farm crops, timber trees, garden plants, and weeds. When a non-native plant

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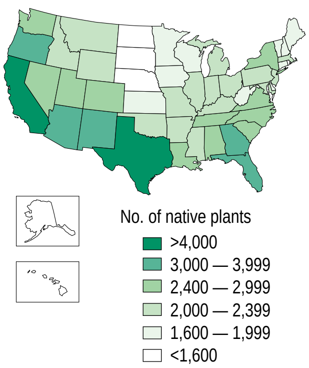

Fig. 1. The number of native vascular plant species in each state.

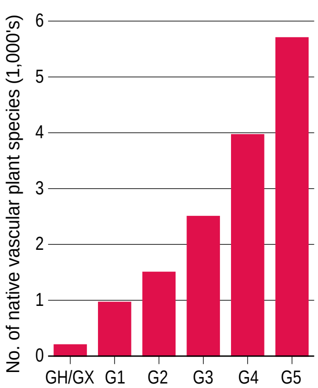

Fig. 2. The number of native vascular plant species in the United States in each global rank. GH/GX means species is potentially extinct; G1 to G5 rank the species from rarest (G1) to most common (G5).

species is found growing outside cultivation, it is considered an exotic species in that area. About 5,000 exotic species are known outside cultivation in the United States. While many exotic plant species are desirable in some contexts (such as horticulture), hundreds of invasive non-natives have become major management problems when established in places valued as natural areas (McKnight 1991; U.S. Congress 1993). A few particularly troublesome non-natives are regulated under specific federal or state laws as noxious weeds.

Geographic Distribution

Western and southern states have the largest numbers of native vascular plant species in the country. (Fig. 1, revised from Kartesz 1992). California, with more than 5,000 native vascular plant species, has almost one-third of the total number for the entire United States. Texas, with about 4,500 native species, ranks second. Arizona, Florida, Georgia, New Mexico, and Oregon all have over 3,000 native species.

Hawaii, as a remote oceanic island archipelago, has relatively few native species (Carlquist 1970), but nearly all (89%) of the native Hawaiian flowering (angiosperm) species are endemic to that region (Wagner et al. 1990). A small number of vascular plants, including a species of lycopod (*Huperzia haleakalae*), are native to both Hawaii and the North American mainland.

In every state, hundreds of plant species are established as exotics. States with coastal areas, major agricultural regions, and large cities generally have the highest numbers of non-native plants. A modest number of native U.S. species, such as the northern catalpa (*Catalpa speciosa*), have also spread from cultivation beyond their native ranges. Some familiar mainland species, like a wild blackberry (*Rubus argutus*) and a grass known as broomsedge (*Andropogon virginicus*), have become problem weeds in Hawaii (Smith 1989).

Rare Species

As of February 1994, 403 native U.S. species, subspecies, or varieties of vascular plants and one nonvascular plant have been formally protected under the provisions of the U.S. Endangered Species Act of 1973 (USFWS 1994). Nearly half the 822 native U.S. federally listed species are plants. The U.S. Fish and Wildlife Service considers an additional 1,953 kinds of plants as candidates for such listing (Federal Register 1993).

The first U.S. national lists of rare plants depended largely on nominations from specialists already familiar with various rare species and omitted many potential candidates. Many state-level rare plant lists were also developed in the 1970's; these generally addressed species considered rare in a particular area regardless of abundance elsewhere.

The Nature Conservancy and the network of Natural Heritage Programs use a consistent methodology to inventory natural diversity and to assess rarity and endangerment for all currently recognized species of vascular plants in North America, Hawaii, and portions of Latin America (Jenkins 1985). By using a five-level scale from 1 (rarest and most vulnerable—typically five or fewer existing occurrences) to 5 (demonstrably widespread, abundant, and secure), a global or rangewide rank (G1 to G5) is determined for each species. With the use of the same five-level scale, conservation priority ranks are assigned for national (N1 to N5) and subnational or state (S1 to S5) status. Ranks are used conservatively throughout the Natural Heritage Network and are assigned after careful review of a species' status. Additional ranks are used to indicate species that occurred historically within a jurisdiction, but which are not presently known. A species is presumed extinct if efforts to relocate it are unsuccessful, if no suitable habitat remains, or if the loss has been well documented. Species are considered "historic" (possibly extinct) if there is reliable evidence from biological surveys that the species occurred within the past few centuries in a given area (Snyder 1993).

The Natural Heritage Network has documented the status of thousands of rare species. At the same time, plant surveys have shown that a comparable number of plants are substantially more common than previously believed. Species status information from all 50 U.S. State Natural Heritage Programs is combined with national and rangewide data in the Natural Heritage Network's Central Scientific Databases maintained by The Nature Conservancy. The inventories and data bases of the Natural Heritage Network continuously gather, organize, and revise information on species rarity and distribution as it becomes available.

The number of species in the United States in each global rank is presented in Fig. 2. For example, more than 4,850 species (about 28%) of the native U.S. vascular plants are considered globally rare (ranked G1, G2, or G3) by The Nature Conservancy and the Natural Heritage Network. Of these, about 960 species are ranked G1 and occur at fewer than five sites globally or are comparably imperiled.

Globally rare native species of vascular plants are concentrated in the western and southern states (Fig. 3), with greatest proportions in Arizona, California, Florida, Georgia, Hawaii, Nevada, New Mexico, Texas, and Utah.

In addition to these globally rare species, about 4,500 other species of widespread or more common vascular plants (ranked G4 or G5) are being actively inventoried in at least one state where they are rare.

Loss of Species

The patterns and causes of plant species' losses are often important components of state-level conservation studies. The loss, or suspected loss, of a species from a portion of the landscape is referred to as "extirpation."

A recent study (Kutner and Morse, unpublished report) of the losses of U.S. native vascular plants revealed that about 1,772 (9.8%) of these species have been lost from at least one state. Of these species, 438 (25%) may be lost from the floras of two or more states. The proportion of species potentially extirpated from each state varies dramatically across the nation (Fig. 4), with the largest losses reported from northeastern states and from Hawaii. Delaware has experienced the proportionately highest loss from its flora, with more than 15% of its species potentially extirpated. Many of the northeastern and mid-Atlantic states have lost more than 5% of their native vascular plants. This region of the United States has experienced hundreds of years of human development and includes many of the most densely populated and intensely developed states. Many plants that have been lost from these states may now be similarly threatened in portions of their remaining ranges.

About 28% of the native flora is considered globally rare (ranked G1, G2, or G3) by the Natural Heritage Network, but only 12% of the potentially extirpated species are globally rare. Most potentially extirpated species have been lost from one or two states and are currently globally common (ranked G4 or G5). In the United States, 110 of these globally common species have been lost from three or more states, and more than 35 species have been lost from four or more states. Of the most common species (global rank G5), about 285 have been lost from two or more states. Common species that have been lost from many states may not be as secure from imperilment as previously believed. Additionally, the effect of species' losses on other plants and animals in a community is often unknown. Rangewide analyses could indicate species that would benefit from further research and a better understanding of potential threats, thus helping prevent subsequent losses.

Many species that are endangered, threatened, or formal candidates for federal protection have also lost parts of their ranges. Nearly 6% of listed and proposed endangered species and 20% of listed and proposed threatened species are reported extirpated from at least one state. About 16% of the category 1 candidate species (top candidates for listing as endangered or threatened) and almost 11% of the category 2 candidate species (possibly qualifying for threatened or endangered status, but more information is needed) have been similarly affected.

Some currently rare species had widespread historical distributions. For example, American chaffseed (*Schwalbea americana*) is a federally listed endangered species with a Natural Heritage rank of G2. The historical range of this species extended from Mississippi to Massachusetts; the plant is currently known from about 20 populations in five states, mostly in South Carolina. The most significant threat to this species is fire suppression, which allows plant succession to proceed to the point where there is not enough light for the plant to compete successfully. Habitat loss has also caused the extirpation of several *Schwalbea* populations. For rare species such as *S. americana*, further state-level extirpations could seriously affect the species' survival.

Wetland Species

Although there are fewer than 7,000 native wetland vascular plant species in the United States, plants that occur mostly in wetlands are more likely to be extirpated from at least one state. Based on the USFWS National Wetlands Inventory (Reed 1988), about half of the potentially extirpated species are either obligate (*see* glossary) or facultative (*see* glossary) wetland species.

Wetlands and aquatic ecosystems have been severely affected in the United States; approximately 53% of these ecosystems have been destroyed in the 48 contiguous states (Dahl 1990). Aquatic species frequently have specific habitat requirements and can be threatened by both habitat loss and changes in local hydrology. In the mid-Atlantic region, several intertidal vascular plants have been extirpated from the Delaware River system because of habitat alteration (Ferren and Schuyler 1980).

Possibly Extinct Species

About 90 mainland U.S. and 110 Hawaiian vascular plant species may be extinct, according to records of the USFWS and The Nature Conservancy (Russell and Morse 1992). For

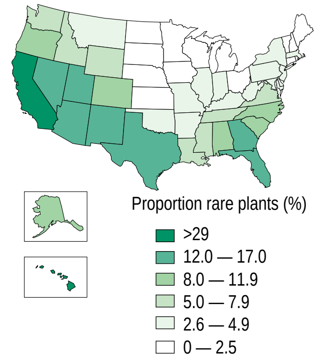

Fig. 3. The proportion of globally rare vascular plant species (ranked G1, rarest, to G3, more common) in the native flora of each U.S. state.

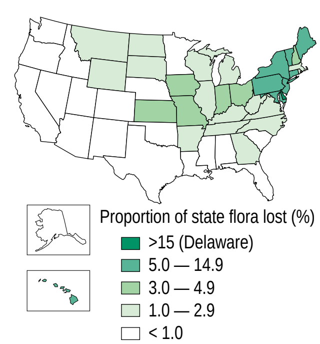

Fig. 4. The proportion of species reported potentially extirpated from the native flora of each U.S. state.

example, Nuttall's mudwort (*Micranthemum micranthemoides*) has been recorded from Delaware, the District of Columbia, Maryland, New Jersey, New York, Pennsylvania, and Virginia, but despite searches, it has not definitely been seen since September 1941.

Several species of U.S. plants are extirpated from the wild, but still exist in cultivation. Most familiar of these is the Franklinia (*Franklinia alatamaha*), a small tree known historically only from the Altamaha River in southeastern Georgia, but which is now widely cultivated as an ornamental in eastern states.

Ongoing fieldwork has resulted in the rediscovery of many species. The running buffalo clover (*Trifolium stoloniferum*) was rediscovered in West Virginia in 1983 (Bartgis 1985) and has been found subsequently in Indiana, Kentucky, Missouri, and Ohio. In Oregon, a population of *Lomatium peckianum* was located in 1983 for the first time in more than 50 years. The discovery of additional populations has changed the species' federal status from a category 1 candidate to a former candidate (Kagan and Vrilakas 1993). In Montana, several recent rediscoveries have occurred, including a 1985 rediscovery of *Trifolium microcephalum*, a species of clover not seen since it was first collected by Meriwether Lewis in 1805 or 1806 (Hoy 1993). Likewise, during the 1991 field season the yellow passionflower (*Passiflora lutea*) was located at two sites in Delaware for the first time since the early 1800's (Clancy 1993). These examples illustrate the importance of ongoing inventories as well as the dynamic nature of local and regional floras.

Threats to Diversity

Habitat alteration and incompatible land use are the major threats to most rare U.S. plant species. Apart from certain species of cacti, ginseng, and various showy wildflowers, relatively few rare U.S. plants are primarily threatened by overcollecting. Global climate change (Peters and Lovejoy 1992; Morse et al. 1993) and sea-level rise (Reid and Trexler 1991) may pose additional threats to some native U.S. plant species.

Species at higher risk of extinction usually include those having small geographic ranges, narrow habitat requirements, unusual life histories, or vulnerability to exotic pests or diseases. In addition, reduced biodiversity of local floras is of high concern, even if plants lost from a particular geographical region are common and secure elsewhere. Finally, depletion of even widespread species can occur if exploitation or habitat destruction occurs beyond a sustained-yield rate.

Assessment of the causes and patterns of species losses in the United States, combined with ongoing documentation of natural diversity and studies of rarity, endangerment, and threats, will refine conservation priorities by identifying species or areas that will most benefit from further protection and research. Analyses of ongoing inventory and monitoring work could provide early warnings of widespread threats to biological diversity, thereby perhaps improving the protection of both rare and more common plants and allowing the development and implementation of conservation strategies before crises occur.

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Tracking the Mosses and Vascular Plants of New York (1836-1994)

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New York, the third most populous state, has highly varied topography, geology, soils, and climate, and a complex history of land use, all of which are reflected in a rich flora of native, introduced, and opportunistic species. Large parts of the state support beech-maple, oak-chestnut (now modified as a result of the elimination of chestnut), or hemlock-northern hardwood forest, and there are extensive tracts of red spruce-balsam fir forest in the Adirondack and Catskill mountains. Alpine tundra is present on the highest Adirondack peaks at elevations above about 1,372 m (4,500 ft), while salt marshes, freshwater ponds, and dwarf pine barrens occur at or near sea level on Long Island. Almost all land in the state has been glaciated and therefore available for plant occupation no longer than 18,000 years. In 1880 nearly 78% of the state's land was in farms or farm woodlots, but by 1980, 61% of New York was classified as forested.

The flora of New York is an economically important resource and the foundation of healthy sustainable environmental systems. The state's flora and its composition have been studied since the early 1800's, allowing researchers to present trends in the numbers of vascular plant and moss species. In our work, we have emphasized the study of voucher (*see* glossary) specimens, which allow us and our successors to verify identifications and evaluate the application of species concepts of other researchers.

Status

Organized study of the New York flora began in 1836 with a botanical survey that was a part of the New York State Geological and Natural History Survey. This survey led to the publication of John Torrey's *A Flora of the State of New-York* (Torrey 1843). The state's plant resources continued to be investigated at the New York State Museum under government sponsorship that began in 1867 and continues to the present. The regionally significant herbarium and extensive data collections that have resulted from this research and exploration provide the documentation for this article as well as our ongoing work and information from other important botanical collections.

Totals for the major groups of mosses and vascular plants (as of February 1994) are given in Table 1, and increases in the numbers of known species are listed in Table 2. Torrey's 1843 flora enumerated 1,452 species, while a 1994 compendium (R.S. Mitchell, unpublished data) lists 3,451, an increase of 58%. The differences, in part, are due to a dramatic increase in the number of reported non-native species, of which 77% (1,122 of 1,449) are naturalized (naturally reproducing and spreading). The differences are also due to a significant rise in the number of species recognized as indigenous to the state (an increase of 711). Native species from other parts of the United States are listed in the tables as such, even if they are also known to have been introduced into New York. Although the number of known native plant species has steadily increased, the apparent decrease in the number of native species from House's to Mitchell's list (Table 2) was the result of taxonomic reinterpretation that reduced many taxa (especially species of *Rubus* and *Crataegus*) into synonymy over the latter half of the 20th century.

Plants	Native	Non-native	Total
Vascular plants			
Pteridophytes	113	7	120
Gymnosperms	18	13	31
Angiosperms	1,871	1,429	3,300
Total	2,002	1,449	3,451
Persisting	1,933	1,122	3,055
Mosses			
Sphagnidae	52	-	52
Andreaeidae	3	-	3
Bryidae	417	4	421
Total	472	4	476
Persisting	469	4	473

Table 1. Current tally of New York flora.

The data reflect both an intensification of botanical exploration during the 19th and 20th centuries and the arrival of numerous plant waifs (nonpersistent alien species), mainly from Eurasia, many of which became naturalized as population centers, commerce, and transportation networks enlarged. In addition, a few native species apparently continue to expand their ranges northward, as exemplified by discoveries in 1993 of the large floating bladderwort (*Utricularia inflata* Walter) and beakgrain (*Diarrhena americana obovata* [Gleason] Brandenb.) in southeastern New York state. The list of mosses (Table 2) grew most dramatically between 1866 and 1957 as a result of field and herbarium study. Miller's 1994 synopsis of the state's bryophyte flora (unpublished data) shows that many new discoveries continue to be made. Several non-native moss species have been recognized near nurseries and botanical gardens, the

Courtesy R.S. Mitchell

Spreading globeflower (*Trollius laxus* Salisbury), a threatened species in New York.

Table 2. Historical documentation of New York flora.

Plants	No. of species by reference			
Vascular plants	Torrey (1843)	House (1924)	Mitchell (1986)	Mitchell (1994 tally)*
Pteridophytes	59	94	110	120
Gymnosperms	14	25	29	31
Angiosperms	1,379	2,825	3,252	3,300
Native	1,291	2,133**	1,995***	2,002
Non-native	161	811	1,296	1,449
Total	1,452	2,944	3,291	3,451
Mosses	**Peck (1866-1912)**	**Ketchledge (1957)**	**Ketchledge (1980)**	**Miller (1994 tally)***
Sphagnidae	15	29	46	52
Andreaeidae	3	2	3	3
Bryidae	295	413	414	421
Total	313	444	463	476

* R.S. Mitchell, unpublished data; N.G. Miller, unpublished data.

** Of this number, some 300 species are now placed in synonymy in the light of modern taxonomic research.

*** This number has been reduced by four, to reflect species eliminated from the list as a result of changes in taxonomic status, discovery of incorrectly identified plants, and faulty literature reports.

likely points of introduction, and more adventive (*see* glossary) mosses will almost certainly be discovered as field exploration continues.

The numbers of vascular plants and mosses considered rare in New York are substantial. In conformity with New York State Heritage Program designations, we tallied the number of species in the following categories: S1 (5 or fewer sites), S2 (6-20 sites), and SH (no site verified within the past 15 years). By these criteria, roughly a fourth of New York's native vascular plants (435 species: 22%) and mosses (119 species: 26%) are rare. Of the native species, we consider 69 of the vascular plants and 3 of the mosses extirpated because most have not been observed within New York this century.

Trends

For the past 70 years, an average of 11 species of vascular plants per year were newly documented for New York. Since 1980 the number of native vascular plants added to the flora has been 1 per year, while the number of exotic species has been over 200. For mosses, a less well-known group of plants, one additional native species per year on average was discovered between 1957 and 1994. Although the steepest increase in knowledge of both groups occurred in the 1800's and early 1900's, significant information on plant diversity continues to accumulate at a steady rate, as the ranges of species in the state become better known.

Although there is a long history of botanical exploration in New York state, many areas still have not been surveyed adequately. Poorly known regions include parts of the Allegheny Upland of central and western New York, the Champlain Valley, and portions of the Adirondack Mountain region and adjacent districts. The Hudson Highlands area, previously poorly explored, is being intensively studied by botanists from the New York State Biological Survey.

In the last decade, 11 New York plant species considered extirpated have been discovered at new sites, including *Sphagnum angermanicum* Melin, a rare peat moss, and prairie smoke (*Geum triflorum* Pursh), an herb thought extirpated by Torrey in 1843 and rediscovered in the 1980's. Nine additional species thought extirpated and over 50 species designated "critically imperiled" by New York State Heritage Program criteria were reclassified into less sensitive categories as new information became available, thereby lessening the urgency of conservation measures. Of about 70 extirpated species, some have been lost because of expanding population centers, but many have been lost because of wetland drainage and increased forest cover that altered their specialized, often calcareous habitats.

We predict that one or two native species per year will continue to be added to the vascular plant and moss floras of New York state through new discoveries. By contrast, previously undocumented non-native vascular plants will be added at an annual rate some 20-fold greater than that of the native flora. Inventories and assessments of liverworts, fungi, lichens, and terrestrial, aquatic, and marine algae, are much less advanced in New York than those for the vascular plants and mosses, which deserve attention as well.

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